ARHAI Scotland

Antimicrobial Resistance and Healthcare Associated Infection

NHS National Services Scotland

Literature Review and Practice Recommendations:

Existing and emerging technologies for decontamination of the health and care environment Electrolysed Water

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Key Information

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Document information

Purpose: To inform the existing and emerging technologies used for decontamination of the health and care environment section on Electrolysed Water.

Target audience: All health and care staff involved in the prevention and control of infection in Scotland.

Circulation list: Infection Control Managers, Infection Prevention and Control Teams, Public Health Teams

Description: This literature aims to review the evidence base for using Electrolysed Water for decontamination of the health and care environment.

Update/review schedule: Updated as new evidence emerges with changes made to recommendations as required.

Cross reference: National Infection Prevention and Control Manual (NIPCM)

Update level: Practice – The implications for practice are updated based on a review of the extant scientific literature on Electrolysed water used for decontamination of the health and care environment.

Research - The implications for research are updated based on a review of the extant scientific literature on Electrolysed water used for decontamination of the health and care environment.

Version History

This literature review will be updated in real time if any significant changes are found in the professional literature or from national guidance/policy.

Version	Date	Summary of changes
2.0	August 2021	Review of the extant scientific evidence on Electrolysed Water using the National Infection Prevention and Control Manual (NIPCM) methodology. New recommendations added.
1.1	December 2016	Addition of categories for recommendations. No changes made to the content of the literature review.
1.0	May 2015	Final for publication.

Approvals

This document requires the following approvals

Version	Date Approved	Name
2.0	August 2021	National Infection Prevention and Control (NIPC) steering and consensus groups.

Contents

1 Objectives

The aim of this review is to examine the extant scientific literature regarding the use of Electrolysed water (EW) for decontamination of the health and care environment to form evidence-based recommendations for practice.

The specific objectives of the review are to determine:

- What is the actual or proposed mechanism of action of Electrolysed Water?
- Is Electrolysed Water currently in use in UK health and care settings?
- When should Electrolysed Water be used in health and care settings?
- What is the procedure for using Electrolysed Water?
- What is the scientific evidence for effectiveness of Electrolysed Water for decontamination of the healthcare environment?
- Are there any safety considerations associated with using Electrolysed Water in health and care settings?
- Are there any practical or logistical considerations associated with using Electrolysed Water in health and care settings?
- What costs are associated with using Electrolysed Water in health and care settings?

Inclusion/Exclusion Criteria

This literature review only considers the use of Electrolysed Water for decontamination of the health and care environment as part of standard infection control precautions and transmission based precautions. This review does not include the evaluation of electrolysed water in specialist applications e.g. decontamination of endoscopes.

2 Methodology

This targeted literature review was produced using a defined methodology as described in the National Infection Prevention and Control Manual: Development Process.

Supplementary sections to the applied methodology for this specific literature review can be found in Appendix 1.

3 Discussion

3.1 Implications for practice

What is the actual or proposed mechanism of action of Electrolysed Water?

Electrolysed Water (EW) also known as electrolysed oxidising water (EOW) or electrochemically activated solution (ECAS) or electro-activated water or super-oxidised water is a relatively novel disinfectant which has been widely used in the food, aquaculture and agriculture industry.[1-3] EW has been proposed as an environmentally friendly alternative disinfectant to chlorine-based products such as sodium hypochlorite in the decontamination of the health and care environment. Electrolysed water is formed by the process of electrolysis, which involves passing an electric current through a diluted salt (NaCl) solution with the anode (positive charge) and cathode (negative charge) separated by a membrane.[1-9] It can produce two types of water simultaneously: acidic EW and basic/alkaline EW. Acidic electrolysed water is produced at the anode side having properties of low pH levels (pH 2 – 3), high oxidation-reduction potential (ORP) >1000 mV and available chlorine concentration (ACC) between 40 – 1500 ppm while basic or alkaline electrolysed water is generated at the cathode side having properties of high pH levels (pH 10 – 13) and low ORP (-800 to -900 mV).[1-3, 7-9] This process is considered to provide a higher level of available hypochlorous acid than can be delivered using chemical forms.[10]

There are three different types of EW available:

- Acidic electrolysed water
    - Strongly acidic electrolysed water
    - Slightly acidic electrolysed water
- Alkaline electrolysed water
- Neutral electrolysed water

Acidic EW is the product of negatively charged ions being attracted to the anode (positive electrode), resulting in the formation of hypochlorous acid and a weak solution of hydrochloric acid.[1, 5, 6] Strongly acidic EW has a pH of 2.2 – 2.7 and is formed in a generator where the cathode and anode chambers are separated by a membrane. Slightly acidic EW has a pH of 5 – 6 and can be produced in generators where there is no separating membrane.[2, 4]

Alkaline or basic EW is the product of positively charged ions being attracted to the cathode (negative electrode), resulting in the formation of a weak solution of sodium hydroxide.[5, 6] Alkaline EW has a pH of 10 – 13 and ORP of -800 to -900 mV.[2]

Neutral EW is produced in a similar way to acidic EW, except it has additional hydroxide ions introduced to produce a neutral solution with a pH of 6 – 8.[11, 12]

The antimicrobial effect of EW is based on the combined action of the pH, oxidation-reduction potential (ORP) and available chlorine concentration (ACC).[4, 13-16] A low pH may sensitise the outer membrane of bacterial cells and destroy cell wall compounds such as polysaccharides allowing the entry of active chlorine species such as hypochlorous acid to inactivate the cell.[1, 3, 4, 13] Most microorganisms do not survive well in acidic solutions, as a pH of below 3 impacts on their ability to grow and multiply. The chemical process of oxidation occurs when oxygen interacts with other compounds, causing loss of electrons and breakdown of the compound. In the case of microbes, the ORP is thought to damage cell membranes and create disruption in metabolic processes and loss of intracellular components, thereby destroying microorganisms.[3, 4] In addition, the bactericidal activity of EW increases with a higher ACC. The chlorine compound in EW can be free chlorine, hypochlorous acid (HOCl), hypochlorite ions, or a combination of these. Inactivation by chlorine can result from a number of factors including damage and/or destruction of cell wall, membranes, proteins and nucleic acids (DNA and RNA).[2, 3, 17] At an acidic pH, available chlorine is usually in the form of hypochlorous acid, which is reported as significantly more effective than an equivalent concentration of hypochlorite ions.[14] Ding et al[18] demonstrated that exposure of *Staphylococcus aureus* to slightly acidic EW caused disruption of cell membrane permeability and damage to ultrastructure as evidenced by shrinkage and/or destruction of cell wall on scanning electron micrographs.[18]

Acidic EW has a lower pH and a higher ACC than neutral or alkaline EW. This increases its potency but also makes it more corrosive and unstable, with a shorter shelf life.[1] Alkaline EW has a higher pH but a lower ACC.[3]

Is Electrolysed water currently in use in UK health and care settings?

There is no mention of EW products in the NHSScotland National Cleaning Services Specification,[19] the National Patient Safety Agency (NPSA) Revised Healthcare Cleaning Manual,[20] Public Health England,[21] Public Health Scotland,[22] Health Facilities Scotland,[23] or the NHSScotland National Infection Prevention and Control Manual (NIPCM).[24] These findings suggest that EW is not widely in use within UK health and care settings. The Rapid Review Panel[25] (RRP) is a panel of UK experts established by the Department of Health to review new technologies with the potential to aid in the prevention and control of healthcare-associated infections. In 2018, the RRP evaluated Ultracleanse (b), a hypochlorous acid solution developed by WCS Services Ltd.[26] The product achieved RRP Evaluation Level E6 (lowest evaluation score): "*Evidence presented does not demonstrate that the product has a contribution to make to improvements in infection prevention and control interventions to reduce healthcare associated infections*" however it is not clear if the hypochlorous solution is an electrolysed water product i.e. whether it was generated by electrolysis and there is no mention of the product on the manufacturer's website. To date, no EW products have been reviewed by the RRP.

When should Electrolysed Water be used in health and care settings?

There is a very limited evidence base on this topic as EW is not widely used in the health and care setting. Most were experimental studies performed under laboratory conditions that evaluated the efficacy of EW as a disinfectant against biofilms, cultured microorganisms (including surrogate human norovirus, SARS-CoV-2) and fungi.[7, 14, 16, 18, 27-30] Results from suspension test studies demonstrated that exposure to EW led to reduction of microbial growth however the test organisms and methodologies (e.g. susceptibility assays) used by different studies often vary making direct comparisons problematic.

Galvin et al.[29] and Park et al.[28] performed their experimental studies using EW applied as mist/fog in simulated ward settings on stainless steel, ceramic tiles and 10 cm^2 sections of environmental surfaces (vinyl floor, table, mattress, curtain, wool blanket and cotton sheet) inoculated with microorganisms. There was no mention of precleaning the surfaces by either authors before applying EW although Park et al.[28] treated the stainless steel and ceramic tile carriers with 70% ethanol and 15 min autoclave at 121°C before commencing their experiment. The authors state that fogged EW has potential to be an effective disinfectant for terminal cleaning or to help control norovirus-associated outbreaks. Manufacturers' instructions relating to cleaning prior to fogging disinfection of environmental surfaces should be followed.

Only three studies were identified evaluating the efficacy of EW when applied to environmental surfaces in a health and care setting.[10, 12, 31] Meakin et al.[10] used EW for routine cleaning purposes on surfaces of nursing homes in England including sluice door handles, lavatory sinks, patient hoists, bedroom worktops and commode seats. Stewart et al.[12] used EW spray followed by wiping with detergent wipes for routine cleaning of near-patient surfaces such as bedside lockers, cot sides and overbed tables instead of detergent alone. Swan et al.[31] tested efficacy of EW on elimination of biofilm and microbial contamination in hospital washbasin u-bends using an automated system programmed to 3-weekly treatment cycles (Monday, Wednesday and Friday).

However, this review is unable to generalise evidence from the 3 studies due to limitations such as variations on methodologies, small sample size, lack of control and/or detergent/disinfectant comparators, lack of details on standard cleaning protocols, single ward setting and other biases such as a Hawthorne effect and potential funding bias. There was also no mention of precleaning environmental surfaces prior to disinfection with EW despite Park et al.[28] commenting in their discussion that manufacturers recommend this step before fogging with electrolysed water.

There is insufficient evidence to recommend when EW should be used in health and care settings. Current United Kingdom recommendations specify the use of detergents for routine cleaning unless there are specific indications for disinfectant use i.e. in cases of known or suspected infection and/or colonisation as part of transmission based precautions.[24, 32] Additionally, it is generally reported that the effectiveness of disinfectants including EW is significantly reduced by soil load.[9, 33] To ensure a full antimicrobial effect, it is essential to remove soil and organic matter by thorough cleaning prior to disinfection.[9, 17]

What is the procedure for using Electrolysed Water?

There is limited evidence found on this topic with most studies performed under laboratory conditions. The EW used by Meakin et al.[10] was provided in ready-to-use spray bottles and did not require any special instructions for use for routine cleaning of surfaces. They report that the spray bottles dispensed approximately 1.5 mL of product per trigger spray and that surfaces were wiped with a microfibre cloth afterwards. Stewart et al.[12] used EW provided by the manufacturer for routine cleaning of near patient surfaces and stated that each site was sprayed with 1.5 mL of product, wiped clean with detergent wipes 10 to 15 seconds later and then allowed to dry naturally. EW can also be applied as a fog using a mist/fogging machine. Galvin et al.[29] produced EW in situ using a generator and applied EW to test surfaces including soft furnishings in a simulated ward environment using a mist fogger for 1.5 h treatment time and 15 min post-treatment aeration. In an experiment by Park et al.,[28] EW was also applied using a fogging machine at a rate of 0.4 litre/min with droplet size of 20-50 µm. Contaminated carriers were exposed to EW fog for at least 10 mins and 1 h was allowed for the fog to settle within the room. EW delivered as mist/fog to a vacated room has potential to be used during terminal cleaning or during outbreaks e.g.norovirus. Manufacturers' instructions relating to cleaning prior to fogging disinfection of environmental surfaces should be followed

What is the scientific evidence for effectiveness of Electrolysed Water for decontamination of the healthcare environment?

One before-and-after study[10] and thirteen laboratory-based non-randomised trials[4, 7, 11, 14, 16, 18, 27-31, 33] evaluated the efficacy of EW for decontamination of the healthcare environment..

Meakin et al*.*[10] compared the cleaning efficacy of a quaternary ammonium compound disinfectant and neutral EW (pH 6.5 – 7.5) for the routine cleaning of hand-touch surfaces in an English residential care home. Five surfaces (sluice door handle, lavatory sink, patient hoist, bedroom/vanity unit worktop and commode seat) were sprayed with either electrolysed water or the in-use quaternary ammonium disinfectant then wiped with a microfibre cloth. Results showed that neutral EW significantly reduced mean surface bacterial load compared to quaternary ammonium disinfectant ($P<0.0001$) suggesting neutral EW may be a potential cleaning product in environments such as care homes. It is worth noting that this was a small-scale study in a single care home therefore, results may not be generalisable to other health and care settings. The study compared EW with quaternary ammonium compounds rather than chlorine releasing agents such as hypochlorite solution, the current standard recommended within NHSScotland therefore this comparison with EW is problematic.[24] Additionally, the study tested both disinfectants for routine cleaning of surfaces which included the general environment, patient equipment and sanitary fittings however this practice does not reflect current UK routine cleaning recommendations. The NIPCM[24] recommends neutral detergent for routine cleaning of the environment and non-invasive patient equipment and

1,000 ppm available chlorine disinfectant for routine cleaning of sanitary fittings and as part of transmission based precautions.

Moorman et al.,[33] Swan et al.[31] and Galvin et.[29] al also investigated the efficacy of neutral EW (NEW) against human norovirus, *Escherichia coli, Acinetobacter baumannii, Clostridioides difficile, Pseudomonas aeruginosa*, methicillin resistant *Staphylococcus aureus*, vancomycin-resistant *enterococcus* (VRE), *Aspergillus fumigatus* using suspension tests. NEW (1000 ppm) was also applied to a room using a mist fogger. Findings from these studies showed neutral EW led to reductions in bacterial density on test surfaces[31, 33] while NEW mist successfully killed all test microorganisms from all surfaces including soft furnishings achieving ≥ 7 log_{10} reduction except against *C. difficile* spores (1.5 log_{10} reduction).[29]

Issa-Zacharia et al.[14] investigated the in vitro inactivation of *E. coli*, *S. aureus* and *Salmonella* spp. using weakly acidic EW and compared this to strongly acidic EW and sodium hypochlorite solution. The results showed that strongly acidic EW had the greatest bactericidal effect, with weakly acidic EW and sodium hypochlorite showing similar levels of bactericidal effects, despite the hypochlorite solution having more than five times available chlorine. This is thought to be due to the greater ORP and lower pH of strongly acidic EW. A longer treatment time was also associated with a greater effect. It is relevant to highlight that the study took place in Japan and that the concentration of sodium hypochlorite used was not specified: the study only stated that a 10% solution was diluted with distilled water. This study produced the EW in-house using a generator.

Quan et al.[4] evaluated the bactericidal activity of weakly acidic EW on *Vibrio vulnificus* and *Vibrio parahaemolyticus* and compared it to that of sodium hypochlorite solution. Weakly acidic EW was able to kill organisms more quickly than sodium hypochlorite, even at an equivalent ACC. Weakly acidic EW maintained its bactericidal activity for one week under open storage conditions, and for more than five weeks under closed storage conditions, demonstrating that it has a relatively stable shelf life. This study was conducted in the Republic of Korea (South Korea).

Deza et al.[11] compared the efficacy of neutral EW at inactivating *Escherichia coli*, *Listeria monocytogenes*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* with a sodium hypochlorite solution of the same ACC, and similar pH levels and ORP. Neutral EW and sodium hypochlorite had similar efficacy in reducing bacterial populations on surfaces, with neutral EW having the advantage of being safer to handle. This study was located in Spain.

Several in-vitro studies investigated the antimicrobial effect of acidic EW (slightly acidic EW and strongly acidic EW) on cultures of *E. coli, S. aureus, Salmonella* spp, human and surrogate norovirus and biofilms of *P. aeruginosa*.[7, 14, 16, 18, 27, 28, 30] Their results consistently demonstrated that treatment with acidic EW reduced microbial contamination and/or inactivated microorganisms under specific laboratory conditions. Park et al.[28] evaluated the fog-based application of EW (pH 5.5-6.2 and initial ACC 180-200 mg/L) against carriers contaminated with human norovirus and surrogate viruses murine norovirus and MS2 bacteriophage. The freshly prepared EW fog was generated toward the carriers for at least 10 min and 1 h was allowed for settling time. Findings from the study showed that fogging of EW was effective against all test viruses achieving at least 3 log_{10} reductions in both infectivity and RNA titres despite 70% immediate loss of available chlorine concentration (ACC) during fogging.[28]

It is difficult to generalise from the evidence identified due to several limiting factors. Most studies were performed under controlled laboratory conditions with varying methodologies (e.g. suspension tests, assays), test organisms, disinfectant comparators, different EW forms (liquid, spray, fog) and properties in terms of pH, ORP and ACC. Further high quality clinical trials are required to investigate if EW can be a suitable alternative disinfectant to the current standard recommended for use within NHSScotland. There is consensus however that the presence of soil and organic matter significantly reduce the antimicrobial effect of chlorine-based disinfectants including EW.[1, 33] This is an important consideration in their application as an environmental disinfectant. For disinfectants to be effective, any organic material must first be removed by thorough cleaning.[9, 17]

Are there any safety considerations associated with using Electrolysed Water in health and care settings?

Chlorine-releasing agents are considered easy-to-use and the least expensive environmental disinfection method available. However, they do feature a number of limitations such as the release of irritating vapours and toxic gases which may affect the eyes and respiratory tracts of healthcare workers at high concentrations (i.e. 10,000 ppm available chlorine), and personal protective equipment (PPE) is recommended for this reason. Sodium hypochlorite-based products can be corrosive to various materials and potentially cause damage to environmental surfaces. This has led to a renewed interest in alternative methods of environmental decontamination.[34-36] Neutral EW and slightly acidic EW (SAEW) have neutral pH and are reported to be safe, have low toxicity compared to other commonly used biocides, have low odour and do not cause irritation to mucous membrane and skin.[1, 2, 7, 29] EW has also been used for wound care as an antimicrobial and wound healing agent and dental applications including oral hygiene.[2]

Sipahi et al.[7] carried out an in-vitro biocompatibility study to evaluate the safety profile of EW. In-vitro assays using HET-CAM test method and reconstructed human epidermal model (EpidDerm) showed no potential for eye and skin irritation.[7]

EW is considered to be more environmentally-compatible and safer than traditional cleaning agents, as it is less corrosive than standard hypochlorite-based cleaners however it can be mildly corrosive after long-term contact with metal surfaces.[1, 6, 14] EW is produced from NaCl and water and reverts to regular water after use.[1, 2] This means that no PPE or barrier protection is required, there are no chlorine fumes released and that contact with the skin does not pose a concern.

Meakin et al.[10] used a product that had undergone sensitivity and toxicology studies to demonstrate that it is non-toxic to humans and safe for the environment. The product is supplied in ready-to-use spray bottles, unlike some quaternary ammonium disinfectants which need to be diluted in situ and require the wearing of PPE during the dilution process.

Deza et al.[11] report that neutral EW is safer than acidic EW because no chlorine gas is produced at a neutral pH, making it safer for anyone using it, as well as for the environment. They also report that it is stable, has a good shelf life and is less corrosive than its acidic counterpart.

Are there any practical or logistical considerations associated with using Electrolysed Water in health and care settings?

Different types of EW require different considerations in terms of shelf life; acidic EW is more unstable and has a much shorter shelf life than neutral EW.[11, 15] Neutral EW (~pH 6.5 – 7.5) has been reported to have a shelf-life of up to 1 year[10, 15] according to manufacturer’s label and is more stable when stored in closed/sealed containers at 4°C than at 25°C.[37] Studies have shown that weakly acidic EW (pH ~5.9) is able to maintain its pH, ORP and ACC for 1 week if stored in open (unsealed) conditions and for 5 weeks under closed (sealed or capped) storage conditions.[14] Purchased or hired generators provide the ability for on-site generation of EW but consideration should be given to the method of storage and use of the product.[2]

The available chlorine concentration (ACC) of EW decreases over time and the solution loses its antimicrobial potential quickly due to the breakdown of hypochlorous acid and evaporation of chlorine gas. The loss of ACC from freshly generated EW was greatest at over 24-30 hours.[38, 39] ACC decline was also fastest when stored in polystyrene at 20°C and slowest at 4°C in closed glass bottles.[37, 38] Park et al.[28] applied EW using a mist fogger and demonstrated a 70% immediate loss of ACC during fogging treatment from initial concentration of 203 $\pm$ 12 mg/L to 140 mg/L. If applying EW using a mist fogger, the room should be vacated prior to its use and manufacturer's instructions should be followed regarding contact/treatment time, aeration/settling time and any pre-cleaning requirements.[28, 29]

Meakin et al.[10] and Dancer et al.[40] both used stabilised electrolysed hypochlorous solutions, which can be supplied in ready-to-use bulk containers/spray bottles, or generated on-site. On-site generation requires water, salt, electricity and electrolysing equipment, and can be useful in situations where the transport, delivery and storage of large volumes of liquid is costly and impractical. The ready-to-use products have a shelf-life of 12 months, and the manufacturers state that the product remains stable without compromising its effectiveness.[41] The ready-to-use solution does not require special instructions for use, therefore there is no need to purchase any equipment or hire special personnel or train existing staff.[10, 15]

In Park et al.[28] and Galvin et al.'s[29] studies, freshly prepared electrolysed water was produced on site using generators and delivered using mist fogging equipment. Manufacturer's instructions and protocols were followed in the generation of EW solution and operation of the mist fogger. This has implications requiring additional training of existing staff or hiring specialised personnel to operate the equipment. Further considerations should be given relating to the space required to house the EW generator.

What costs are associated with using Electrolysed Water in health and care settings?

Landa-Solis et al.[15] considered the use of EW to be an inexpensive option, and state that the end-product is non-flammable and has no special requirements for handling or disposal. Some ready-to-use pH-neutral EW has a 12-month shelf life according to manufacturer label therefore it may not be necessary to purchase any equipment to produce fresh EW on-site or to hire specialised personal for its operation.[15]

On site production of EW requires a generator therefore an initial expenditure is required however once installed, the production of the active solution is reported to be inexpensive due to the relative abundance of the raw materials water (H_2O) and salt solution sodium chloride (NaCl).[1] Block et al.[42] reports that EW systems costing less than $275 (US dollars) are available on the market however further cost-benefit analyses are required for a comprehensive economic assessment of EW as a viable alternative to standard chlorine-releasing agents for the environmental decontamination in UK health and care settings.

3.2 Implications for research

The review identified several gaps in the literature in relation to EW. There is a paucity of high quality clinical studies e.g. randomised controlled trials investigating the effectiveness of EW against important pathogens including healthcare associated infections and comparing it with established cleaning practices and disinfectants. There is also a lack of studies making direct comparison between acidic (including its variants slightly acidic, weakly acidic, strongly acidic EW) and neutral electrolysed water that warrants further investigation especially in areas relating to production, storage and shelf-life. None of the studies mentioned any precleaning requirements prior to EW use nor additional steps after EW treatment. One manufacturer recommends cleaning prior to fogging disinfection of surfaces however it was not clear how this should be done and study authors did not carry out any precleaning in their experiment. Further studies performed in health and care settings taking into account routine and enhanced cleaning practices are required in order to make informed decisions when considering EW as an alternative disinfectant to standard hypochlorite solutions.

Future studies assessing the clinical effectiveness of EW for decontamination should include suitable comparison groups to enable the results to be transferable to clinical practice within NHSScotland and other health and care settings.

There was also significant variability in the formulation of EW products, including differences in available chlorine concentration (ACC), pH level and oxidation-reduction potential (ORP) and method of EW delivery. These factors may all impact upon the effectiveness of the product. For the purposes of evaluating comparability, the optimal values of these factors should be determined before subsequent analyses measuring the effect of EW against appropriate comparison groups. In accordance, some authors have advocated the establishment of standardised benchmarking measures for the evaluation of environmental surface disinfectants.

The extant research focussed exclusively upon the efficacy of EW products in reducing environmental bioburden, whether clinically-based or laboratory-based. Extrapolating the findings of such studies to the prevention of nosocomial infections may not be valid under normal clinical working conditions. It is therefore necessary to conduct further studies demonstrating the effect of EW on the reduction of healthcare-associated infections and patient acquisition of nosocomial pathogens before conclusions on the efficacy of EW can be reached.

Finally, very few studies thus far have evaluated the cost-effectiveness of EW. Of the few that have, most have appealed to the inexpensive ingredients required for the production of EW and the low disposal costs for the harmless waste products that result from its degradation. It can therefore be seen that a comprehensive cost-effectiveness evaluation for the use of EW in NHSScotland would be timely.

4 Recommendations

This review makes the following recommendations based on an assessment of the extant scientific literature on Electrolysed Water (EW) used for decontamination of the health and care environment:

What is the actual or proposed mechanism of action of Electrolysed Water?

Electrolysed water (EW) is generated by the electrolysis of dilute salt (NaCl) solutions where acidic electrolysed water is produced at the anode side (positive charge) having properties of low pH levels (pH 2 – 3), high oxidation-reduction potential (ORP) >1000 mV and available chlorine concentration (ACC) between 40-1500 ppm while basic or alkaline electrolysed water is generated at the cathode side (negative charge) having properties of high pH levels (pH 10 – 13) and low ORP (-800 to -900 mV).

(No recommendation)

The antimicrobial effect of EW is based on the combined action of the pH, oxidation-reduction potential (ORP) and available chlorine concentration (ACC).

(No recommendation)

The exact mechanisms by which EW causes microbial inactivation have not been fully elucidated but it is thought to be a combination of factors including damage and destruction of cell well structures, disruption of cell membrane permeability, denaturing and inactivation of proteins and damage of nucleic acids RNA and DNA.

(No recommendation)

Is Electrolysed water currently in use in UK health and care settings?

There is no mention of EW products in the NHSScotland National Cleaning Services Specification, the National Patient Safety Agency (NPSA) Revised Healthcare Cleaning Manual, Public Health England, Public Health Scotland, Health Facilities Scotland and the National Infection Prevention and Control Manual (NIPCM) suggesting that EW is not widely used within UK health and care settings.

(No recommendation)

When should Electrolysed water be used in health and care settings?

There is currently insufficient evidence to support the use of EW as an alternative to a chlorine-releasing agent in the decontamination of the health and care environment as recommended by the National Infection Prevention and Control Manual.

(Category C recommendation)

What is the procedure for using Electrolysed water?

There is currently insufficient evidence to recommend the procedure for using EW in the decontamination of the health and care environment.

(Category C recommendation)

What is the scientific evidence for effectiveness of Electrolysed water for decontamination of the healthcare environment?

There is currently insufficient scientific evidence to support the effectiveness of electrolysed water for decontamination of the health and care environment.

(Category C recommendation)

Are there any safety considerations associated with using Electrolysed water in health and care settings?

EW reverts back to regular water after use without the release of chlorine gas and has been reported to be safe for the environment, have low toxicity and odour compared to other commonly used biocides and does not cause irritation to eyes, other mucous membranes and skin therefore PPE or barrier protection is not required.

(Category C recommendation)

Are there any practical or logistical considerations associated with using Electrolysed water in health and care settings?

EW that has been purchased must be stored appropriately following manufacturer's instructions and effective stock rotation must be in place.

(Category C recommendation)

Locally/on-site produced EW must have a use-by date incorporated into the production programme appropriate for the type of EW produced. Suitable space is required to house EW generators.

(Category C recommendation)

Additional consideration should be given to the time and resource required when using EW through a mist fogger and the need to vacate the room during treatment.

(Category C recommendation)

What costs are associated with using Electrolysed water in health and care settings?

EW is produced using a generator therefore an initial expenditure is required. On-site produced EW negates the need for transport or storage of biocidal chemicals.

(Category C recommendation)

EW end product is non-flammable and has no special requirements or costs associated with handling or disposal.

(Category C recommendation)

Some pH-neutral EW has manufacturer reported 12-month shelf life therefore it is not necessary to purchase any equipment to produce EW on-site or to hire specialised personnel for its operation.

(Category C recommendation)

An assessment in each health and care setting should be carried out to estimate the costs involved in using conventional cleaning products versus EW, as numerous factors are involved that depend on the overall cleaning regime specific to each setting.

(Category C recommendation)

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Appendix 1: Methodology and search strategies

Search strategy

V1.0 (2014): searches were run between 24/06/2014 and 25/06/2014 with date limits: 2004-2014

V1.1 (2016): search performed on 18/08/2016 with date limits: 2014-2016

V2.0 (current update): search performed on 17/07/2020 and 14/04/2021 with date limits: 2000-2021

The following search strategy was applied in all versions.

Embase/Medline

1. Electrolysis/
2. electroly?ed adj water*.mp
3. electrochemically activated water.mp
4. (electrochemically activated adj2 solution*).mp
5. Exp Sterilization/
6. Decontamination/
7. Housekeeping, Hospital/
8. clean*.mp
9. steril*.mp
10. 1 or 2 or 3 or 4
11. 5 or 6 or 7 or 8 or 9
12. 10 and 11

CINAHL

S1 (MH "Electrolysis") OR "electrolysis"

S2 electroly?ed N2 water*

S3 "electrochemically activated water"

S4 "electrochemically activated" N3 solution*

S5 electro* water*

S6 activated water

S7 electro* solution*

S8 "activated solution*"

S9 (MH "Sterilization and Disinfection")

S10 decontaminat*

S11 (MH "Housekeeping Department") OR housekeeping

S12 clean*

S13 steril*

S14 S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8

S15 S9 OR S10 OR S11 OR S12 OR S13

S16 S14 AND S15

Databases and resources searched

The databases and resources searched for this literature review are specified in the NIPCM methodology. The following online resources were searched additionally to identify any relevant policy or guidance documents or any significant grey literature:

- NHS Evidence (http://www.evidence.nhs.uk/)
- Health Technology Assessment (HTA) database (http://www.crd.york.ac.uk/CRDWeb/)
- Database of Abstracts of Reviews of Effects (DARE) (http://www.crd.york.ac.uk/CRDWeb/)
- National Patient Safety Agency (NPSA) (http://www.npsa.nhs.uk/)
- National Institute for Health and Care Excellence (NICE) (http://www.nice.org.uk/)
- Medicines & Healthcare products Regulatory Agency (MHRA) (http://www.mhra.gov.uk/)

- Rapid Review Panel (RRP): product evaluation statements (http://www.gov.uk/government/groups/rapid-review-panel/)

Appendix 2: Grades of Recommendation

Final recommendations are given a grade to highlight the strength of evidence underpinning them, the NIPCM grades of recommendations are as follows:

Grade	Descriptor	Levels of evidence
Mandatory	Recommendations' that are directives from government policy, regulations or legislation	N/A
Category A	Based on high to moderate quality evidence	SIGN level 1++, 1+, 2++, 2+, AGREE strongly recommend
Category B	Based on low to moderate quality of evidence which suggest net clinical benefits over harm	SIGN level 2+, 3, 4, AGREE recommend
Category C	Expert opinion, these may be formed by the NIPC groups when there is no robust professional or scientific literature available to inform guidance.	SIGN level 4, or opinion of NICP group
No recommendation	Insufficient evidence to recommend one way or another	N/A