Many food processing operations generate high-strength wastewaters requiring unique approaches for cost-effective treatment and residuals management. These high-strength wastewaters are typically generated from cleaning processes, product spillage and poor quality batches. Wastewater may be subject to discharge requirements, and, for indirect dischargers, surcharge fees may be levied.

Wastewater treatment may include preliminary treatment and aerobic and anaerobic biological treatment. Wastewater treatment residuals management may incorporate sludge stabilization, dewatering and composting, and can include beneficial use of residuals.

Wastewater discharge requirements in the U.S. have evolved significantly since the federal Water Pollution Control Act Amendments of 1972 and the Clean Water Act of 1977. The resulting system of wastewater discharge standards, permits and enforcement mechanisms require substantial levels of treatment prior to discharge.

There are two types of wastewater discharge: direct and indirect. Direct discharges are to surface waters or groundwaters. Indirect discharges are to publicly owned treatment works (POTWs).

Direct discharges are governed by National Pollutant Discharge Elimination System (NPDES) regulations (40 CFR Part 125, Subpart K). For food processing wastewaters, NPDES permit standards are commonly based on receiving water quality considerations. However, federal effluent guidelines and standards have been developed for seven types of food processing facilities: dairy products, grain mills, canned and preserved fruits and vegetables, canned and preserved seafood, sugar processing, feedlots and meat products. At present, federal standards for food processing wastewater discharges address direct discharges only.

Indirect discharge of food processing wastewater is very common because many food processors are located in built-up areas, close to markets and sources of raw materials. Others have located in sewered areas to take advantage of relatively inexpensive treatment by POTWs. Indirect discharges to POTWs are subject to federal standards, embodied in the general pretreatment regulations (40 CFR Part 403), and to local standards, typically embodied in a sewer use ordinance, and possibly in a sewer use permit.

Local standards for the constituents typically discharged by food processors are often cursory or non-existent, since municipal wastewater treatment plants are designed to treat five-day biochemical oxygen demand (BOD5) and total suspended solids (TSS). However, a recent trend has been for POTWs to implement limits or surcharge trigger levels for BOD5 and TSS, which effectively require or encourage pretreatment by high-strength wastewater dischargers.

For example, in cases of POTW treatment plant capacity limitations, local limits can be lowered to the point that on-site pretreatment is necessary for high-strength wastewater dischargers. More often, the decision to employ pretreatment is driven by discharge costs or surcharges. In some instances, food processors contribute to the capital cost of building or expanding municipal wastewater treatment plants.

Another trend of consequence is flow restrictions, which may lead to production limitations and tend to encourage wastewater minimization.

Surcharge fees

In the U.S., food processing facilities in sewered areas have historically discharged to municipal treatment plants with little or no pretreatment. This practice evolved because food processing wastewaters are generally compatible with municipal treatment plants, and the philosophy during the time of the federal Construction Grants program (primarily the 1970s and 1980s) and earlier was to design municipal fa-

Stricter wastewater discharge regulations have compelled industrial sources, such as food processors, to pretreat wastewater before discharge to public facilities.

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A sequencing batch reactor serves as an equalization tank, aeration tank and clarifier in one vessel.

A sequencing batch reactor system treats dairy wastewater at Rutter's Dairy in York, Pa. (Source: Aqua-Aerobics Inc.)

Preliminary treatment

Food processing wastewaters often contain elevated levels of some or all of the following substances, compared to levels typically present in municipal wastewater: BOD5, TSS and other forms of solids, nitrogen compounds, phosphorus, color, and fats, oils and greases. It is not uncommon for pH to fluctuate over time due to acid and caustic-based cleaning events.

The predominant characteristic of many food processing wastewaters is a high oxygen demand. This oxygen demand can usually be treated biologically. However, some characteristics of food processing wastewaters require preliminary treatment for consistent biological system performance and satisfactory effluent quality. Preliminary treatment may perform one or more of the following functions: flow or load equalization, neutralization, solids removal, and removal of fats, oils and greases.

Flow and load equalization is typically accomplished by providing tankage that serves to dampen temporal fluctuations, as well as providing for incidental pH control. Neutralization involves adding acids or bases, typically through an automated pH control system. Solids can be controlled through several types of unit operations, including screening, grit removal, gravity separation and dissolved air flotation. Fats, oils and greases can be removed by these same unit operations, though chemicals may be needed to effect emulsion breaking.

Aerobic biological treatment

Aerobic biological treatment is the most common major unit operation for treating food processing wastewaters, whether at an on-site pretreatment facility or off-site at a POTW treatment plant. Aerobic biological treatment involves the conversion of organics to carbon dioxide, water and new bacterial cell growth by employing a heterogeneous mixture of microorganisms under aerobic conditions. The major types of aerobic biological treatment include:

- Aerated lagoon
- Facultative lagoon
- Oxidation ditch
- Activated sludge
- Extended aeration
- Sequencing batch reactors
- Trickling filters
- Rotating biological contactors
- Overland flow
- Spray irrigation

Aerated lagoons can be strictly aerobic or strictly facultative or both types can be incorporated into a lagoon system (aerobic followed by facultative in series). Aerated lagoons are in-ground systems with mechanical aeration characterized by extended hydraulic retention times, low biomass concentrations, low sludge production, high removals of BOD5, effluent suspended solids approaching 100 mg/L, and reduced performance under cold weather conditions. Aerated lagoons are well mixed, while facultative lagoons maintain dissolved oxygen in the upper portion of the lagoon, and anaerobic conditions and settled biomass in the lower portions of the lagoon.

Oxidation ditch systems use an in-ground channel in an oval race-track configuration. Both aerobic and anoxic zones can be used for removal of BOD5 and nitrogen.

Activated sludge systems typically recycle a portion of sludge to the aeration...
reactor. Activated sludge systems treat high-strength waste streams with a high removal efficiency in a limited space compared to an aerated lagoon, oxidation ditch or extended aeration system. Activated sludge systems are relatively susceptible to upset, however, due to limited hydraulic retention times (less than 12 hours).

Extended aeration systems are a variation of activated sludge where longer hydraulic retention times are maintained. Extended aeration systems generate less sludge and are less susceptible to upset than conventional activated sludge systems, but require more space, and yield higher effluent suspended solids levels.

Sequencing batch reactor (SBR) systems are a variation of the conventional activated sludge process. SBRs act as semi-continuous systems where wastewater is fed batch-wise over time to one or more batch reactors. An SBR serves as an equalization tank, aeration tank and clarifier in one vessel. Therefore, secondary clarifiers and return sludge pumps and piping are unnecessary.

Advantages of SBR systems include inherent equalization, the flexibility to handle varying influent, automated operation, nutrient removal capability, an enhanced ability to control filamentous growth, no need for clarifiers or sludge return pumps and piping, reduced oxygen requirements, enhanced settling, and limited or no short circuiting. Disadvantages can include higher capital costs (compared to continuous flow systems) at some influent flow and loading conditions, and the need for trained operators to take advantage of operating flexibility.

A trickling filter is a fixed-film process that typically uses plastic media packed or dumped into a tower. Wastewater flows by gravity from the top of the tower through the biomass-covered media.

A rotating biological contactor (RBC) is composed of several microorganism-covered plastic discs mounted on a horizontal shaft. Typically, several RBCs are operated in series. Each unit is partially submerged in wastewater. Each contactor rotates, carrying wastewater through the air, allowing oxidation to occur.

Fixed film systems (trickling filters and RBCs) are suited to waste streams with a high soluble BOD5 component. BOD5 removals in fixed film processes are generally lower than in suspended growth processes such as activated sludge, and fixed film processes are less susceptible to toxicity effects. Conversely, peak organics loadings are more likely to pass through a fixed film process inadequately treated.

Spray irrigation and overland flow systems are fixed film processes suited to lower-strength wastewaters. Spray irrigation requires permeable soils, while overland flow treatment is enhanced where soil permeabilities are low, surface slopes are 2 to 8 percent, and application rates are carefully controlled.

**Anaerobic biological treatment**

Anaerobic systems offer several advantages over aerobic systems for high-strength wastewater:

- Energy requirements and costs are significantly lower due to low energy input and potentially recoverable energy from methane.
- Sludge generation and nutrient requirements are lower.
- Space requirements are lower for high-rate anaerobic systems.

Disadvantages of anaerobic systems can include long startup times, efficiencies of less than 90 percent, and effluent odor problems.

Several types of anaerobic systems are used to treat food processing wastewaters, including anaerobic lagoons, anaerobic contact systems, upflow anaerobic sludge blanket systems, anaerobic filters (both downflow and upflow), fluidized bed and hybrid systems.

An anaerobic lagoon is a low-rate system (0.5 to 3.0 kg COD/m³/d) with a hydraulic retention time of 5 to 15 days. The large volume provides for equalization and solids storage and decomposition. Biogas development yields partial biomass suspension.

The natural cover anaerobic lagoon is the most common anaerobic technology for food processing wastewater treatment, with hundreds of installations worldwide. The synthetic cover anaerobic lagoon is a more recently developed version of an anaerobic lagoon system.

The anaerobic contact process is analogous to the aerobic activated sludge process in that biological solids are recycled from a solids separation unit to a biological reactor. Typical loading rates are low, ranging from 1 to 5 kg COD/m³/d. Solids separation in a separate conventional or Lamella clarifier is a critical aspect of the contact system.

The advantages of both the anaerobic lagoon and anaerobic contact processes include: influent suspended solids are accumulated or degraded in the reactor due to the high solids retention time, and loading fluctuations can be readily accommodated. The anaerobic contact system may offer slight advantages over the anaerobic lagoon system in that higher loading rates allow smaller reactor volumes.

The upflow anaerobic sludge blanket (UASB) process is a high-rate system, with organic loading rates ranging from 5 to 20 kg COD/m³/d. A UASB system typically comprises two tanks, the conditioning or acidification tank and the sludge blanket reactor. The sludge blan-
Researchers are investigating the use of old tires as anaerobic filter media for treating wastewater.

The sludge bed is a dense mass of solids at the bottom of the reactor. The overlying sludge blanket encompasses about 70 percent of the reactor volume. Biomass particles attached to gas bubbles rise through the sludge blanket, gas is separated and collected, and solids settle back into the blanket. The effluent overflows weirs for discharge and recycle. UASB sludge is unique and a key component of a successful system, as are the influent distribution system, and particularly the solids/liquid/gas separator. New UASB systems are started up with sludge from existing UASB systems, because it is difficult and time-consuming to create new UASB sludge from scratch.

Anaerobic filters are high rate systems (5 to 20 kg COD/m³/d) that use filter media and operate in either upflow or downflow modes. Anaerobic filters are suited for low solids waste streams. Research at Georgia Tech is investigating the use of old automobile tires as anaerobic filter media in treating food processing wastewater. Results so far indicate the tires can outperform conventional plastic media.

Anaerobic fluidized bed systems are upflow fluidized sand (or other inert media) bed reactors and are very high rate systems (10 to 40 kg COD/m³/d). These systems have not, however, enjoyed commercial success in the U.S. for food processing wastewater.

Hybrid anaerobic systems use a mixture of two or more anaerobic treatment techniques, such as the UASB and the filter process. Very few of these systems are currently used for treating food processing wastewater.

Sludge stabilization/dewatering
Wastewater treatment residuals generally require thickening, stabilization, volume reduction and beneficial use or final disposal. The most common stabilization methods in the food processing industry include lime stabilization, aerobic digestion and anaerobic digestion. Stabilization limits the potential for putrefaction and odors, while digestion also provides mass reduction.

Sludge dewatering reduces sludge volume and enhances sludge handling given the relative ease of handling a semi-solid vs. a largely liquid sludge. Sludge dewatering is done by sludge drying beds, lagoons, centrifuges, belt filters, filter presses and vacuum filters. Drying beds and lagoons are land-intensive and climate-dependent.

Recent equipment advances and demonstrated performance of mechanical dewatering devices tend to favor horizontal belt filters and centrifuges for mechanical dewatering of food processing wastewater sludges.

Conclusions
Most food processing wastewater discharges in the U.S. are to POTWs. Until recently, many of these discharges did not undergo substantial pretreatment and sewer use costs did not reflect true treatment costs. In many locales, sewer use costs for food processors have increased, and in fewer instances, discharge limits for conventional pollutants have been lowered.

These two phenomena are driven largely by reduced federal and state contributions to POTW capital and operating expenses, and, in turn, increased costs and lowered limits have compelled some food processors to install biological pretreatment.

Aerobic biological treatment remains the predominant technique in the food processing industry. The sequencing batch reactor is an emerging biological treatment technique worth looking at. Anaerobic treatment techniques include anaerobic lagoons, contact systems, upflow sludge blanket systems and anaerobic filters.

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