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HYDROCOOLER WATER SANITATION IN THE SAN JOAQUIN VALLEY STONE FRUIT INDUSTRY

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Most packing house operators in the San Joaquin Valley use chlorine in their hydrocoolers to kill pathogens in the water and on fruit surfaces. Such practices prevent the buildup of pathogens in the water and can greatly reduce fruit infections during subsequent storage and transportation. Chlorination is also advantageous because it leaves no residue on the fruit for human health concerns. Further, in our research we have not seen any damage of fruit treated with up to approximately 500 ppm sodium hypochlorite. However, because chlorination leaves no residue on the fruit, pathogens which land on the fruit surface after treatment will not be killed.

The main forms of chlorine used include sodium hypochlorite (NaOCl), calcium hypochlorite ($Ca(OCl)_2$) and chlorine gas (Cl_2). Sodium hypochlorite comes in a 5.25% solution (household bleach) and 12.75 or 15% solutions available through laundry and swimming pool chemical suppliers. Calcium hypochlorite usually comes as a powder or tablets in formulations of 65%. However, it does not dissolve readily (especially in cold water) and undissolved particles can cause phytotoxic chlorine burns on the fruit. To prevent this, one should first dissolve the powder or granules in a small amount of warm water before adding to the hydrocooler water. If using tablets for continuous, slow-release of chlorine, ensure that the tablets are placed so that water circulates well around them. Chlorine gas comes in pressurized gas cylinders and should be handled cautiously according to label instructions.

Factors Controlling Sanitation Activity There are several factors that influence available chlorine levels and how effectively pathogens are killed:

pH: When sodium hypochlorite is added to water, it forms sodium hydroxide (NaOH) and hypochlorous acid (HOCl) (Reaction #1).

Reactions:
1) $NaOCl + H_2O <-> NaOH + HOCl$ (active form)
2) $HOCl <-> H^+ + OCl^-$
3) $HOCl + HCL <-> H_2O + Cl_2$ (gas)

All three forms of chlorine produce hypochlorous acid (also called available chlorine, free chlorine or active chlorine) which is what kills the pathogens. In solution, the hypochlorous acid can disassociate to form hypochlorite ion (OCl^-) (Reaction #2). Hypochlorite ions are relatively ineffective against pathogens. At low pHs, most of the chlorine is in the hypochlorous acid form while at high pHs, most of the chlorine will be in the ion form (Fig. 1). However, at pHs below 6 available chlorine activity is lost rapidly because another reaction is favored which produces toxic chlorine gas (Reaction #3). Therefore, maintaining a pH of around 7 will maintain about 80% of the chlorine in the hypochlorous acid (active) form with very little in the gaseous form.

Adding either sodium hypochlorite and calcium hypochlorite will increase pH, while adding chlorine gas will decreases pH. After adding commercial chlorine, adjust the pH of the water to 7 by adding either acid or base. One can determine the pH of water by using an electronic pH meter or color-changing paper indicator. Muriatic (HCl) or citric acid are commonly used to lower pH while sodium hydroxide (lye) will raise pH. Typically, in this area we may need to decrease pH of our hydrocooler water. To lower pH, one can determine the amount of acid to add by taking a sample of the water, adding acid to the sample until the pH drops to 7, and then multiplying the amount of acid added per gal. of sample by the total number of gallons in the tank. For example, if 1 fl oz of acid added to a 5 gal. water sample reduces the pH to 7 and the tank holds a total of 300 gal., then (1 fl oz/5 gal. sample) x (300 gal. tank) = 60 fl oz or about 1.9 quarts of acid to lower the tank to pH 7. After adding acid to the hydrocooler tank and allowing about 10 minutes for thorough mixing, verify its pH and "fine tune" it if necessary.

<u>Chlorine concentration</u>: Although low concentrations of hypochlorous acid (<40 ppm) have been reported to kill most pathogens within 1 minute, higher concentrations (75 -100 ppm) are commonly used to compensate for various losses of available chlorine in the tank.

<u>Exposure time</u>: High available chlorine concentrations kill pathogens after short exposure times (< 1 min.). At lower concentration, more contact time is required to kill the pathogens.

<u>Amount of organic matter in the water (e.g. fruit, leaves & soil)</u>: Organic matter in the water will inactivate hypochlorous acid and can quickly reduce the amount of available chlorine. Chlorine which combines with organic matter no longer is active against pathogens but will still be measured by total chlorine testing kits.

<u>Water temperature</u>: At higher temperatures, hypochlorous acid kills pathogens more quickly but is also lost more rapidly due to chlorine gas formation and reactions with organic matter.

<u>Type and growth stage of the pathogens</u>: Although germinating spores and mycelium are relatively easy to kill, spores are much more resistant to chlorine and pathogens growing inside the fruit (inside wounds or as quiescent infections) are shielded from the chlorine and not killed.

San Joaquin Valley Hydrocooler Water Survey

During the 1995 stone fruit season, we surveyed both total and available chlorine levels in several commercial hydrocoolers. We found that available and total chlorine levels started out high in the morning, but then quickly declined by about 50% during the first 48 bins. Under these conditions, pH was not an important factor because both total and available chlorine levels dropped so quickly. Therefore, frequent monitoring (~ every 30 bins) of available chlorine levels is essential to control pathogens in hydrocooler water.

Kits for measuring total and available chlorine can be easily purchased. Those that measure available chlorine are preferred because chlorine ions or "combined chlorine" may give high readings in total chlorine kits.

When using sodium hypochlorite, sodium ions are released (Reaction #1) and can accumulate to levels which may damage the fruit (Table 1). Sodium levels are cumulative and rise each time more sodium hypochlorite is added. Because of this and accumulating dirt, it is important to drain the tank daily and add fresh, clean, potable water. Drained water can usually be applied to nearby farmland. However, check pollution control regulations and local restrictions before disposing of the water.

Recommendations:

- Check available chlorine levels often (~every 30 bins). Total chlorine measurements may be adequate when water is clean and pH is near 7. Installation of automated systems to monitor and adjust available chlorine and pH levels may be worth consideration.
- Maintain available chlorine levels between 75 and 100 ppm.
- Maintain pH around 6.5 - 7.5.
- Drain the tank at the end of each day and refill with clean water.
- Use all chemicals according to their labels (e.g. chlorine, muriatic acid, lye, etc.).
- Use self cleaning screens in hydrocoolers to remove large debris.

Table 1.

pH	Ounces of 65% $Ca(OCl)_2$ per 100 gal. of water	Resulting ppm $Ca(OCl)_2$	Pints of 5.25% NaOCl solution per 100 gal. of Water	Pints of 12.75% NaOCl solution per 100 gal. of Water	Resulting ppm NaOCl	ppm Na
6	2.1	104	1.6	0.7	108	33
	2.8	139	2.2	0.9	144	45
7	2.5	120	1.9	0.8	125	39
	3.3	160	2.5	1.0	167	51
8	5.8	282	4.5	1.8	294	91
	7.7	376	6.0	2.5	392	121
9	38.9	1892	30.0	12.4	1970	608
	51.8	2523	40.0	16.5	2627	811

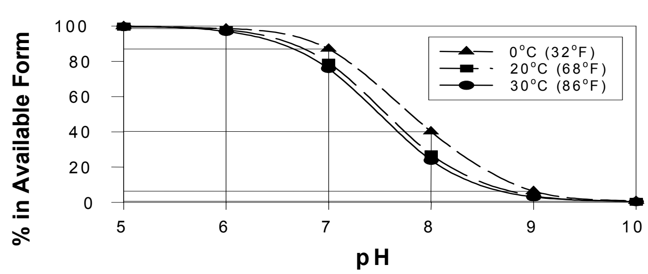

Fig. 1. Percent of chlorine in the available (HOCl) form at different pHs and temperatures.