Wastewater Reduction and Recycling in Food Processing Operations

Statement of Need Summary

The food processing industry seeks cost-effective reduction and recycling technologies for food processing wastewaters. These technologies include both source reduction options (technologies to reduce the amount of water used) and treatment options (technologies to reduce the amount or contamination level of wastewaters requiring discharge).

Enforcement of wastewater discharge regulations and escalating sewage surcharges have forced the food processing industry to look for cost-effective technologies to provide pretreatment or complete treatment of their wastewaters. Historically, food processors located within or adjacent to municipalities have relied on local publicly owned treatment works (POTW) for wastewater treatment and disposal. Increasingly, this option is becoming less available. Especially in the last five to ten years, because of increasing enforcement pressure to comply with wastewater discharge permits and dwindling federal grants for constructing new and upgrading existing treatment works, municipal and regional sewer authorities are applying more pressure on industries to reduce their organic (BOD and COD), and suspended and dissolved solids loading to the sewers.

Background

Water has traditionally been a key processing medium in food processing plants. Water is used throughout all steps of the food production process, including food cleaning, sanitizing, peeling, cooking, and cooling. Water is also used mechanically as a conveyor medium to transport food materials throughout the process. Finally, water is used to clean production equipment between operations. All in all, food processing is a water-intensive operation.

Wastewater derived from food production has attributes that are very distinct from other industrial activities. In particular, food processing wastewater can be characterized as "friendly"[1] in that it generally does not contain conventional toxic chemicals such as those listed under EPA's Toxic Release Inventory (with a few exceptions, such as phenolics from the processing of some plant materials). However, food processing wastewaters can be subject to bacterial contamination, which represents a special issue for wastewater reuse.

More generally, food processing wastewaters are distinguished by their generally high BOD concentrations, high levels of dissolved and/or suspended solids [including fats, oils, and grease (FOG)], nutrients such as ammonia, and minerals (e.g., salts). If separated or recovered, many of these constituents have value in secondary markets. Reclaimed materials have value through 1) direct in-plant reuse (e.g., recovery of sugars from fruit canning), 2) sale to external markets (e.g., recovery of pasta starch for animal feed or for compost), or 3) use in energy recovery (e.g., through biological or thermochemical gasification).

The characteristics and generation rates of food wastewater are highly variable, depending on the specific types of food processing operations. One important attribute is the general scale of the operations, since food processing extends from small, local operations ("the corner bakery") to large-scale national or international producers. This difference in scale is relevant not only in identifying sources of wastewater, but also in determining appropriate reduction or recycling options. In addition to scale differences, the types of food production processes (e.g., fruit, vegetable, oils, dairy, meat, fish, etc.) vary widely, with associated differences in the specific wastewater contaminants. Even within a given food processing plant, the wastewater discharged from different unit operations—or from different seasons—may vary with respect to flow rates and compositions. These characteristics will all affect how readily a new reduction or recycling technology can show a return on investment (ROI).

In addition to the variability in internal operating conditions, external constraints on food production wastewater management also vary widely. Wastewater disposal costs, which are a key driver for reduction/recycling technologies, will vary based on a given food processor's location and pertinent regulatory requirements (which will vary by region/city). Additionally, since byproducts recovered from wastewater streams are typically of low bulk density and marginal economic value, markets for these materials often vary widely regionally and seasonally.

As a result of these variations in context and application, the determination of the cost-effectiveness of current and emerging reduction technologies must generally be made on a case-by-case basis. Nonetheless, certain general principles will apply. First, certain technologies and operating strategies can provide an easy ROI regardless of the scale of operation. In addition, certain technologies will only be applicable to small operations (e.g., because of the inherent flexibility of the production process), while others will generally only apply to larger operations (e.g., because of high capitalization costs). These distinctions will be provided in the following sections as relevant.

Current Technologies

A number of methods are used to reduce wastewater discharge amounts and/or contaminant levels. For the purpose of clarity, a distinction will be made between source reduction and treatment technologies as follows:

- Source reduction includes technologies and operations that *reduce the amount of wastewater generated in the first place*

- Treatment includes technologies and operations that *treat wastewater to reduce levels of contamination, either to facilitate in-plant recycle or to reduce costs of treatment (which are often indexed to contaminant concentrations).*

Both of these strategies are important to food processing and to wastewater reduction strategies.

Source Reduction

A series of simple techniques are currently available as a first stage in minimizing wastewater generation. These techniques represent generally low-investment options that are available to virtually all food processing operations regardless of size. The techniques can be generally categorized into two groups: 1) techniques to minimize the amount of food (or other) waste that becomes water-borne, and 2) techniques to optimize the use of water.

The objective of preventing food or other waste from becoming waterborne is to keep "dry waste dry and wet waste wet." Approaches currently being used include dry cleanup before floor rinsing and manually cleaning vessels before rinsing to remove solids for recovery or disposal. Other approaches focus on changing production procedures to minimize product or byproduct wastage, such as installing spill collection trays to collect solids at appropriate places in the production line. In addition, water-based conveyor systems can be replaced by mechanical systems (augers or conveyors).

Optimizing the use of water includes techniques such as modernizing water sprays to include jets or nozzles, using high-pressure low-volume washing systems, and auto shut-off valves [5]. Other more capital-intensive options include installing clean-in-place (CIP) systems. Finally, one important option includes improving operations and maintenance programs to identify process upsets, problems, or malfunctions early in the process so as to minimize the amount of waste produced and wastewater generated. This process-control based strategy is also an important area of emerging technology, as improved sensors and control algorithms become available.

Treatment

Because water is ubiquitous throughout food processing plants, in-plant treatment of wastewater as a means of permitting reuse in other parts of the plant is a key strategy. A wide range of treatment options is currently being used to minimize the amount of wastewater generated, or to reduce the concentration of contaminants in the wastewater.

Retention/redirection simply means determining uses for wastewater other than discharge to the POTW. Examples of redirection include using "clean" wastewater for initial floor scrubdown or using nitrogen-rich wastewater as a fertilizer for plant grass areas [7]. As with any wastewater reuse, these approaches require close attention to regulatory requirements.

Separation/concentration technologies provide a means of separating out solids or other materials from wastewaters. Low-technology options include installing drain screens, settling basins, berms, or systems to separate waste products out of wastewater before it is discharged.

Other common technology options currently in use include the following (information relies heavily on [2]):

- Centrifugation is useful for oil/water separation and for large particle separation (solids of particles sizes ranging from 1 to 5000 microns. Particles greater than 5000 microns (5 mm) may require pretreatment (grit removal or grinder) before centrifugation. Several different types of centrifuges are available, including basket, solid-bowl, countercurrent-flow and concurrent-flow systems. Costs range from $60 to $2,000 per million gallons treated.

- Evaporation is well suited for wastewaters containing primarily inorganic salts. There are two primary types of evaporators: mechanical evaporators and evaporation ponds. Mechanical evaporators require an energy source, but can allow for water recovery. Foaming, scaling, and fouling are typical operational difficulties, which may require ancillary treatment systems. Technology costs can vary widely from $20 (ponds under minimal regulatory constraints) to over $10,000 (thermomechanical system) per million gallons treated.

- Filtration is used primarily to reduce suspended solids or oils and grease. Filtration is generally used as a pretreatment step or a final wastewater "polishing" step before discharge. Several different types of filters exist, including granular-media, cartridge, membrane, and diatomaceous earth precoat filters. The most common in the food processing industry include cylindrical or pleated cartridge filters, belt and press filters, vacuum filters, hydrosieves, and continuous scraped surface filters [1]. Filtration is generally effective for particles larger than about 1 micron in size. Costs can vary from $20 to over $100 per million gallons treated.

- Flotation is another treatment for suspended solids or oils and grease. Flotation generally involves passing gas bubbles through the wastewater. The gas adheres to water contaminants and causes them to rise to the surface into froth where they can be skimmed off. Dissolved air flotation (DAF) and induced air floatation (IAF) are the two principal types of flotation. Costs can vary from $20 to over $100 per million gallons treated.

- Gravity separation can occur in settling ponds or in specific vessels and is useful for materials with significantly different densities than water, such as oils and grease (which would rise to the surface to be skimmed) or various suspended solids (which would generally sink to the bottom). Costs can range from $50 to $500 per million gallons treated.

- Membrane systems represent a primary source of separation for the food processing industry. Many different types of membrane systems are currently in use. Because of the intensive research currently being conducted on this topic, membrane systems will be addressed in full under Emerging Technologies below.

Conversion of constituents into more manageable or valuable forms includes the fermentation of sugars to alcohol, apple waste to vinegar, or enzymatic conversion of starch to fructose [1]. Because conversions are fairly complex and site-dependent, their application is currently limited; however, opportunity for these types of conversions may grow as the product value of byproducts becomes more clearly identified.

Biotreatment involves the use of a biological reactor that contains a high specific concentration of either suspended or attached growth microorganisms [2]. As wastewater is passed through the reactor, the microorganisms metabolize organic compounds into carbon dioxide. Both aerobic and anaerobic technologies exist. A detailed treatment of these technologies and their limitations is provided in the State-of-the-Art Report on BOD which was prepared by the Food Manufacturing Coalition.

An important type of *chemical treatment* is the use of gaseous chlorine and chlorine derivatives to address bacterial contamination. Because of safety concerns about the potential generation of chlorine by-products, newer technologies being tested include ozonation and ultraviolet light treatment (covered below).

Finally, *incineration* is a treatment approach that can be coupled to other systems (filtration, flotation, etc.) to provide final disposal of food waste byproducts [2]. Incineration can be used to treat essentially all forms of waste, including concentrated wastewater, liquid wastes, solid wastes, gases, and sludges. Forms of incinerators include liquid injection, fluidized bed, and rotary kiln incinerators. Clearly, this approach is problematic, given the high cost of technology deployment (more than $1 million per million gallons treated), as well as the heavy regulatory and public scrutiny it faces. It also represents a high-intensity approach to waste management that creates potentially problematic secondary waste (ash) and bypasses the option to reuse food waste products.

EMERGING TECHNOLOGIES

Source Reduction

Pneumatic (Air-Based) Transport Water has historically been a common transport medium in food production. There exist increasing opportunities for non-water based transport. Pneumatic transport is currently used in facilities ranging from coffee bean preparation to flour milling [3].

Process Modeling A significant source of wastewater arises from improperly adjusted process activities that lead to product wastage. Process modeling is a technique to use computers to optimize process conditions. Process modeling will help fine-tune such input parameters as material or water flow velocity, temperature, and chemical concentration, as well as vessel design (e.g., input/output configuration) and overall process configuration. A major brewery used this technique to improve the product quality and batch repeatability of their brewing process by identifying both an improved mixing blade design for the mash tubs and a change in water application rates, thus reducing liquid product wastage [3]. Another application by a decaffeinated coffee manufacturer improved timingand thus the efficiency of the caffeine separation process. Process modeling can also support optimization of material flow through

processing tanks (e.g., activated charcoal) to avoid areas of dead flow that allow bacterial buildup [3].

Process Sensors and Control Related to process modeling, process sensors and control represent computer systems and other in-process sensors to identify and control the production process in real-time. Process sensors and controls are common and well developed in the chemical manufacturing industry. Emerging techniques such as Artificial Neural Network (ANN), model-predictive and fuzzy-logic-based control all promise improved control of washing, blanching, cooling, and cooking operations that can result in reduced wastewater loads and higher yields. Along with new optimization techniques such as genetic algorithms, these concepts could be extended to improving the scheduling of sequential batch operations, food production vessel cleaning, rinse water control, and similar applications to reduce water demand.

Low or No-Water Cooking and Processing Continuation of industry trends towards lower water use (such as steam blanching and microwave drying) can be expected to continue as the technology improves and the cost and regulatory drivers for reduced water consumption increase. Many of the emerging technologies are being explored under the aegis of the EPRI Food Technology Center and include such concepts as high hydrostatic pressure or electric field processing. The underlying concept in all of these technologies is to find non-thermal means of destroying microorganisms that present food deterioration or safety concerns. In applications such as blanching or pasteurization, these technologies present an opportunity to eliminate the use of steam and/or hot water, resulting in reduced wastewater production. Other specialized technologies being developed include the use of ohmic (electrical) thawing of frozen foods to replace water bath immersion and direct electrical or plasma pasteurization of meats and poultry.

Integrated WaterReuse Although integrated water reuse does not rely on a specific technology, interest and experience in total integration of water demands in manufacturing through heat recovery, "cascading" of wastewater streams, and byproduct recovery from concentrated streams are growing. Emerging techniques such as the extension of "pinch" design technology (an energy integration strategy that has proven very successful in the chemical and refining industry) to wastewater reuse hold some promise for identifying integration opportunities. However, successful application of this design approach depends in large degree on the improvement of key reduction and treatment technologies, especially disinfection (UV, ozone, plasma) and separations methods.

Treatment

Membrane Applications – As mentioned above, membrane systems represent a primary source of separation for the food processing industry. In addition, they represent one of the most active areas of current research and emerging technologies. The following discussion relies heavily on [2], [9], and [11].

Membrane processes employ a semipermeable membrane and osmotic or other pressure differential to force materials (water or contaminants) across the membrane. The most common configuration in food processing application is designed to have water pass through a membrane as permeate, with dissolved solids or other constituents captured as retentate. Membrane materials are typically organic polymers, although new types of inorganic polymer, ceramic, and metallic membranes are currently being investigated and deployed.

Membranes are commonly used by a number of process industries, including chemicals, food, pulp and paper, and power generation. Within the food industry, membrane technologies have been in use for at least 15 years for such applications as concentrating whey in the dairy industry, clarifying juices and other beverages, and reclaiming sugars from fruit processing. New materials and technologies are continuing to expand the range of economic applications into other areas of food water treatment and product recovery.

The basic membrane systems commercially available include microfiltration, ultrafiltration (UF), and reverse osmosis (RO), each of which treats a different range of particle sizes. Specifically, microfiltration generally addresses the largest constituents - that is, from 0.05 - 2 microns; ultrafiltration, middle-range constituents from 0.005 - 0.1 microns; and reverse osmosis, smaller constituents in the Angstrom range (e.g., molecular weight above 200). In practice, this means that microfiltration of food processing wastewater can separate microbes; UF separates microbes and suspended solids; while RO can separate microbes, suspended solids, and dissolved solids. RO is notable in that when coupled with ozonation or other sterilization, it is capable of generating drinking quality water. Newer technologies include nanofiltration (also known as ultraosmosis), which generally covers a range of particles between UF and RO.

Common configurations of membrane systems include plate-and-frame, spiral wound, tubular, and hollow fiber modules. The plate-and-frame is a flat sheet membrane, with alternating layers of membrane and spacer/permeate carrier plating that creates a sandwich effect. It is one of the simplest (and cheapest) configurations used. The spiral wound design is an extension of plate-and-frame that basically wraps the membrane sandwich around a collection pipe into which the permeate is directed. This design provides higher membrane packing density than the plate-and-frame, but also increases the opportunity for clogging. Tubular modules are designed following the structure of heat exchangers, with a series of hollow, thin-walled membrane tubes used to carry the feed stream. By increasing the size of the tubes (up to 2 cm), one can treat water with higher levels of suspended solids or with more viscosity; however, such systems require higher pumping energy and represent greater capital and operating costs. Finally, hollow fiber modules consist of tiny, hollow, hair-like membrane fibers bundled together inside a pressurized vessel. As the feed stream enters the space surrounding the fibers, permeate passes through into the center of the fibers and is carried away. Hollow fiber modules allow high packing density and require lower pressure drops, leading to systems with both lower capital and operating costs. However, these modules are delicate and highly susceptible to fouling.

Fouling is a major issue for membrane systems [1]. Fouling results from material build-up that blocks fluid flow across the membrane. Reverse osmosis is particularly susceptible to blockage. Temperature, solute-solute, and solute-membrane interactions all affect the fouling process. One common means of addressing fouling is to provide high cross flow velocities to reduce the thickness of the build-up, and to control pressure and permeate recovery.

Newer designs for membrane systems include centrifugal and vibrational systems, both of which are designed to limit buildup of solids along membrane surfaces. Other specialized types of membrane separation processes include pervaporation, which is the separation of more volatile compounds out of a liquid into a gas, and electrodialysis, which involves the separation of ions from a solution across an electrically charged membrane. These are currently less common in food applications.

Membrane configurations often include multiple membrane or other systems. For example, Zenon Environmental Inc. has developed a membrane biological reactor that combines an ultrafiltration process with a biological reactor. This system maintains a high biomass concentration while continuously removing the clarified permeate with zero BOD [1]. Among other advantages, this approach significantly minimizes the space requirements of biological systems for holding tanks and sludge handling.

Membrane systems can show several advantages over other conventional separation treatments (evaporation and distillation), including lower energy use, smaller space requirements, better control of microbes and organic matter in the process effluent, and improved product quality. In addition, unlike vaporization and freeze concentration, membrane separation does not require temperature and phase changes of the selected components[10].

Ongoing research in membrane separation techniques involves exploration of new membrane materials and of new module design configurations to address issues of fouling and treatment of difficult waste streams (high suspended solids or viscous waste streams). Of particular interest to the food industry are 1) the cost-effective separation of waters with high dissolved and suspended solids, and 2) the treatment of microbes. Microbial treatment is particularly noteworthy as food safety issues limit many types of wastewater minimization opportunities. In addition to these issues, much attention in membrane separation for the food industry is being given to demonstration efforts that provide bench- and pilot-scale testing of membrane configurations for specific food processing applications.

A major membrane demonstration effort—the mobile Membrane Test and Demonstration Unit (MTDU)—has been in operation primarily on the west coast since 1992 [10]. This trailer has recently been supplemented by MTDU2, a second trailer designed to operate on the east coast. These mobile trailer units include a variety of membrane materials and configurations to provide wide-ranging test conditions. The objective of this effort is to demonstrate the application of membrane separation technology in various food plants as a effective method to reduce effluent contaminants, conserve water and energy, and recover byproducts. The project is conducted by the California Institute of Food and Agricultural Research, under the sponsorship of the Electric Power Research Institute (EPRI) and several other sponsors, including various utilities, the U.S. Department of Energy (through Pacific Northwest National Laboratory), the California League of Food Processors, the National Food Processors Association, and others. The MTDU trailer has traveled to 18 sites in 10 states as of January 1996 and has completed membrane studies of processing plants including fruit, dairy, pasta, fermentation products, soft drinks, confectionery, and seafood.

Performance experience with membrane technology has shown important cost savings. EPRI reports of 16 MTDU case studies [12 and 13] shows that several applications were cost-effective. In some cases—including the treatment of raisin washwater, peach processing water, and peach pitter water—the net cost savings were driven by byproduct recovery. For example, a Dole Raisin Plant experienced a capital cost of $250,000 and annual operating costs of $82,000 for a membrane treatment system; however, annual benefits due to recovery of sugar concentrate were estimated at $528,710 [12]. In other cases, the cost-effectiveness of the treatment was based on reduced disposal costs, such as the reduction in BOD charges at a vegetable processing plant through treatment of carrot peeler wash water [12]. This type of cost is, of course, highly site-dependent. In a few other cases, indirect benefits made the difference in the treatment of the cost-effectiveness. For example, even though direct benefits of membrane technology at the Hunt-Wesson tomato processing plant did not exceed costs, the improved effluent treatment levels enabled the plant to extend its period of operation. In this case, increased production outweighed the additional treatment expenses by a wide margin [12].

As another example outside of the EPRI program, a combination UF/RO system implemented at a Kraft plant to treat bakery wastewater showed net annual savings of $600,000 [1]. Savings included reduction in BOD surcharge, wastewater discharge volume charge, sludge volume, and labor. Costs include the annual O&M costs of the system ($600,000 for a 125 gpm system). This system is expected to show a full payback of design and installation costs in less than 3 years.

Other Separation Techniques   Other separation techniques that facilitate recovery of suspended solids from wastewater streams are being developed. Two examples are acoustic separation and electro-osmotic dewatering. These technologies use an applied acoustic, electrical, or combined field to enhance the rate and efficiency of separation. They are typically targeted towards suspended solids and can reduce wastewater generation by making it more economically viable to recover solids from high solids streams. The U.S. Department of Energy, Office of Industrial Technology is currently sponsoring a project in this area: the Improved Electroacoustic Dewatering Belt Press for Food.

High Energy Systems   Over the past several years, research interest in high-energy approaches to wastewater treatment has increased. The term "high energy" refers to the fact that these technologies (such as Corona discharge and plasma reactors) use highly excited, or energetic fields, to treat the waste. These technologies are largely being explored for their potential in destroying pathogens and reducing BOD loading in high BOD wastewater streams. They are not generally applicable to high ionic strength (salt and brine solution) streams, which remain as a critical challenge to wastewater reuse.

The EPRI Food Technology Center is currently proposing a research partnership to develop a silent electric discharge (SED) reactor for improving the safety and efficiency of recycling processing water [15]. The criteria for success will be improved BOD and COD removal with less cost than conventional ozone generators.

Sterilization– Ozonation and ultraviolet light treatment are being tested as methods to provide sterilization and reduce bacterial counts, permitting closed-loop recycling of rinse and chiller waters. Ozonation works in a manner similar to chlorine disinfection (in both technologies, a reactive gas is introduced to the wastewater stream to chemically disinfect the stream), but avoids the concern of introducing chlorinated organic compounds to the wastewater stream. Ultraviolet disinfection can be used especially in low-concentration wastewater streams (or high-concentration streams with high clarity) to permit reuse of the water. It is of particular interest in applications such as chiller water recycling, where pathogenic contamination is the primary obstacle to recycling of the water stream. These technologies are closely related to other "high tech" field-enhanced techniques described under the emerging source reduction category.

An ozone demonstration project is currently being sponsored by EPRI and conducted by scientists at the University of Arkansas with engineers from American Water Purification, Inc. [14]. The first phase of this demonstration project includes a Mobile Ozone Treatment Laboratory (MOTL); phase II will extend the demonstration to include membrane testing. This project is focused on the poultry industry, with the intent of addressing the rising concern over food safety and quality and regulatory compliance in poultry processing plants. The MOTL will conduct on-site tests of ozonation of poultry chiller water.

Conversion   Research is being conducted on new methods for converting food byproducts to more valuable products. Argonne National Laboratory is investigating the opportunity for large-scale production of lactic acid and its derivatives from carbohydrate wastes [8]. The conversion train for this process includes fermentation, primary and secondary purification, and various polymerization technologies. Traditionally, lactic acid is purified by adding sulfuric acid to the fermentation broth that contains calcium lactate. This step generates large volumes of calcium sulfate salt waste. By contrast, the Argonne primary purification process uses advanced desalting and water-splitting electrodialysis technologies that purify the lactic acid without generating a salt waste stream. In addition the Argonne process includes the use of a different chemical pathway to facilitate high-volume manufacture of several different lactic derivatives.

Fuel Conversion– Though interest in fuel recovery from wastewater streams is not as intense as it once was, research and development continues on the development of efficient, robust systems for recovery of energy value from high-concentration wastewater streams. Both biological (anaerobic digestion) and thermochemical (catalytic reduction) technologies exist, as well as hybrid systems which combine both technologies. In general, the applicability of these systems is limited to relatively high concentration (>2 weight % organic) streams with high BOD loadings, and relatively low inorganic (brine or salt) concentration.

Next Steps for Technology Implementation

This report has identified a wide range of emerging technologies and techniques for reducing and recycling wastewater in the food processing industry. To date, the food industry has been a part of this technology development process through several joint initiatives to pool resources and sponsor development and demonstration projects [see particularly references 9 through 14]. Many of these initiatives are collaborations among committed allies, including EPRI and the utility industry, the Department of Energy (through the Office of Industrial Technology and other offices), as well as many state-level Waste Minimization Programs.

While a significant amount of progress has been accomplished to date, further opportunities for collaboration in technology development remain. This collaboration can be shaped in a number of ways. The following list represents one perspective—a complementary set of activities that span the range from basic research to information exchange.

- *Pre-competitive Research*- The food processing industry should pursue opportunities to work jointly on research topics that are still at the pre-competitive stage; that is, the stage where expected results would not be proprietary. One example is in the area of advance fuzzy logic control for water-intensive processes. Based on the experience in the chemical industry, there is good reason to believe that fuzzy logic control could lead to significant process improvements for the food processing industry. However, basic research questions remain. Because this type of research area is likely to be outside the scope of any individual food processor, a collaborative effort is needed to ensure progress.

- *Demonstration Project*– The food processing industry should continue to sponsor demonstration projects in wastewater reduction and recycling, particularly in the area of membrane technology. The MTDU program—in which the National Food Processors Association and Pacific Northwest National Laboratory have already been participating—has shown some significant progress in testing and demonstrating various membrane systems for wastewater management. One significant area of application that remains to be adequately demonstrated is the membrane treatment of meat and poultry wastewaters. In particular, a significant challenge is to provide membrane treatment that allows water reuse while completely addressing issues of bacterial contamination. The food industry should leverage experience gained under previous MTDU tests by creating a new initiative to demonstrate the value of membrane technology in providing safe, clean, and cheap water management for the meat and poultry industry.

- *Management of Regulatory and/or Public Perception Issues*–Successful technology deployment depends on adequately resolving regulatory and public perception issues; the best technology will fail if its sponsors do not attend to these issues. Accordingly, the food processing industry should initiate a collaborative issues management program. Such a program would be designed to proactively address issues in regulatory and public perception related to new wastewater reduction and recycling technologies. For example, the program could work to ensure that regulations are developed that allow chiller water recycling while still fully protecting public health.

- *Information Exchange* To support the above substantive areas for collaboration, efforts to create greater information flow across the industry would also be useful. The food processing industry should establish an industry forum to review and compare best practices in wastewater reduction. This forum might include a national database on experiences with new technologies and techniques of wastewater reduction, an information clearinghouse or networking service, and/or periodic national conferences or workshops.

Much change is in store for the food processing industry over the next decade, as production processes become more automated and computerized and more oriented towards integrated systems. At the same time, the expectations of customers, government regulators, and the public for both environmental performance and product quality are likely to increase. An active effort to develop and deploy emerging wastewater reduction technologies—technologies that reduce wastewater loads, save energy, and insure public health—should serve the industry well in responding to these changing conditions.

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For additional information, contact:

R. J. Philips & Associates, Inc.
Systems Manager, Food Manufacturing Coalition
P.O. Box 741
Great Falls, Virginia 22066
(703) 406-0072 (phone)
(703) 406-0114 (fax)
E-mail: rphil1140@aol.com