Alternative for Food Processor’s Wastewater: Water and Wastewater Minimization Protocol

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Numerous Food Processors in Michigan
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1. Introduction
Water is used extensively in the food processing industry including as an additive to processed food and in the processing of that food. The latter can be significant as water is used for cleaning, conveying, peeling, cooking, and cooling. In addition, water is used to maintain sanitary conditions at the facility and clean equipment after processing. Conserving water and minimizing wastewater through more efficient manufacturing may save money, both in obtaining and disposing of the water and the associated energy costs. Additionally, a positive public image is projected by minimizing the use of a natural resource that has an increasing value.

This water conservation protocol offers guidance to minimize water consumption and the resulting wastewater production associated with food processing. Techniques considered include water use reduction, reuse, and recycling. Information used to prepare the guidance largely was obtained from detailed tours of over a dozen fruit and vegetable commodity food processing plants throughout the state of Michigan. The characteristics of the plants varied greatly from small, seasonal, single commodity processors to large diverse, corporate facilities. Each chapter within this report is discussed below.

Section 2 describes tools to analyze the facility’s total water and energy costs. The tools also help identify water and waste reduction areas. Guidelines to calculate payback periods are provided to estimate the potential savings of a minimization practice. In Section 3, an overview of housekeeping practices to conserve water is presented. In Section 4 water use in fruit and vegetable processing is broken down into specific processing operations and opportunities to conserve water in each are discussed. Food quality is always a priority, regardless of water conservation practices. Section 5 discusses the importance of food safety and the need for monitoring, regardless of what practices are put into place.
2. General Concepts and Tools

In this Chapter, several concepts and tools to analyze the facility’s total costs for waste, water, and energy are described. Such an analysis is the first step to highlight the areas of unnecessary water use and waste generation.

First the fundamentals of flow measurements and flow balances are discussed. With a flow balance, techniques to determine associated water costs are discussed.

2.1. Source Water

Traditionally source water comes from either a municipality or private wells. Costs associated with municipal water include payment to municipalities and required conditioning. Private well water is often considered free but there are a substantial cost associated with pumping it from the well and pressurizing that are often overlooked. Section 2.4 discusses estimating this cost.

Alternative sources of water should not be overlooked. Cooling system condensate may be of very high quality. Also water from minimum contact units such as freezer defrosts and pump cooling water may be used for non-contact food units. Further rain water can be collected and may have use for some facility operations.

2.2. Flow Rate Determination

The most important first step in analyzing water use and wastewater production is to understand flow rates. A flow rate is defined as volume over time such as gallons per minute. To compare and add flow rates the same units must be used. Table 1 provides useful conversion values that might be needed to calculate flow rates.

Table 1. Useful Conversions Needed to Calculate Flow Rates

<table>
<thead>
<tr>
<th>To convert from:</th>
<th>To:</th>
<th>Multiply by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liters (L)</td>
<td>m³</td>
<td>0.001</td>
</tr>
<tr>
<td>m³</td>
<td>L</td>
<td>1000</td>
</tr>
<tr>
<td>US Gallons</td>
<td>L</td>
<td>3.785</td>
</tr>
<tr>
<td>US Gallons</td>
<td>m³</td>
<td>0.00378</td>
</tr>
</tbody>
</table>

In measuring flow, replication is essential. A minimum of three flow rates should be measured if a continuous data logger is not being used. If the values are not within 10% of each other (the difference between any two values divided by their average), more measurements should be taken. Understanding changes in flow throughout the day and processing steps is essential. Typical methods to measure flow follow.

2.2.1. Bucket and Stopwatch Method

This method, one the easiest and most accurate, can be used when there is a constant flow and the location the flow exits is accessible or can be diverted without substantial additional head loss (values and fittings). However, this method is difficult if flows are not constant and is time consuming so its utility is limited to on/off flows with a precisely known time cycle. All that is required for this technique is a bucket of known volume and a stopwatch or watch with a second-hand. The time it takes to fill a known volume is recorded, as shown in Figure 1. This volume is then divided by the time. Table 2 is an example of collected data.
Table 2. Sample Flow Rate Calculations

<table>
<thead>
<tr>
<th>Trial</th>
<th>Volume (Gallons)</th>
<th>Time (sec)</th>
<th>Flow Rate (Gallons/sec)</th>
<th>Flow Rate (Gallons/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>40</td>
<td>0.100</td>
<td>6.0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>42</td>
<td>0.095</td>
<td>5.7</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>39</td>
<td>0.100</td>
<td>6.0</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>0.098</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Note that all samples are within 10% of each other. For example, trials 1 and 2, 1 and 3, and 2 and 3 are 5%, 2%, and 0% different from each other, respectively.

Figure 1. Example of Stop Watch and Bucket Flow Calculation

2.2.2. Flow Meters

In general, flow meters provide readouts directly in units of flow or another unit that can be correlated to flow. Very simple meters may have a relative scale, such as 0 to 100%, and only provide a visual readout. Many meters however, provide a direct flow read out in the desired units and can be connected to a data logger so that flows can be recorded continuously or at set intervals.

Two general types of flow meters are ones that clamp to the outside of the pipe and those inserted into the pipe, in line with the flow. Both require proper installation to obtain accurate and precise data.

External clamp-on meters send ultrasonic signals through the pipe wall and across the water flow. A straight section of pipe with a length at least 3 times the diameter is required before and after the meter. An electromagnetic head senses the returned signals. To be effective, the flowing stream must have some solids. Another variation is a magnetic flow meter. However, such meters take the form of a pipe coupling and
become part of the plumbing and are considered permanent. For both types, head loss is minimal as there is no blockage or path change of the water.

The other type of meter is inserted into the flow. One of the most common is a rotameter. The rotameter consists of a tapered tube, typically made from glass or plastic. There is a float within the tube that is pushed up by flow and down by gravity - consequently the rotameter must be mounted vertical. Another design entails a turbine within the water stream that is calibrated to flow. The flow meter is either attached directly into the plumbing or can be inserted by tapping. Excessive solids and corrosive liquids limit the usefulness of these meters. Further there can be considerable head loss caused by insertion meters. These meters are typically permanently installed.

2.3. Flow Balances

“A water flow balance is a numerical account of where water enters and exits the facility and where it is used within the facility. Typically, it also contains the amount of water used in each process. It is based on the concept what goes in must come out…somewhere” (ETBPP, 1998C).

The best way to represent flow balance is through a flow diagram of the facility. Included are all areas and processes that use water in the facility. Walking through the facility while creating the flow diagram will help capture all water inlets and outlets. This will also help in discovering leaking taps and pipes, unattended running hoses, and other unnecessary waste areas. Dividing this flow diagram into processes and including how multiple processes link is helpful. In each process area all important features should be noted, including the following.

- Operations
- Source of Water
- Use of the Water
- Wastewater Stream
- Drains and Location of discharge
- Addition of Chemicals and Detergents
- Links to other Process or Sections within the Plant

Although actual values are best, accurate estimates can be entered. Data can be found by reading calibrated existing meter readings, installing new flow meters, rotating portable flow meters to different locations, and examining water and sewage bills. Estimates can be made if they are believed to be accurate. A detailed flow balance example is shown in Figure 2.

The mapped water flow can now be studied to identify potential savings. Below are useful questions to consider while reviewing the process (ETBPP, 1998C).

- Is equipment operating at water flows recommended by the manufacturer?
- Can less water be used to achieve the same result?
- Are there alternative units that use less water?
- Can water be recovered and reused without treatment in current unit or another?
Figure 2. Detailed Water Flow Balance Example
2.4. Total Water Cost
There is cost for water at every food processor regardless if its source is from a municipality or a private well. Often well water costs are neglected since there is no utility bill, however pumping costs can be significant. Steps to estimate pumping costs are presented below. It must be noted that these calculations are not inclusive of other costs such as well maintenance and water conditioning.

Step 1. Estimate facility required water flow rate in gallons/min (GPM) using conversion factors if necessary.

Example: Total flow to facility = 705,600 gallons/day, need to convert to GPM

\[
\frac{705,600 \text{ gallons}}{\text{day}} \times \frac{\text{day}}{1440 \text{ min}} = 490 \text{ GPM}
\]

Step 2. Calculate Total Dynamic Head (TDH) in feet

Total dynamic head is the elevation the water is lifted plus the resulting friction loss. To determine the equivalent feet of head caused by friction loss, the flow rate, pipe inner diameter, pipe length, pipe material, and major fittings (such as valves) in the pipe line are needed. Tables and TDH calculators are available on the internet (http://www.csgnetwork.com/csgdynamichead.html).

Example: Find the TDH (feet that the water must be pumped, including major friction losses) using the following data.

Well Depth = 150 ft
Pipe Length (distance to facility) = 450 ft
Pipe Inner Diameter = 6 in
Pipe Material = Steel Pipe (Schedule 40)
One Gate Valve
One Check Valve
Flow Rate = 490 GPM (as provided in Step 1)
Pressure Head (pressure required at facility) = 55 psi

- Find friction loss in ft from tables in a reliable reference.

Pressure Head at Discharge = 55 psi which converts to 127 ft
1 check Valve = 2.11 psi which converts to 5 ft of head
100 feet of 6 in Schedule 40 Steel Pipe with 490 GPM is 1.348 psi

\[
\frac{1.348 \text{ psi}}{100 \text{ ft}} \times \frac{2.31 \text{ ft of head}}{1.0 \text{ psi}} \times 450 \text{ ft} = 14 \text{ ft}
\]
• Add all Heads Losses

\[ \text{TDH} = 150 \text{ ft (well depth)} + 14 \text{ ft (friction)} + 5 \text{ ft (check valve)} + 127 \text{ ft (pressure head)} = 296 \text{ ft} \]

Step 3. Calculate Horsepower (HP)

*HP can be estimated with the following formula. It is important to keep the same units as listed above.*

\[
\text{HP} = \frac{\text{TDH (ft)} \times \text{Flow Rate (gpm)}}{3960 \left( \frac{\text{HP}}{\text{ft \times gpm}} \right) \times \text{pump efficiency (as fraction)}}
\]

Example:

\[
\text{HP} = \frac{296 \text{ ft} \times 490 \text{ gpm}}{3960 \times 0.80} = 45.8 \text{ HP}
\]

Step 4. Determine Pump Power Consumption (KW per HP)

*Consult the pump manual for its typical power consumption value, often stated as kilowatt consumed per horsepower.*

Example:

\[
45.8 \text{ HP} \times 0.743 \frac{\text{KW}}{\text{HP}} = 34.2 \text{ KW}
\]

Step 5. Compute KWhr Used per Day

*Multiply the KW value by the hours of pump operation per day.*

Example: Pump is operated 24 hours a day.

\[
34.2 \text{ KW} \times 24 \text{ hrs} = 821 \text{ KWhr/day}
\]

Step 6. Obtain Cost per KWh

*Reference electricity bills to obtain this cost.*

Example: Electricity costs $0.09/KWhr

\[
821 \text{ KWhr/day} \times $0.09 \text{ per KWh} = $73.89 \text{ per day}
\]
Step 7. Determine the Annual Cost

*Determine the number of days the pump is operated.*

Example: The pump operates 240 days a year.

$73.89 \text{ day} \times 240 \text{ days/year} = $17,700 \text{ year}$
3.0. General Housekeeping Water Conservation Practices

General housekeeping entails upkeep of the facilities, cleaning, and maintenance of sanitary conditions. Included are recommendations concerning diverting storm water runoff, controlling manual cleaning, and improving cleaning practices.

3.1. Cleaning Schedules

It is generally thought that frequent cleaning is necessary to maintain sanitary conditions. However, by maximizing cleaning efficiency, the frequency may be reduced as long as the required levels of cleanliness and hygiene are still maintained. Further the scheduling of production may also eliminate some intermediate cleaning events.

Example

A yogurt company changed from batch processing to continuous processing. In between yogurt batches instead of rinsing out remaining yogurt, the remainder was mixed with 50 liters of the next planned batch and packaged. The combined flavor batches were sold as cattle feed. No product was lost and 110 liters of wastewater was eliminated (United Nations Environmental Protection, 2000).

Example

In jam factories, if strawberry jam is manufactured first, followed by apricot and then raspberry jam two full cleans are required. If, instead, strawberry jam is followed by raspberry, then apricot, only one full clean is required. At the changeover from strawberry to raspberry jam, either no clean or a short clean will be carried out, depending on the clients requirements (ETBPP, 1998B).

3.2. Solid Waste Removal

Often wash water is used to move solids to disposal locations. Removing these solids from the bulk water stream can be expensive and interferes with efficient water treatment. The solids add small diameter suspended solids and biochemical oxygen demand to the water. Applying such water with solids to irrigation land causes a build-up and can be a source of odors (Brown and Caldwell, 2007).

Methods to keep solids out of the bulk water stream vary greatly. The most fundamental is not to transport waste solids with water. This requires the use of collection buckets where the solids are produced. If this is not practical, floors is first be swept and solids collected before being washed. If solid deposition on floors are wide spread and water transport is the most practical technology, limiting the transport distance saves water. Covering catch basins with screens to prevent the solids from entering drainage channels and pipes is a simple means to limit the journey of solids.

3.3. Floor Washing

The two common methods to clean floors are manual and mechanical. Manual operation uses brooms, mops, squeegees, and hoses. Mechanical operations include floor sweepers, scrubber dryers, and vacuums. Regardless, removing solid waste first, as described in Section 3.2, reduces water consumption and simplifies the disposal of that water.
3.3.1 Automatic Waster Supply Shut-Off Mechanism

Often hoses are left running continuously. Water supply can be controlled by trigger-operated spray guns on hoses. During various processor visits it was found that trigger nozzles where frequently run over by forklifts when left unattended. A simple solution to prevent this from occurring is to install self-reeling water hose reels.

Example
At an Estonian dairy processing plant, open ended rubber hoses were used to clean delivery trucks. Operators used their fingers at the discharge end of the hose to produce a spray. Also the hose was not equipped with any shut-off valve and the water was often left running. High pressure systems were installed with trigger nozzles throughout the plant (for cleaning the trucks, the production area, and other equipment). The cost of this equipment was $6450 and the savings in water charges was $10,400 per year; a payback period of less than 8 months. Water consumption was reduced by 30,000 m³ per year (United Nations Environmental Protection, 2000).

3.3.2. High Pressure Sprayers

Nozzle, spray and jet technologies have improved and the latest designs are less susceptible to blockage (ETBPP, 1998A). However, there are many choices and careful consideration and consultation with professionals is needed in selecting high pressure sprayers. In addition to instituting high pressure sprayers, careful maintenance is required. The nozzles are subject to wear that causes deterioration of the orifice and distortion of the spray pattern. In general, 10% nozzle wear will result in a 20% increase in water consumption (McNeil and Husband, 1995). In selecting a high pressure spray system, the nozzle material is critical in its long-lasting efficiency. Table 3 provides abrasion wear index for alternative materials.

Table 3. Abrasion Wear Index for Nozzle Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Abrasion Wear Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass</td>
<td>1 (poor)</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>4-6 (good)</td>
</tr>
<tr>
<td>Hard plastic</td>
<td>4-6 (good)</td>
</tr>
<tr>
<td>Ceramic</td>
<td>90-200 (excellent)</td>
</tr>
</tbody>
</table>

Source: McNeil and Husband, 1995

To continue to gain maximum benefit from a high pressure spray system, a nozzle monitoring and replacement program must be budgeted and integrated into a preventive maintenance program.

Example
A dairy farm uses a flush system to clean the floor after cows are milked. A regular hose is used resulting in the need for 7,100 gallons of water per day. This waste water is hauled by truck to a storage lagoon at an annual estimated cost of $43,680. A high pressure cleaning system was installed at an approximate cost of $10,000. The resulting amount of water used annually was reduced to 1,775 gallons and the cost to haul was reduced to $10,920 a year (Larson, 2008).
3.4. Runoff
Food processors that use outdoor concrete or asphalt processing surfaces may cause impact to storm water as precipitation travels through the stored commodities. Included is water that exits roofs onto these surfaces. Although practices to minimize this contact does not save water it does reduce the amount of wastewater produced as often this impacted storm water needs to be diverted into the wastewater treatment system.

Keeping clean water clean can be as simple as directing down spots from buildings that exit into processing areas to clean surfaces. Curbs and gutters can also be installed to direct clean water away from processing surfaces. More expense is required if the installation of gutters is needed to direct rain water from roofs that drain into processing areas to non impacted surfaces. Further, outdoor surfaces can be roofed to keep precipitation from contacting commodities.

**Example**

Storm water from a 20,000 sq ft roof is diverted away from the wastewater treatment system. For every inch of rainfall about 12,500 gallons less water will need to be treated. The average rainfall in MI varies between 30 - 38 in a year. For an average of 34 in a year, about 424,000 gallons of water will no longer require treatment.

Processors must realize that diverting storm runoff that was once captured in the wastewater treatment system may require some type of flood control system such as a retention basin.
4. Fruit and Vegetable Processing

Water intensive operations from fruit and vegetable processing and their associated units discussed in this protocol are listed in Table 4.

A water conservation protocol entails the use of the proper amount of water for specific processing equipment. Reference manuals contain baseline water requirements and direct flow measurements should be conducted to determine if water consumption matches manufacturer recommendations. Equipment should also be regularly inspected for leaks and promptly repaired when needed. Additionally, some equipment will function adequately when less water is used. Studies can be conducted to determine if there are any negative impacts. However, care must be taken not to compromise food safety, and quality or equipment longevity, efficiency, and warranties.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning</td>
<td>Sprayers</td>
</tr>
<tr>
<td></td>
<td>Counter Current</td>
</tr>
<tr>
<td>Conveying</td>
<td>Dry Feed systems</td>
</tr>
<tr>
<td></td>
<td>Hydro-Feed Systems</td>
</tr>
<tr>
<td>Preparing</td>
<td>Coring</td>
</tr>
<tr>
<td></td>
<td>Cutting</td>
</tr>
<tr>
<td></td>
<td>Peeling</td>
</tr>
<tr>
<td></td>
<td>Pitting</td>
</tr>
<tr>
<td>Processing</td>
<td>Blanching</td>
</tr>
<tr>
<td></td>
<td>Freezing</td>
</tr>
<tr>
<td></td>
<td>Cooling</td>
</tr>
<tr>
<td>Packaging</td>
<td>Bottle Preparation</td>
</tr>
<tr>
<td></td>
<td>Bottle Washing</td>
</tr>
</tbody>
</table>

4.1. Cleaning

Common first stage fruit and vegetable processing entails removing leaves and stems, rough sorting, and cleaning. The water used in this initial stage is mainly for conveying and to remove soil and dirt. Consequently, very high quality water may not be needed as the commodity will most likely continue to be handled and washed with higher quality water. As a result, recycled water or wastewater after minor or no treatment from other downstream operations has the potential to be adequate. In recycling water, the potential degradation of the commodity must be considered and often, the water must first be disinfected and monitored for microorganisms.
Make up water must also be added. Specific water saving practices for cleaning are described below.

4.1.1. Sprayers
A common cleaning technique is to spray the commodity as it moves on a conveyor. The use of high-pressure, low-volume nozzles, located close to the commodity in order to maximize pressure effect and the elimination of overlap saves water. The replacement of nozzles with waterfalls (Figure 3) offers a unique advantage if water is recycled or reused. Specifically, nozzles tend to clog when solids are present resulting in malfunctions. This does not occur with waterfalls. If water is recycled, large material must first be removed, typically in a hydrosieve (Figure 4) and disinfection may be required. A common disinfectant used in the food processing industry is chlorine dioxide (Figure 5). As with any disinfection system, safety precautions are necessary. Further, a systematic, fail safe water quality check, especially for pathogens, is mandatory.

![Figure 3. Waterfall Cleaning System](image-url)
Figure 4. Hydrosieve

Figure 5. Chlorine Dioxide Disinfection System
4.1.2. Counter Current
Countercurrent washing may consist of 2 to 3 stages as illustrated in Figure 6. Fresh water is added at the final stage. The water from the final stage is reused in the second to final state. Thus, the water and product travel in opposite directions. This method is efficient because the cleanest wash water is used on the cleanest product with the least clean wash water is used to wash the dirtiest product.

![Figure 6. Basic Principle of Countercurrent Rinsing](image)

4.2. Conveying
Transporting fruits and vegetables between processing stages can be efficiency achieved by dry feed and hydro feed systems. Each is discussed in more detail below.

4.1.1. Hydro-Feed Systems
If hydro-feed systems are used, water use can be minimized by preventing leaks and splashing. Preventing water spillage on the floor also improves safety and sanitary conditions. Further, water recycling for raw commodity transport is feasible, especially if the water first passes through a hydrosieve to remove large solids and is disinfected, if needed, as discussed in Section 4.1.1.

4.2.2. Dry Feed Systems
Dry feed systems use conveyer system to transport the commodity, as compared to water (Figure 7). Further, a hydrosieve and disinfectant is not needed as water is not used. The most common is a special food grade belt. Such a belt allows for easy cleaning and disinfection. Care in using the proper food grade lubricants must be exercised. A critical issue in replacing a hydro feed with a dry conveyer belt is potential damage of the commodity. Several apple processors have found that commodity damage on a dry conveyer did not exceed that of a hydro-based system.
4.3. Preparing
Food preparation processes are diverse, depending on the product and customer requirements. Listed below are the more common units for fruit and vegetable processing and associated water minimization techniques.

4.3.1. Water Cooling
Water chilling is often an initial processing step for fruits that are sensitive to heat. Cherries that are cooled immediately after harvesting are more easily pitted and release less sugar. The result is an increase in yield and a higher grade. Reusing this cooling water is often possible with little treatment, perhaps just filtering to remove large solids. Reuse of cooling water not only results in substantial fresh water savings but also saves on the cost to chill the water. In fact chilling water without recirculation is not practical.

4.3.2. Coring, Cutting, Pitting
Fruit and vegetables often must be cored, have pits removed, and be cut, requiring the use of blades, corers, and/or cleavers. Commonly, water is used in this process to lubricate and to carry the waste away from the commodity. Equipment manufactures typically specify water requirements. Typical water reduction procedures follow.

- Review equipment manuals to verify that the minimum amount of water is being used.
- Run tests and check with manufacturer to determine if water use to a specific piece of equipment for a specific commodity can be reduced or eliminated.
- Optimize water pressure, spray nozzles, and spray patterns for maximum coverage.
- Verify spray nozzles are not clogged and/or worn, resulting in the need for excess water.
4.3.3. Peeling
Peeling can be achieved by two primary means. The commodity can first be steam treated to loosen the skin which is then mechanically removed. Alternatively, dry caustic peeling uses a caustic solution to loosen the peel which is then removed by a high pressure water spray or a mechanical system. For some commodities, there is a preferential peeling system. For example, Brown and Caldwell (2007) recommend steam peeling versus caustic peeling for tomatoes to reduce sodium concentrations in the effluent.

Steam peeling requires more water than caustic peeling, however the amount is highly variable. Caustic peeling combined with high pressure water to remove the peel requires about 850 gallons of water per ton of commodity (Carawan, 1989). As discussed in Section 4.1.1, sprayers should be optimized. A dry caustic peeling system uses 90 gallons of water per ton of commodity (Carawan 1989). Changing peeling techniques represents a major change in process equipment and, consequently cost.

4.4. Processing
Two categories of processing fruit and vegetable commodities that use a substantial amount of water include blanching and freezing. Water use associated with each is discussed below.

4.4.1. Blanching
Blanching deactivates microorganisms and enzymes. Typically, blanching involves submerging the commodity in boiling water or steam and then immediately cooling. The commodity typically travels through the heating and cooling processes on a conveyer belt.

Water savings entails reuse of the steam or boiling blanching water. In addition to saving water, savings of energy to heat the water is also realized. Maintaining water quality is imperative in producing a safe product. Consequently, filtration and disinfection may be required, at a minimum.

Alternative processes include high pressure processing (HPP) and pulsed electric field processing (PEFP). HPP uses elevated pressures, with and without the addition of heat, to achieve microbial inactivation and alter the food attributes in order to achieve consumer desired qualities (OSU, 2004). PEFP uses electricity for microbial inactivation (OSU 2005). PEF preserves food without the use of heat, which helps preserve aroma, taste and appearance. Such equipment represents a substantial investment.

Cooling the commodity after heating for blanching or pasteurization is one of the most water intensive operations in the food industry. Of importance in any cooling operation is matching the heat transfer rate with the water flow. Flowing more cool water onto a

Example
At a cherry processor, the two de-pitters were using more water than recommended by the manufacturer. It was found that if the proper amount of water was used, a savings of 123,000 gallons during the 6 months processing season can be realized. No additional infrastructure was required and $150 in water pumping costs were saved during each season (Cogan, 2008).
hot commodity faster than the heat can transfer has no benefit. The optimum cool water flow rate should match the heat transfer rate.

If a once-through cooling system is used, the resulting water is relatively clean and has good reuse potential for non-contact purposes such as floor washing. However, recirculating cooling water for contact purposes requires much care to ensure no bacteria and/or organic debris builds up. Treatment is required. Further, much infrastructure is needed including a cooling tower, pumps, monitoring, and storage (ETBPP, 1998A).

Countercurrent cooling also offers water savings and maximizes heat transfer. The concept is similar to that used for counter current cleaning, as discussed in Section 4.1.2 and illustrated in Figure 4.

Alternatively, water used for cooling can be eliminated by installing refrigerated closed loop systems or cooling towers. Such systems require substantial capital investment.

**Example**
A food company produces around 3,000 tons of ham/year. Previously, showers were used to cool cooked hams for 4 hours at a flow rate of 3.8 liters/minute (14.36 gallons/minute). Following a review of process requirements, nozzles were fitted to the showers to deliver water at a reduced rate of 1.08 liters/minute (4.08 gallons/minute) and also intermittently, i.e. three minutes on, three minutes off. Water consumption was reduced by 64% - from 124 liters/hamster to 45 liters/hamster (170 gallons/hamster), while process efficiency increased allowing a greater production capacity. Total cost savings of £120 000/year ($235,000 USD/year), exchange rate £1 = $1.96USD) have been achieved. (ETBPP, 1998A)

### 4.4.2. Freezing
Flash freezing fruits and vegetables after blanching does not require water. However, the freezer must be periodically defrosted, typically twice a day. This often requires a tremendous amount of water that has minimum or no contact with the commodity. This water has the potential to be reused with minimum pretreatment.

**Example**
Water used to defrost refrigeration and freezing systems can be collected and used for floor cleaning. The savings may be realized in energy cost for supplying the water. If water is obtained from a well that is 200 to 300 feet deep, a substantial amount of electricity is required to pump it through the units. Collecting defrost water in a tank may only require pumping through a head of 20 feet and will offer a very short payback period.

### 4.5. Packaging
Packaging may be for bulk use or individual consumers. For individual consumers, packaging is more water intensive as cans and bottles require cleaning before and after filling.

Cleaning cans and bottles before filling represents a major safety practice. However, water quantity use should be periodically monitored to check for excessive use. The simplest water reduction practice is to halt the water spray when no bottles are present. This can be achieved
manually or with an automated sensor system. Cleaning and sanitizing chemicals may also be selected to minimize water use.

The majority of residue on cans and bottles results from overfilling, misalignments, and poor container integrity. All equipment should be kept in optimum working order and the needed amount of water matched to washing needs. As previously discussed in Section 3.3.2., high pressure nozzles reduce the amount of water needed to achieve cleaning goals. Counter current rising, as discussed in Section 4.1.2 is also applicable.

**Example**

Uttamangkabovorn, (2005), modified its can washing station from a fully open valve to a 45 degree opening with a 60°F water rinse for more efficient cleaning. This modification reduced the water consumed for can washing by 55%.

**Example**

Water use was reduced by 83% on the container wash systems on its fruit snacks and cordial production lines by installing water-saving nozzles. The overall projected savings was $12,152/year (exchange rate £1 = $1.96) with a payback period of ten weeks (ETBPP, 1998B).
5. Water Reuse and Safety

High quality water that has the potential to be used directly for non-contact needs can come from the following sources.

- Final rinse of tanks.
- Refrigeration and freezer defrost.
- Cooling effluent.

Uses of this water could include the following.

- First rinse in wash cycles.
- Primary cleaning of floors and gutters.
- Boiler make-up.
- Caustic dilution.

Treatment may be required prior to some of these uses. This could be as simple as using a filtering device, such as a hydrosieve. More advanced treatment may include disinfection, distillation, micro-filtration, nano-filtration, and reverse osmosis. Specific details concerning these technologies are beyond the scope of this guidance manual.

The reuse of process water was discussed in several sections. An absolute goal is not to compromise sanitation and food safety. All regulations regarding water reuse and general sanitation and food safety must be followed. Two accepted/required criteria follow.

- Hazard Analysis and Critical Control Points (HACCP)
- US Department of Agriculture and Food and Drug Administration Guide to Industry

HACCP is a food safety management system used to prevent hazards that could cause foodborne illnesses. It is based on seven principles which are used to identify critical control points in the food manufacturing process (http://www.haccptraining.org).
In 1998, the US Department of Agriculture and the Food and Drug Administration released the “Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables.” This guide addresses microbial food safety hazards and provides good management practices for minimally processed food. Specific guidance is provided concerning process water. Applicable section headings in this guide follow (available online (http://www.foodsafety.gov/~dms/prodguid.html).

**General Considerations**

- Follow good manufacturing practices to minimize microbial contamination from processing water.
- Consider practices that will ensure and maintain water quality.

**Antimicrobial Chemicals**

**Wash Water**

- Use appropriate wash methods.
- Maintain the efficacy of wash treatments.
- Consider the wash water temperature for certain produce.
- Consider alternative treatments for water-sensitive produce.
Cooling Operations

- Maintain temperatures that promote optimum produce quality.
- Maintain air cooling equipment and cooling areas.
- Consider the use of antimicrobial chemicals in cooling water.
- Keep water and ice clean and sanitary.
- Manufacture, transport, and store ice under sanitary conditions.
- Equipment should be clean and sanitary.
6. References


ETBPP, Environmental Technology Best Practice Programme. Reducing the Cost of Cleaning in the Food and Drink Industry (GG154). United Kingdom, 1998B.

ETBPP, Environmental Technology Best Practice Programme. Tracking water to reduce costs (GG152). United Kingdom, 1998C.


