Technology name: Chlorination

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1 Used for

- Preparation of irrigation water

2 Region

- Nordic
- NorthWest Europe
- CentralEastern Europe
- Mediterranean

3 Crop(s) in which it is used

- All vegetables
- All ornamentals

4 Cropping type

- Soilbound
- Soilless
- Protected
- Open air

5 Description of the technology

5.1 *Purpose/aim of the technology*

Growers, packers and processors in the horticulture and potato industries require supplies of clean water, free of human and plant pathogens, for irrigation, fertigation, post-harvest washing and surface or equipment cleaning and hydro-cooling. Chlorination is a method to prepare water for these purposes.

5.2 *Working Principle of operation*

Chlorine is added to water as either sodium hypochlorite, calcium hypochlorite or as chlorine gas. The form used most frequently in Europe is sodium hypochlorite (NaClO). Sodium hypochlorite is purchased as a liquid concentrate that is injected into water using a simple electric dosing pump (Figure 1). Calcium hypochlorite is normally bought as solid granules that need to be made up into a concentrate in water prior to injection by a liquid pump. Chlorine added this way reacts with the water by hydrolysis to form hypochlorous acid – the main active ingredient of chlorination.

Dissolved, the disinfectant will breakdown to form active (free) chlorine: hypochlorite acid (HOCl) and hypochlorite ions (OCl^-). In the case of sodium hypochlorite:

$$NaClO + H2O \leftrightarrow Na^+ + OH^- + HOCl$$

$$HOCl \leftrightarrow H^+ + OCl^-$$

HOCl is a stronger oxidising agent than OCl^-, and is more effective as a disinfectant.

Therefore, a lower pH (more acidic) is favourable to achieve a more effective disinfection.

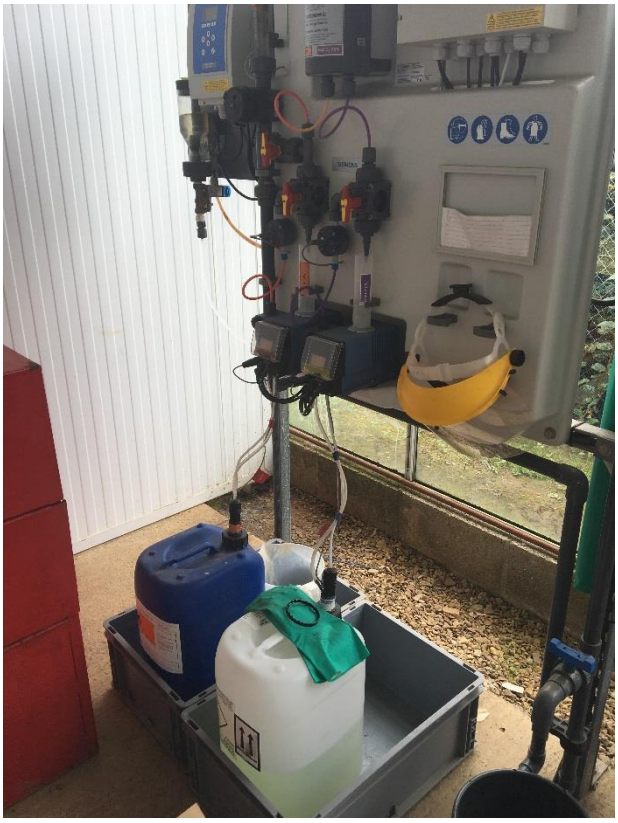

Figure 1. Sodium hypochlorite injection system using an electric pump and reservoir water at a UK ornamental grower's nursery.

5.3 *Operational conditions*

The extent of disinfection required for the water depends on its organic matter and microbial loading and its origin (i.e. reservoir and surface water are commonly treated, but bore hole and mains water are not often treated, depending on water quality). The pH also determines formation of hypochlorous acid; the ideal pH being between 6 and 7,5. The effective concentration of hypochlorous acid depends on the type of the waterborne microorganisms. For instance, a treatment with 0,6 mg/l of NaOCl during 10 min is enough to inactivate 100 % of *Botrytis cinerea* propagules but for *Phytophtora spp.,* the effective treatment is 5 mg/l of NaOCl during 1 min to inactivate 100 % of the propagules. A more complete list of chlorine efficacy on waterborne microorganisms is available in the review article wrote by Raudales et al. (2014).

5.4 *Cost data*

Installation costs:

Very little information is available regarding costs. The calculated costs below are based on work by one person in the United States, working with growers. The amounts have been converted to Euros and metric measurements (Table 1). For installation, the costs include establishment costs of wells, ponds or rainwater systems and the purchase price of pumps, estimate: € 2837.

Yearly maintenance or inputs needed:

The cost of chlorine dioxide did not change between 10 000 and 100 000 litres of water per day suggesting that chlorine dioxide may be more cost effective for large volumes of water. Below the amount of 10 000 litres, UV disinfection may be more cost effective.

Fund-intensive technologies with lower consumable costs have advantages from economies of scale where large volumes of water are treated.

Table 1. Capital and running costs for chlorination systems based on several growers in the USA (costs and volumes have been converted to Euro and metric units)

	Capital total cost	Annual total cost	Marginal cost (€/1000 litres) (percentage from total cost)			
			Capital	Consumables	Labour	Total cost
Calcium hypochlorite	€ 2837	€ 1701	€ 0,08 (22%)	€ 0,15 (44%)	€ 0,11 (33%)	€ 0,34
Sodium hypochlorite	€ 4583	€ 1701	€ 0,11 (33%)	€ 0,11 (33%)	€ 0,11 (33%)	€ 0,34

5.5 *Technological bottlenecks*

It may not be an appropriate treatment for waters containing high concentrations of dissolved organic matter. It is important to pre-filter water before treatment.

An electric dosing pump is required to inject the sodium hypochlorite liquid concentrate into the irrigation water since water-powered injection pumps can fail prematurely due to corrosion.

5.6 *Benefit for the grower*

5.6.1 Advantages

- Relatively simple to install and maintain
- Long record of successful use
- Creates environment hostile to algal growth
- Keeps pipework and irrigation system clean
- Economic installation
- Residual disinfectant activity

5.6.2 Disadvantages

- High rates could cause phytotoxicity
- Chlorate is a competitive inhibitor of iodine uptake in the thyroid
- Risk of organochlorine formation
- Chlorine reacts with ammonium and cannot be used with this form of nitrogen fertilizers (precipitation occurs)

- Reacts with iron and manganese forming insoluble salts that can cause mineral fouling of irrigation lines
- It is corrosive
- Chlorates can build up in edible produce
- Depending on concentration, dosed water needs to be stored for a time to allow dissipation of chlorine

5.6.3 Review by growers with experience

The grower has trained several staff to use the technology and sodium hypochlorite. One person is responsible overall for making sure that it works. The grower has organized health and safety training and has ensured that the correct bunds surround the acid and that appropriate safety gear and signs are present. He has had no problem with the technology, and no issue with contamination of the water. Overall he is very satisfied with how it works.

5.7 *Supporting systems needed*

Filtration systems to remove organic matter and other particulates are needed.

5.8 *Development phase*

- **Commercialised**

5.9 *Who provides the technology*

- Netafim
- Mazzei
- Swimming pool supply stores (calcium hypochlorite)
- Industrial chemical suppliers
- Farm suppliers

5.10 *Patented or not*

This technique is not patented.

6 Which technologies are in competition with this one

- Dioxychloration
- Alternative technologies such as ozone, copper salts, hydrogen peroxide, iodine

7 Description of the regulatory bottlenecks:

7.1 *Brief description of the European directive and implications for growers at European level*

Chlorine, Sodium Hypochlorite and Calcium Hypochlorite are listed in the Biocidal Products Regulation (BPR) EU 528/2012 which concerns the making available on the market and use of biocidal products.

7.2 *Implementation at the country level*

In the absence of information of what an appropriate level might be, a default MRL (maximum residue level) of 0,01 mg chlorate/kg, the minimum level of detection for chlorate, has been set for all foods in the UK.

7.3 *Implementation at the regional level*

Not applicable

8 References for more information

[1] Gordon, G. and Tachiyashiki, S. (1991). Kinetics and mechanism of formation of chlorate ion from the hypochlorous acid/chlorite ion reaction at pH 6-10. *Environmental Science & Technology*, 25, 468-474.

[2] Raudales, R. E. (2014). Characterization of water treatment technologies in irrigation. University of Florida.

[3] https://horticulture.ahdb.org.uk/oomycetes

[4] Raudales, R. E., Parke, J. L., Guy, C. L., & Fisher, P. R. (2014). Control of waterborne microbes in irrigation: A review. *Agricultural Water Management*, *143*, 9–28.

9 Keywords

- chlorination
- hypochlorite
- pathogens
- filtration
- hygiene
- maximum residue level (MRL)
- algae
- cleaning
- purification