By using this type of bottom heating it is possible to take advantage of newer production systems much more effectively. In addition to improving automatic watering results, the flexible hose and connection makes it possible to use rolling or removable benches quite easily. Remember that with any production routine it is important to evaluate each part and determine how well a new segment will fit into the whole. This must be done on an individual basis. Test a system such as Biotherm first on a small basis. By so doing, much can be learned to make complete installation and management much easier and much more profitable.

CHLORINATION OF IRRIGATION WATER

BILL DAUGHTRY

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Our nursery is a container operation where we place all of our containers on polyethylene. Most of our beds drain into one of our ponds, along with any pathogens that are washed out of the containers. Therefore, recycling the water will distribute these pathogens over the entire nursery. While researching this problem, we found that many pathogens may be inherent in the water supply and that recycling the water can only increase the problem. Before considering chlorination, have the water tested to make sure that it is part of the problem.

Chlorine compounds have been used for the disinfection of water for 100 years, but how it works is still not fully understood. We chose the injection of Cl_2 gas as our method of chlorination.

The element chlorine exists as a gas at room temperature. It has a characteristic pungent odor, which can be detected at extremely low concentrations. It is greenish-yellow in color, 2½ times as heavy as air, and will seek the lowest point in the building if a leak occurs. Chlorine is neither explosive nor flammable but will support combustion. It is reactive with almost all elements and will form many inorganic and organic compounds. Dry chlorine (Cl_2 in the presence of less than 150 ppm H_2O) does not react with most metals, but in the presence of moisture it becomes highly corrosive. When chlorine gas is compressed, it forms a clear, amber-colored oily fluid that is

1½ times as heavy as water. As the liquid vaporizes, its volume increases 460 times. Chlorine gas at low concentrations is primarily a respiratory irritant. In sufficient concentrations it will also irritate mucous membranes and skin. At high concentrations it can cause death from lack of oxygen in the air or from lung damage.

Chlorine gas is supplied in pressurized cylinders that are appoximately 80% liquid and 20% gas. Pressure in the cylinder provides no indication of the weight of the remaining liquid chlorine. It will remain steady until all of the liquid has been vaporized as long as the temperature is constant. The rate of flow of Cl_2 from a cylinder is only as rapid as the rate at which the liquid can be vaporized. This is temperature dependent. As the temperature increases, the pressure and rate of flow will increase. At ambient temperatures the rate of flow from a 150-lb. cylinder is appoximately 1.75 lbs. per hour and from a one-ton cylinder is 15 lbs. per hour.

When chlorine is mixed with water, it quickly hydrolyzes to form hydrochloric and hypochlorous acids.

$$Cl_2(g) + H_2O(liq) \rightleftharpoons HCl(aq) + HOCl(aq)$$

The hydrochloric acid concentration is extremely low and has a negligible effect on pH. The hypochlorous acid will partially dissociate to form hydrogen and hypochlorite ions.

$$HOCl \rightleftharpoons H^+ (aq) + OCl^- (aq)$$

The level of this reaction is controlled by the pH of the water. At a pH of 6.0 or below, HOCl is present. As the pH increases, the reaction shifts toward the formation of OCl^- until at pH 9.0 the HOCl is almost totally dissociated. As a disinfectant, HOCl is 80 times more active than OCl^-. Irrigation water normally is in a pH range that will keep the HOCl from dissociating significantly.

The total quantity of chlorine in the three forms Cl_2, HOCl, OCl^- are called free residual chlorine or free available chlorine (F.A.C.).

The difference between the amount of Cl_2 added to a given quantity of H_2O and the amount of F.A.C. remaining at the end of a given contact period is referred to as the Cl_2 demand. This chlorine has been tied up by reacting with any impurities in the water: organic matter, fertilizers, colloidal materials, etc.

Ammonia (NH_3) has the most influence upon the chemistry of H_2O chlorination. The reaction of Cl_2 and NH_3 is not instantaneous but requires up to one minute for completion, depending upon the pH and temperature. During this initial delay the F.A.C. is being rapidly reduced, but an enhanced rate of disinfection occurs because of the initially elevated levels of F.A.C. During this brief period many pathogens that concern us are controlled. The 30-minute to 2-hour contact time indicated in available literature for the decontamination of industrial waste water and sewage effluents may not be necessary to obtain relatively clean irrigation water.

After several attempts at injecting various chlorinated materials that were expensive, highly corrosive, and labor intensive to mix and regulate, we decided to use chlorine gas. Chlorine gas is extremely dangerous, so we purchased what we still think is the safest injector available. We bought a series V500-remote vacuum chlorinator manufactured by Wallace & Tiernan, a division of the Pennwalt Corporation, 25 Main Street, Belleville, N.J. 07019

There were several reasons for this purchase. The Cl_2 is maintained in the system under a vacuum; it will signal when the cylinder is empty and Pennwalt has the technical support to help install, operate and maintain the equipment.

We are on a constant fertilization program. When the Cl_2 that has been injected comes in contact with the fertilizer, the Cl_2 is almost immediately tied up. To increase our contact time, we take a 1-in. water line from the pressure side of our pump and treat it with a high concentration of chlorine. This chlorinated water is piped into the lake. The water is dispersed through a header 18 in. long with ¼-in. holes 1 in. apart. The header is slightly above and 1 ft. in front of the intake screen. The chlorinated H_2O and lake H_2O are mixed as they are drawn into the suction line. Our contact time is the time the water takes to move from that point to where our fertilizer is injected, which is approximately 15 sec.

To achieve maximum control, enough chlorine gas must be injected to obtain an F.A.C. reading. We try to maintain a level of 0.3 ppm (or 0.3 mg/l) F.A.C. Our chlorine testing is carried out with a simple swimming pool test kit that is based on the D.P.D. (diethyl-phenylene-diamine) chlorimetric method. Kits are also available which use the o-tolidine method, but these are not considered as accurate.

Tests have shown that we can control the motile spores of *Pythium* and *Phytophthora* and greatly decrease our population of bacteria. We cannot prove any other benefits, but we no longer have *Fusarium* leaf spot on 'Hershey Red' azaleas, and we are now controlling *Rhizoctonia* with our normal 30-day spray program.

This year we used nine 150-lb. cylinders of chlorine. Our total cost of this 1,350 lbs. was $371.67, including demurrage of tanks and delivery. We treated approximately 35 million gal. of water. The same amount of Cl_2 purchased as calcium hypochlorite under the trade name of H.T.H. would cost $2,065.50. We purchased three Cl_2 injectors @ $2,100.00 each. Without considering the difference in the labor and equipment required to mix H.T.H. (which is considerable), the return on our investment would still be only 3 years.

Safety should always be considered when handling Cl_2. Several rules should be followed:

1. Secure tanks in an upright position.

2. Never change a tank alone.

3. Have available a full-face respirator with the Cl_2 canister or have an independent air supply.

4. Always use new lead gaskets when connecting tanks.

5. Check all connections with concentrated NH_3 solution. Household NH_3 is not strong enough. A leak will look like cigarette smoke.

6. Have protective caps in place when moving tanks.

The installation of equipment and use of chlorine gas has become an efficient and effective means of controlling waterborne diseases at Lancaster Farms.