TROUBLESHOOTING WATER AND WASTEWATER PLANT MIXING EQUIPMENT PROBLEMS

By **Li Wang** and **Greg Jackson**

Mixing is one of the key factors impacting the performance of water and wastewater treatment plants. Improper mixing increases capital, operation and maintenance costs. Many plants experience unnecessary energy and chemical consumption, frequent equipment maintenance and overhauls, tankage cleanups, process upsets and shutdowns. These events are labour-intensive, pose safety concerns and have the potential to cause regulatory violations. Most of these events can be avoided and up to 80% of the costs can be saved by selecting the right mixing technology.

Mixing is essential to achieve many process objectives, including: homogenization, prevention of settling, chemical/biological reactions, prevention of short-circuiting, chemical dissolution, etc. Typical mixing applications at water treatment plants include: coagulation, flocculation, chlorination, sludge holding, carbon makeup, and chemical makeup. For wastewater treatment plants, mixing is required for: FOG/scum breakup in lift stations, septage receiving, anaerobic/anoxic tanks, sludge blending/storage, digesters, chemical makeup, etc.

Mixing objectives of these facilities vary based on applications. For example, homogenization and avoiding short-circuit are the keys to satisfactory chlorine mixing in a water treatment plant. For anaerobic digester mixing, the primary objectives are increasing gas production and volatile solids reduction. Secondary objectives include: preventing solids buildup at the tank bottom, avoiding foam formation and reducing energy consumption.

The difficulty with wastewater mixing is rooted in complicated physical attributes of the water, multiple process objectives, misunderstanding and limitations of mixing technology.

A high performance centrifugal dispersing impeller used for sludge mixing at the Banff WWTP.

EQUIPMENT ISSUES

1. Submersible mixer seal failures. It is not unusual for some wastewater treatment plants to experience moisture problems in submersible mixers. Mechanical seals are the most prone to failure of submersible fittings, often due to wear and tear.

Water may pass through the seals into the mixers or through the cable entry system. Some of these incidents are caused by the mixer's blades coming in contact with the whip-like cable. If there is fibrous material in the water, ragging of the mixers causes its propellers and shafts to become unbalanced. This in turn damages the seals and causes intrusion of water.

Poor hydraulic conditions around the mixer may also cause an indirect short circuit, resulting in mechanical damage. For example, shallow submergence of mixers will create a vortex and draw air down from the surface. This will cause vibration of the impeller and damage the seal. Vortexing is also the major cause of mixer impeller cavitation.

Costs of a failure include direct mixer rebuild as well as process unit shutdown. The solutions are to improve the mixer working conditions, or to switch to a different mixer. Most wastewater treatment plants solve this problem by upgrading to new mixers that have been proven to have less seal failures. Other plants upgrade to top entry mixers with many other benefits, including easy and safe maintenance.

2. Ragging of mixers. Wastewater facilities such as lift stations, septage tanks, equalization tanks, sludge storage and digesters, often contain fibrous rag-like materials. Such materials tend to build up on mixer impellers and cause down time and mechanical damage to the mixers if they are not cleaned.

Some mixer manufacturers have developed products with anti-ragging impellers that resist the accumulation of rags. Most of the time, changing to an anti-ragging impeller will solve the problem.

PROCESS ISSUES

1. FOG/scum buildup. Many municipalities have long battled the buildup of fats, oils and grease (FOG) in sewage lift stations and wetwells of wastewater treatment plants. The FOG can form a thick mat of solidified materials, including grease, paper and anything floating at the water surface. It interferes with the water level control devices, causing false pumping operations. Severe FOG buildup can result in odour issues caused by anoxic conditions below the FOG layer.

The main reason for FOG buildup is that facilities were not designed, or not required to be designed, to remove them. Standard lift station design controls pump operation based on water level, turns on pumps at high water level and turns off at low water level. Some lift stations were designed to run pumps to keep constant water level in the wet well.

With either type of control, all pumps, submersible or dry well installed, withdraw liquid from the bottom of the wetwell. All pumps have minimum submergence requirements. Therefore, the materials floating at the water surface will go up and down, but will not be removed and will ultimately cause problems.

To solve FOG issues, some municipalities use additives or enzymes to dissolve the materials. For municipalities where chemicals and enzymes are not allowed, mechanical mixing is applied. Air mixing has been used for FOG breakup. Mechanical mixers creating a vertical flow pattern provide a simple way to solve FOG buildup.

2. Odour caused by sludge settlement. Odour is a common issue in many wastewater treatment plants. If they are located near residential areas, unpleasant odours can create political and legal problems. Most of these originate from anaerobic decomposition of materials having a high molecular weight, such as proteins. Septic conditions also trigger intense activities of odorous sulfate-reducing bacteria.

It is often impossible or very difficult to prevent septicity in sewer lines, lift stations, inlet works and primary clarifiers. However, if not well mixed, septicity and odour can also come from stormwater storage, aerated secondary wastewater treatment processes, aerobic digesters, or aerated lagoons.

Septicity can also occur in sludge storage tanks and carbon slurry tanks at water treatment plants because of settling. Mixing plays a key role in preventing solids settlement and odour formation in these facilities. Normally, the air/oxygen supply is sufficient to support the bioreaction. If there is no settling, the odour issue should be eliminated. The key is selecting the right mixing technology. The mixer should be able to effectively suspend solids in the wastewater. It also provides mixing to the whole tank volume without dead zones.

3. Sludge settlement and buildup. Solids suspension is still

continued overleaf…

Figure 1. The high performance centrifugal dispersing impeller (HPCDI) suspends solids with a tornado like force.

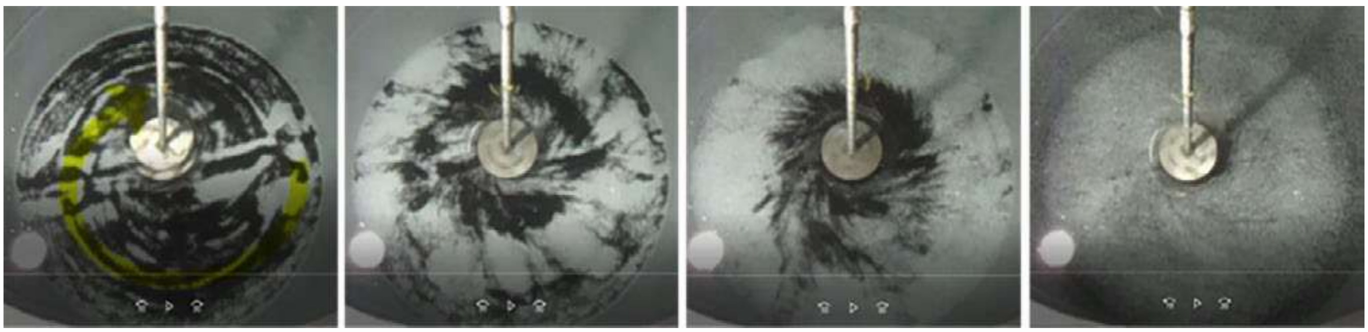

Figure 2. Clean tank bottom using a HPDCI.

a hot topic for many researchers and scientists and the mixing industry. Solids suspension performance is limited to the development of mixer technology.

Submersible propeller and top entry hydrofoil are two types of mixers that have been widely used in water and wastewater treatment. These traditional mixers push water forward or downward. Many water and wastewater treatment plants have experienced severe sludge settling in their facilities. If there is a considerable amount of grit and silt in the water, the problem can be worse.

The theory that governs solids suspension is the Stokes' law. To effectively suspend solids and prevent settlement, mixers should create flow patterns having upflow with sufficient upward velocity to overcome the gravity of the solids.

When selecting a mixing system, the minimum upflow velocity (MUV) at the most difficult point should be calculated. For example, mixers with axial flow impellers push water downward to the tank bottom, where it spreads radially outwards, then goes up along the tank walls. These mixers suspend solids particles from the periphery of the vessel bottom. Solids are flushed up by the upflow along the tank wall.

To evaluate the capacity of solids suspension, the MUV at the periphery of the tank bottom should be calculated. If the MUV at these locations is not higher than the settling velocity required, solids will settle and build up.

IMPROVING SOLIDS SUSPENSION AND SLUDGE SETTLEMENT

Sludge settlement reduces reactor volume and increases the risk of process upset. Cleanup of settled sludge is costly and labour-intensive. Also, septic reactions of settled sludge produce corrosive gases that can damage the vessel structure, and create odorous gases.

1. Install baffles. Baffles are necessary for traditional top entry mixers. For circular tanks, traditional mixers create tangential motion to the liquid with little mixing effect. The whole water volume moves like a solid-body. Baffles are standard design configuration to such mixing systems to improve mixing performance. The primary purpose of installation of baffles is to convert the horizontal swirling motion into an axial flow pattern.

The main drawback of installing baffles is increased power consumption, which can be from 100% – 400%, depending on mixer types and the number of baffles installed.

2. Upgrade to larger capacity mixers. When a sludge settlement problem happens, it is natural to conclude that undersized mixers might be installed. To solve this problem, upgrading the mixers to larger ones is often considered. However, added capital costs include upgrading the power and control system, structures to support the new equipment and lifting systems.

There are also other factors that need be taken into consideration. As an example, most anaerobic digesters have internal corrosion proof coatings. If the new mixer creates stronger jetting flow in the tank, the high-speed mixture of sand/grit and water might cause abrasion to the tank coating or structure. Another concern is the high-speed jetting might cause foaming in anaerobic digesters.

NEW MIXING TECHNOLOGIES FOR SOLIDS SUSPENSION

A new mixing technology, High Performance Centrifugal Dispersing Impeller (HPCDI™) has been developed and applied to solids suspension with satisfactory results. It employs a new mixing concept and a mechanism which is different from that of traditional mixers. The unique tornado- and fireworks-like flow patterns it creates provide improved solids suspension capacity.

The flow pattern of the typical HPCDI appears completely opposite of that of traditional mixers. With the rotation of the impeller, liquid is pushed outwards from inner ends to distant ends of each vane. When liquid is discharged, it creates two low pressure fields: one above the impeller, the other under the impeller. Both fields are replaced by liquid immediately.

Rotation of the impeller and the liquid displacement result in two tornado-like funnels formed above and under the impeller. The funnel below the plate extends downwards until it touches down to the bottom. The funnel above the plate extends upwards until it reaches the liquid surface.

The HPCDI successfully solved a sludge settling problem in the sludge mixing tank at the Banff, Alberta, wastewater treatment plant. This tank receives primary and dissolved air flotation (DAF) sludge. It has a diameter of 8 m and side water height of 4.5 m. Previously, a 5 kW submersible mixer was installed. Because the primary sludge (from primary clarifiers) contains a considerable amount of sand/grit, there was a severe solids settlement in the tank (it was once observed at about 1.5~1.8 m sludge depth along the wall).

The HPCDI was selected after comparison of available mixing technologies on the market. It provides sufficient mixing to the tank, with powerful solids suspension. No sludge buildup was observed in the one and a half years operation since installation.

Measured power withdraw is about 1.0 kW. This translates to a greater than 80% energy savings compared to traditional mixers.

INDUSTRY TRENDS

As with many other industries, the trend with mixing in water and wastewater treatment is to apply new energy-efficient technologies with improved performance. Typically, larger diameter impellers consume less energy than small impeller mixers. Top entry mixers normally have less operation and maintenance issues. For solids suspension, top entry mixers have shown better performance than submersible mixers.

Designing a reliable mixing system is not simply selecting a mixer. There is a long list of physical properties that need to be considered and fully understood, including: specific gravity of the particles, size distribution, shapes and liquid viscosity, geometry of the vessel and the design parameters of the mixing equipment. Detailed attention to these physical properties and attention to the impact on operations will provide a successful process.

Li Wang is with Revolmix. Greg Jackson is with ACG-Envirocan. For more information, email: greg@acgtechnology.com