Clarifier clarity

Innovative improvements decreased the occurrence of denitrification in the secondary clarifiers at an industrial wastewater facility, significantly cutting solids loadings in the effluent

Mikel E. Goldblatt

A chemical production facility in the Midwestern U.S. was troubled by excessive solids in its wastewater effluent. During periods of high organic loadings, denitrification would occur in the secondary clarifiers, creating nitrogen gas bubbles that carried solids to the surface. Similarly, during periods of varying hydraulic conditions, entrained gases would be carried into the quiescent zones of the clarifiers, also causing solids to float to the surface. Ultimately, the solids would escape over the weirs of the secondary clarifiers, elevating the solids concentrations in the facility’s effluent.

To address the problem, the project team first converted an idle basin at the site into an anoxic basin, to enable denitrification to occur ahead of the secondary clarifiers. However, this solution failed to stem the production of nitrogen gas in the
clarifiers adequately. The flotation of solids remained a problem. To provide additional degassing surface area upstream of the clarifiers, a small pipeline was added to direct a portion of the aerated mixed liquor into the outlet end of the anoxic basin. This innovative, but inexpensive, change reduced the propensity for solids carryover into the facility’s discharged effluent.

### Keeping pace with regulatory changes

Originally constructed in the 1950s, the chemical production center added an in-ground facility for treating wastewater in 1973. Along with an equalization pond, the treatment facility comprised six detention ponds, two in-ground aeration basins, and two concrete secondary clarifiers. Because all the ponds, basins, and clarifiers were open to the atmosphere, odors posed a continuing concern, especially on hot, humid days. Originally, wastewater and stormwater had been conveyed onsite by means of open ditches. However, by 2005, pipes were used to convey wastewater onsite, though ditches continued to be used to convey stormwater and water filter backwash.

Around this same time, the facility faced significant compliance costs associated with various regulations issued by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act. In November 2003, EPA promulgated the final rule of the national emission standards for hazardous air pollutants (NESHAP) for miscellaneous organics in the chemical manufacturing industry. The rule set emission limits and work practice standards for new and existing miscellaneous organic chemical manufacturing process units, wastewater treatment and conveyance systems, transfer operations, and associated ancillary equipment.

As a result of this rule, the chemical manufacturer would need to enclose systems used to convey and treat certain streams. Meanwhile, in keeping with the requirements of another NESHAP standard, the chemical manufacturer was incurring significant costs associated with the pretreatment of certain wastewater from various production units.

In 2005, the chemical manufacturer decided to proceed with the design and construction of a new aboveground treatment facility, one that would be sized sufficiently to treat all wastewater in full compliance with the Clean Air Act standards. At the same time, the new treatment facility would comply with an anticipated requirement for an aboveground treatment system, which was expected to be included as part of the manufacturer’s next permit issued in accordance with the National Pollutant Discharge Elimination System. As part of the project, five of the existing detention ponds and the two aeration basins were closed, decreasing hydraulic storage capacity and eliminating primary treatment.

Data analysis for design of the new water resource recovery facility began in 2004. Average and peak hydraulic loadings were determined to be 4500 and 6100 m³/d (1.2 and 1.6 mgd), respectively. Compared to 2004 levels, future loadings were expected to increase by 20%. (See the table below.)

Completed in 2009, the upgraded wastewater treatment facility (Figure 1) includes two new covered wastewater treatment processes.

### Wastewater facility loading in 2004 and beyond

<table>
<thead>
<tr>
<th></th>
<th>2004 loading</th>
<th>20% greater loading</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average (kg/d)</td>
<td>Peak (kg/d)</td>
</tr>
<tr>
<td><strong>Total COD</strong></td>
<td>14,206</td>
<td>26,838</td>
</tr>
<tr>
<td><strong>Soluble COD</strong></td>
<td>12,907</td>
<td>25,534</td>
</tr>
<tr>
<td><strong>Degradable COD</strong></td>
<td>9371</td>
<td>21160</td>
</tr>
<tr>
<td><strong>Total suspended solids</strong></td>
<td>490</td>
<td>849</td>
</tr>
<tr>
<td><strong>Ammonia-nitrogen</strong></td>
<td>186</td>
<td>569</td>
</tr>
<tr>
<td><strong>BOD</strong></td>
<td>2799</td>
<td>4444</td>
</tr>
</tbody>
</table>

COD = chemical oxygen demand.
BOD = biochemical oxygen demand.

![Figure 1. Process flow diagram of wastewater treatment operations in 2009](image-url)
in which influent streams are mixed and recirculated. Flows then enter an anoxic selector, which also receives return activated sludge (RAS) from the two original concrete clarifiers. The anoxic selector discharges to two new complete-mix aeration tanks that operate in parallel.

In the facility’s original configuration, mixed liquor from the aeration tanks was conveyed by means of a 210-m-long (700-ft), 400-mm-diameter (16-in.) pipeline to an open splitter box, and from there to the two clarifiers.

**Solids make their escape**

Following startup of the new facility, several system upsets resulted in elevated solids carryover from the secondary clarifiers. A project team that included Solenis (Wilmington, Del.) and Brown and Caldwell (Walnut Creek, Calif.) investigated the problem. Under many different loading and operating conditions, solids would escape over the weirs of the secondary clarifiers. During periods of high organic loadings, denitrification would occur, stripping chemically bound oxygen from nitrate and leaving nitrogen gas behind. The resulting bubbles, when released in the clarifiers, attached to floc particles and caused solids to float to the surface and carry over into the effluent. Similarly, under various hydraulic loadings, entrained gases would enter the quiescent zones within the clarifiers, causing flotation and loss of solids.

The discharge permit for the treatment facility does not include limits for ammonia, nitrate, or total nitrogen. However, the project team seeking to address the system upsets realized that conducting denitrification ahead of the clarification process would reduce the potential for denitrification to occur in the clarifiers and result in solids carryover.

Therefore, an idle earthen pool known as the “west basin” was recommissioned as an anoxic treatment basin. As part of its upgrade, the rectangular depression was double-lined and equipped with three mixers. All of the mixed liquor from the aeration basins was conveyed by gravity to the west basin.

Although the new configuration facilitated greater removal of chemical oxygen demand (COD) and enabled denitrification, it did not solve the problem of solids flotation in the clarifiers. Despite the presence of the mixers in the west basin, solids tended to gather at the surface near the outlet. This prevented sufficient degassing in the basin immediately upstream of the splitter box. For its part, the splitter box lacked the necessary surface area to enable enough degassing to reliably prevent solids flotation in the clarifiers. Instead, degassing continued to occur in the clarifiers, occasionally leading to significant solids buildup in the center wells and excessive levels of floating solids in the quiescent zones of the clarifiers.

Notably, the original design for the upgrade of the wastewater facility had called for enlarging the center wells and adding baffles to dissipate energy in the clarifiers. The greater surface area in the larger center wells would have facilitated more degassing from the mixed liquor before it entered the quiescent zones of the clarifiers, reducing the likelihood of solids flotation. However, in a cost-cutting effort, these plans were changed before construction occurred. Rather than being enlarged, the existing center wells were equipped with a series of energy-dissipating baffles.

**Improving the solution**

The project team considered the following options for preventing solids flotation in the quiescent zones of the clarifiers:

- Refit the clarifiers with larger center wells to enable maximum degassing before flows entered quiescent zones.
- Partition the west basin and add a post-anoxic aerated zone. This would facilitate removal of remaining biochemical oxygen demand and prevent solids from covering the surface of the basin near the outlet, affording more surface area for degassing.
- Continue reducing sludge blanket levels as much as feasible.
- Divert high-strength wastes to a storage tank for subsequent treatment. This action would reduce the COD in the mixed liquor enough to prevent denitrification from occurring in the clarifiers. Although some diversions were being conducted as feasible, increasing activity at the manufacturing facility generated 50% more COD in 2012 as compared to 2004 levels. As a result, these higher levels of COD sometimes exceeded the treatment capacity of the facility.
- Experiment with methods for sending a portion of the mixed liquor from the aeration basins to the discharge end of the west basin. This approach would create some surface aeration near the west basin exit, partly accomplishing the objectives of the second item above.

![Figure 2. Process flow diagram of modified wastewater treatment operations](image-url)
The project team opted to pursue the last option. Simplifying matters, the pipeline that conveys mixed liquor from the aeration basins to the splitter box passes near the exit end of the west basin. In 2013, a temporary “jump-over” line was installed to divert a small portion of the mixed liquor from the existing pipeline into the final 15% of the west basin. The flows were released in a manner that created surface aeration, thus affecting a crude post-anoxic aeration zone ahead of the clarifiers. The dotted line in Figure 2 illustrates the jump-over line.

In addition, the zone aeration controls for the aeration tanks were adjusted to increase dissolved oxygen concentrations near the discharge point of each tank. This change boosted the aerobic digestion process in the aeration tanks and maximized degassing ahead of clarification. Within the clarifiers, a small sprayer was added to each center well to help keep the surface clear of floating solids and to promote degassing.

Innovation on a budget

Following implementation of these changes, surface clarity improved within the outlet end of the west basin, solids flotation decreased significantly within the clarifiers, and solids concentrations decreased in the effluent. By combining operational experience and design concepts in an innovative way, the project team achieved success and avoided the need to conduct more costly retrofits of the facility.

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