Chlorination of Water for Fluming and Cleaning Fresh Fruits and Vegetables and Cleaning Equipment[0]

Note: *The procedures below are "general" chlorination procedures.*

1. Water Treatment

The purpose of adding chlorine to wash and flume water is to keep the water potable, not to sanitize the product. Chlorine can be used effectively to kill microorganisms present in wash and flume water, but the effectiveness of chlorination depends on the following factors:

- pH of Water: Chlorine is most effective when water pH is between 6.0 and 7.5. Above pH, 7.5, little (<50%) chlorine exists in its active form and below pH 6.0, noxious chlorine gas can be released. This gas can be harmful to workers and makes the solution more corrosive to equipment and less effective for sanitation.
- Organic Matter: Any organic matter (leaves, soil, stems) present in water can reduce the effectiveness of chlorine. More chlorine is required to achieve the same level of control in dirty water.
- Contact Time: Lower concentrations of chlorine require a longer contact time to achieve the same disinfection as higher concentrations.
- Water Temperature: Water temperature has a lesser effect on chlorine effectiveness than the other factors. Lukewarm water is best. Hot water increases the corrosiveness of chlorine while chlorine is somewhat less effective in cold water.

All of the above factors will affect how much chlorine is needed to adequately control the quality of wash and flume water. The following information provides general guidance for adding and monitoring chlorine in wash and flume water and can be used as a starting point to develop operation specific procedures. Chlorine concentrations that are too high can damage the product and harm employees. Concentrations that are too low will not adequately control the growth and survival of microorganisms that cause spoilage and human illness.

a) Using Oxidation-Reduction Potential (ORP) to Determine Appropriate Chlorine Levels and Monitor Effectiveness

Oxidation-Reduction Potential is a rapid and accurate way to measure chlorine effectiveness. ORP is measured using an ORP meter, similar to a digital thermometer or pH probe. A single reading can tell you whether the amount of chlorine in your wash water is effective regardless of organic matter or pH. As the amount of organic matter increases or the pH increases above 7.0, more chlorine will be required to reach the same target ORP. Research has shown that water with an ORP value of 650-700 mV can kill bacteria such as *E. coli* in a few seconds while more resistant types of microorganisms are killed within a few minutes. For most post-harvest washing or fluming systems, it is unnecessary to operate above 800 mV – a level commonly used in primary wash systems where there is a high amount of organic matter.

0 Canadian Horticultural Council, **Appendices to On-Farm Food Safety Manual**, Appendix B, pg. 9-16, Version 4.1, 2010.

Advantages of ORP:

- Easy to use, quick reading tells you if you have enough chlorine regardless of pH and organic matter
- Can help avoid over-chlorination which can be hazardous to product, workers and equipment

Disadvantages of ORP:

- Need to purchase an ORP meter
- Need to clean and (for some meters) calibrate the instrument on a regular basis
- High levels of inorganic compounds in your water such as metals or minerals can interfere with ORP readings. For this reason, when setting up your monitoring system, always double check using chlorine strips and a water test to ensure ORP readings are correct

Using an ORP meter:

- Fill the flume or wash tank and pick a starting chlorine concentration (such as 50 ppm).
- Use the chlorine conversion tables below and add the desired amount of chlorine.
- Always try and take the sample from the same spot and set a target reading between 650-800 mV. A target ORP of 700 or above is recommended to account for variations in meter accuracy.
- For hand-held ORP meters, immerse the meter in water source for 30 seconds or according to manufacturer's instructions. If the water is highly turbulent, use a clean plastic container to collect a sample. Fill the container, swirl, dump the contents, fill again and immerse ORP sensor in water. Gently stir the water with the sensor for 30 seconds (or according to manufacturer's instructions).
- Record the ORP reading on Form (N1) Water Treatment Control and Monitoring. If the reading is below your target level, add more chlorine until you reach the desired ORP. If it is too high, add less the next time so you can determine what the correct starting amount of chlorine is for your system. Record how much chlorine you added.
- It will take some time to determine how often you will need to check ORP and add more chlorine to your system. The first time you use the ORP meter, check ORP levels frequently (e.g., every hour or every product load). If the ORP does not change then reduce the frequency of monitoring. If it drops dramatically, consider starting with a higher level of chlorine and ORP (e.g. 800 mV compared to 700mV or 100 ppm instead of 50 ppm). Over time you will have a better idea of how quickly chlorine is used up in your system, how often you will need to add chlorine and how much to add.
- If you find that the chlorine is being used up too quickly and you have lots of organic matter (dirt, leaves, stems etc.) in your wash water, consider changing the water more often, filtering the water or scooping out some of the plant debris.
- Once you have determined how much chlorine you need to start with, how often you need to check your wash or flume tank, where you take your measurements and your target ORP reading, WRITE THIS DOWN. This will allow your employees to conduct the monitoring and will also save you time at the beginning of next season.
- Occasionally double check ORP readings using pH and chlorine test strips and clean water.

Important Note: High levels of inorganic materials (such as iron) in water can alter ORP readings. Always double check your target ORP with FREE chlorine test strips. You may have to adjust your target ORP

readings to compensate. You can check this by using free chlorine test strips and pH strips in clean filtered water. At pH 7.0, in clean water, 3 ppm of free chlorine corresponds to an ORP of approximately 700 mV and 5 ppm to 750 mV.

There are three basic types of ORP meters:

- Pocket meters are the least expensive, small enough to fit in a pocket, and are reasonably reliable. Generally they need to be replaced after a year or two.
- Hand-held meters offer a high degree of accuracy and reliability and may also provide a temperature and/or pH check. The electrodes of hand-held meters need to be replaced approximately every two years.
- Process meters are mounted in a fixed location and provide continuous monitoring and recording of ORP readings. They are more expensive and most commonly used with automatic chlorine injection systems although they can be used when adding chlorine manually. ORP meters can cost anywhere from $100 for pocket meters to over $1,000 for process control meters with internal record keeping and can be purchased from some scientific supply companies (Fischer Scientific; Canadawide Scientific, Omega Engineering Inc.) or water treatment supply companies, or suppliers can be found online from manufacturers' web sites (Extech Instruments or Oakton Instruments). (Prices as of January 2008.)

Reference: Suslow, T. Oxidation-Reduction Potential (ORP) for Water Disinfection Monitoring, Control, and Documentation, 2004. University of California, Publication 8149 [retrieved December 31, 2007]. http://www.amfiltech.com/media/Suslow%20-%20ORP%20&%20Ozone%20for%20Water%20Disinfection.pdf

b) Using Total and Free Chlorine to Determine Appropriate Chlorine Levels and Monitor Effectiveness

Measuring total and free chlorine through chlorine strips and pH strips (or probes) is another way to monitor the amount of chlorine in wash and flume water. Total chlorine is the total amount that has been added to the water while free chlorine is the amount of chlorine that remains active in the water. Measuring total chlorine is most useful when determining and checking how much chlorine to start with in clean water. Measuring free chlorine is a much more accurate way of monitoring the effectiveness of your chlorination system over time.

Generally, maintaining 2-7 ppm of FREE chlorine and a pH of 6.0-7.5 in wash water at all times is sufficient to kill bacteria in water. However, it is recommended that fresh fruit and vegetables packers add 50-150 ppm of TOTAL chlorine to their wash water to start. This will help ensure the free, active chlorine will not be used up too quickly.

Determining how much total chlorine to start with in your wash and flume water will depend on what type of product you are washing, the amount of organic matter that collects in the wash water and how often you change the water. For example, field tomatoes will have more soil than greenhouse tomatoes and the chlorine will be used up faster.

You will need to determine the initial amount of total chlorine to add to wash or flume water, the frequency at which you need to check chlorine levels, how much chlorine you need to add throughout a typical day and how often you need to change your water:

• Choose a total chlorine level between 50-150 ppm and, using the chorine conversion below, add the required amount of chlorine to your wash water.
• Check the chlorine level after a few minutes to ensure that you have added the correct amount (using TOTAL chlorine test strips or probe) or that free chlorine levels are between 2-7 ppm (using FREE chlorine test strips or probe).
• For the first several days (go through several water changes), continue to check the FREE chlorine levels at a relatively high frequency (every hour or every product load) to ensure levels do not drop below 2-7 ppm.
• As chlorine levels start to drop below 2-7 ppm add more chlorine as required.
• If you find that, after an hour, there is no FREE chlorine left, increase the amount of total chlorine you start with and increase how frequently you check the chlorine levels.
• If, after a week or two, you find that FREE chlorine levels do not change much at this frequency you may be able to check less often as you get an idea of how quickly the chlorine is used up in your system. You may find that over time, as the water becomes dirtier, it becomes more difficult to maintain FREE chlorine levels.
• If you can no longer maintain FREE chlorine levels between 2-7 ppm, empty and rinse out the wash or flume tank and refill. Adding a filtration system or scooping out organic matter with a net can also help to maintain the potability of the water.
• Once you have determined how much chlorine to start with, how often to check chlorine levels, how much chlorine you need to add and how often to change your water, WRITE THIS DOWN. This will save you a lot of time later, will help you remember exactly what you were doing from year to year and allow employees to follow the procedure properly.

***Note**: High levels of chlorine can cause pitting or burning of the product and can be hazardous to workers.*

Reference: Guide To Minimize Microbial Food Safety Hazards For Fresh Fruits And Vegetables. U.S. Food and Drug Administration, U.S. Department of Agriculture and the Centers for Disease Control and Prevention. 1998.

c) Chlorine Conversions

Target ppm	ml/L	tsp/5 gal	cup/50 gal
Sodium Hypochlorite 5.25%			
50	0.95	3 ⅔	¾
75	1.43	5 ½	1 1/10
100	1.90	7 ¼	1 ½
125	2.40	9 1/10	1 ⅞
150	2.90	10 ⅞	2 ¼
Sodium Hypochlorite 12.75%			
50	0.39	1 ½	⅓
75	0.59	2 ¼	½
100	0.78	3	3/5
125	0.98	3 ¾	4/5
150	1.18	4 ½	9/10

Reference: Food Safety Begins on the Farm, A Grower's Guide, Good Agricultural Practices for Fresh Fruits and Vegetables. Anusuya Rangarajan, Elizabeth A. Bihn, Robert B. Gravani, Donna L. Scott and Marvin P. Pritts. 2000.

d) Type of Chlorine to Use

• ONLY use **hypochlorite** (usually 5% or 12%). Carefully read the ingredient label to ensure there are no other chemical additives.
• Note that the pH of the fluming or cleaning water will increase when chlorine is added to the water.

2. Chlorine Conversion

These calculations are to be used to determine the amount of chlorine required to treat fluming and cleaning water and control microbial growth. *Refer to Section 1: Water Treatment (above) to determine the level of chlorine required for the produce you will be fluming or cleaning.*

***Note: ONLY** sodium hypochlorite, calcium hypochlorite or potassium hypochlorite is to be used. Carefully read the ingredient label to ensure there are no other chemical additives.*

a) Important variables to consider when using chlorine

• pH of fluming or cleaning water
• Concentration of chlorine being used (i.e., 5 or 12%, which can be found on the bottle)
• Volume of water in flume or tank
• How long product will be in the flume or tank
• How much organic matter is in the tank

Once these variables have been determined, they must be used in the following equation.

1. Determine pH of fluming or cleaning water using a pH test strip. Add organic acids as necessary to adjust the pH. Note that the pH of the water must be between 6.0 and 7.5 both before and after chlorine is added.

2. Determine the concentration of chlorine required. Convert the concentration to parts per million (ppm).

Example – if a chlorine concentration of 5.25% (standard household bleach) is used:

$$5.25/100 = 0.0525$$

$$\text{Parts per million} = 0.0525 \times 1\,000\,000 = 52\,500 \text{ ppm}$$

3. Calculate the dilution factor.

Example – if a chlorine level of 125 ppm is required:

Dilution factor = 52500ppm/125ppm = 420

4. Determine the amount of chlorine needed.

Example – if the volume of water is 1000 L:

420/1 = 1000/X

Then X = 2.38

Thus, 2.38 L of chlorine is required per 1000 L of water; or 2.38 ml of chlorine per 1 L of water.

Note: *To convert litres to gallons, multiply the number of litres by 0.2642.*

5. It is necessary to account for how long the product will be in contact with the chlorinated water. If this time is less than 2 minutes, **INCREASE** the amount of chlorine that needs to be used without exceeding 150 ppm.

6. ANY type of organic matter (dirt, dust, calyx, leaves) inactivates the chlorine present in the water. Consider how long the fluming and cleaning water will be used and adjust the chlorine to be added accordingly [e.g., if the fluming water will be used for 8 hours there will be more organic matter in the tank (as the water is recirculated) and it will be necessary to add more chlorine; if the fluming water is only being used for 4 hours, then less chlorine is required].

7. To reduce the amount of organic matter, pre-wash in potable water, change the water frequently (e.g., daily) or use filters.

3. Water Treatment Test Strips for Maintaining and Monitoring Fluming and Cleaning Water

a) pH Test Strips

1. BEFORE chlorine is added, dip the pH test strip 1-2 seconds in fluming or cleaning water and compare it to the color chart.

2. Add the required amount of chlorine to the fluming or cleaning water and mix well.

3. Dip a NEW pH test strip 1-2 seconds in the cleaning or fluming water and compare it to the color chart.

4. In order for the chlorine to be effective, keep the pH of the fluming or cleaning water between 6.0 and 7.5.

5. Adjust the pH of the fluming or cleaning water with acids to lower the pH if necessary and to attain a pH value between 6.0 and 7.5.

6. Use strips to monitor pH on a daily basis.

7. Record the pH level on the Water Treatment Log.

b) FREE Chlorine Test Strips

1. Add the required amount of chlorine to the fluming or cleaning water and mix well.

2. Make sure your fingers are dry when you remove a test strip from the vial.

3. Dip the test strip into the fluming or cleaning water. Do not use any agitation.

4. Immediately compare the test strip to the color chart on the vial's label.

5. Record the total chlorine concentration on the Water Treatment Log.

6. The frequency at which you need to test chlorine levels will be different for each operation. You may need to adjust your frequency when temperatures are high, when product is unusually dirty or when running large volumes.

7. Add chlorine as required.

8. Record the total chlorine concentration on the Water Treatment Log.

c) Where to Buy Chlorine Test Strips and Probes

Test strips that measure FREE chlorine can usually be purchased at pool supply stores. Make sure that the strips can measure up to 10 ppm, many pool strips or pool test kits only measure up to 4 ppm. Test strips that measure TOTAL chlorine are more difficult to find. Both types of test strips, as well as pH strips and electronic probes to measure chlorine and pH, can be purchased from scientific supply companies such as Fischer Scientific; Canadawide Scientific, Omega Engineering Inc.; water treatment supply companies, or suppliers can be found online from manufacturers' web sites (Extech Instruments or Oakton Instruments).

4. Cleaning equipment

Equipment that comes into direct contact with product has the potential to transfer contamination if not cleaned properly. The term cleaning refers to the removal of unwanted material (e.g., dirt, chemical residues, organic material) from equipment and food contact surfaces. Cleaning is best achieved with water and friction. Friction is needed to loosen materials so they can be washed away with the water. This can be achieved through wiping or scrubbing with cloths or brushes or using a high pressure spray. The use of soaps or surfactants can also help remove unwanted materials by dissolving them or reducing

their ability to attach to the equipment.

Water cannot be used on some types of equipment. In these cases, at minimum, friction through brushing or sweeping, is needed to remove soils and other undesirable materials.
Sanitizing is not the same as cleaning. Sanitizing is the treatment of a clean surface with a chemical (e.g., chlorine) or physical agent (e.g., heat) that will kill microorganisms and reduce them to a safe level. Sanitizing with chemicals is a useful risk reduction step, but chemicals must be used properly in order to be effective. Some studies have shown that the use of water and adequate friction was more effective in reducing microorganisms on equipment than just using chemical sanitizers.

***Note**: Surfaces must be clean for sanitizers to be effective.*

a) Use of Chlorine for Cleaning and Sanitizing Equipment

Chlorine is the most commonly used sanitizer in food production facilities. However, chlorine can damage sensitive surfaces such as rubber and sponges and can increase rusting and corrosion of some metal surfaces.

The effectiveness of chlorine solutions depends on several factors:

- Chlorine concentration
- Amount of time surface is in contact with chlorine solution
- Water Temperature – lukewarm water is best (24ºC/72ºF)
- pH – works best between 6.5 and 7.0
- Water quality

Chlorine Concentrations and Contact Times for Various Surfaces:

- Non-porous (e.g., metal, hard plastic) food contact surfaces: Use a **100-200 ppm** chlorine solution, soak for 2 minutes and air dry.
- Porous surfaces: Use a 600 ppm chlorine solution for 2 minutes then thoroughly rinse with potable water and air dry.
- Floors and Walls: Higher concentrations (e.g., 1,000-2,000 ppm) may be used on walls and floors.

Prepare solutions using potable water and the chlorine conversion provided above.

Chlorine is relatively unstable so chlorine solutions gradually lose strength even in covered containers. Fresh solutions must be prepared frequently. Maximum storage life is 24 hours. Always label containers containing chemical solutions.

Safety Considerations

- It is wise to wear protective clothing and eye covering when using chlorine solutions. Also, make sure that the area is well ventilated.
- Harmful chlorine gas can be produced if the solution falls below pH 4.0 or if the chlorine is used in hot water.

• Chlorine is incompatible with most other chemicals. Do not mix chlorine with detergent cleaners. When mixing chlorine solutions, **always add concentrated chlorine to water**; never add water to chlorine to avoid possible explosions when mixing chlorine solutions.

b) Use of Other Chemicals for Cleaning and Sanitizing Equipment

The following are other common types of sanitizing chemicals:

- Quaternary Ammonium Compounds or "Quats" are effective on porous surfaces, non-corrosive, non-staining, odourless and effective over a wide pH range. They are more expensive than chlorine but may be safer to use on equipment. A concentration of 200 ppm for 45 seconds (at 24-44 °C) is required for sanitation.
- Iodine/Iodophors are less affected by organic matter than chlorine but have a limited effective temperature range (24-34°C). They can stain or discolour equipment and a concentration of 25 ppm is required.
- Peroxyacetic Acid is more expensive than chlorine but is not as affected by organic matter as chlorine. Different formulations are available for different purposes such as for food and non-food contact surfaces.

When using any of these sanitizing chemicals, be sure to choose products developed for use on food contact surfaces and always follow the label directions.

References:

Ontario Ministry of Agriculture, Food and Rural Affairs. Foods of Plant Origin. Cleaning and Sanitation Guidebook. July 2006 [retrieved December 31, 2007]. Available at: http://www.omafra.gov.on.ca/english/food/inspection/fruitveg/sanitation_guide/cs-guidebook.htm
Chlorine Chemistry Council.

Chlorine and Food Safety White Paper. 2007 [retrieved December 31, 2007]. http://www.americanchemistry.com/s_chlorine/sec_content.asp?CID=1199&DID=4559&CTYPEID=107