Shanghai acrylonitrile plant using BDP achieves total reuse goal

SECCO's water reclamation facility at an acrylonitrile production plant in Shanghai, China, recycles 100 percent of wastewater influent and saves US$4.5 million annually from water supply, energy, and wastewater discharge costs. Authors **Eric Li** and **Ben Chow** of BDP EnviroTech LLC explain how the Biological Double-Efficiency Process (BDP®) helps the facility achieve these results.

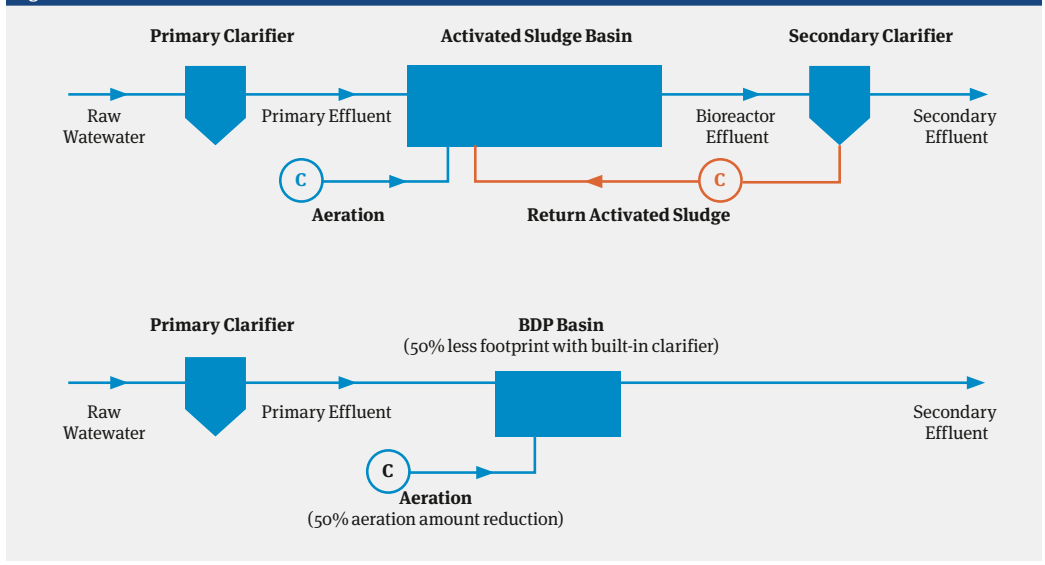
Acrylonitrile is widely used in Asia and many other countries to manufacture products such as acrylonitrile butadiene styrene (ABS) plastic, nitrile rubber (Buna-N), acrylic fiber, and synthetic resin. However, the process used to produce acrylonitrile – catalytic ammoxidation of propylene, also known as the SOHIO process – also produces one of the most difficult-to-treat industrial wastewaters. This process involves the catalytic reactions of propylene, ammonia, and air (oxidizer), forming by-products such as acetonitrile and hydrogen cyanide. It typically has high chemical oxygen demand (COD), total nitrogen (TN), and the extremely toxic compound cyanide (CN^-).

TN removal is one of the major challenges for treating acrylonitrile wastewater. There is no specific discharge standard for TN, and its removal is not typically monitored in other acrylonitrile wastewater treatment plants in China. Therefore, the removal efficiency of conventional wastewater treatment process for TN in acrylonitrile wastewater is not well established.

In 2011, the Shanghai SECCO Petrochemical Company's acrylonitrile manufacturing plant set a goal to reuse 100 percent of its wastewater as a supplementary production water source in order to address growing concerns of the massive industrial water demand and high costs associated with water purchase and wastewater discharge. The company is a joint venture of British Petroleum, China Petroleum and Chemical Corporation, Shanghai Petrochemical Company, and East China Investment Company. It is also the largest petrochemical joint venture in China and one of the biggest acrylonitrile production plants in the world.

To achieve this goal, the Biological Double-Efficiency Process (BDP®) was chosen as the second-

Figure 1



Flow chart comparison between conventional wastewater treatment process and the Biological Double-Efficiency Process.

ary biological treatment process based on the results of pilot tests conducted from 2011 to 2012 at SECCO's acrylonitrile water reclamation plant.

BDP removes TN

It is common practice in the activated sludge process to remove nitrogen by ammonia oxidation followed by nitrate/nitrite reduction to nitrogen gas. The autotrophic organisms use oxygen as the electron acceptor to oxidize the ammonia in the aerobic environment. The heterotrophic organisms using nitrate/nitrite as the electron and carbon from organic compounds, prefer low to zero dissolved oxygen (DO) levels, and are responsible for de-nitrification. The conventional secondary wastewater treatment process for nitrogen removal consists of separated basins for the aerobic process (nitrification) and anoxic process (de-nitrification).

In contrast, the BDP process is a continuous and mainstream simultaneous nitrification and denitrification (SND) process, involving both nitrification and de-nitrification reactions occurring in a single bioreactor. The BDP process also eliminates the secondary clarifier by including a fast-clarification zone into a unique all-in-one integrated structure. The process generates significant savings by eliminating the need to separate treatment processes into anaerobic and aerobic tanks and secondary clarifier. Figure 1 shows the flow chart comparison between the BDP process and conventional activated sludge process.

In the BDP process, the dissolved oxygen level is kept low at approximately 0.3 milligrams per liter (mg/L), creating an oxygen concentration gradient across the granular sludge flocs, with denitrification occurring at anoxic zones within the core of floc particles and nitrification occurring near the surface of floc. Short-cut nitrification/ denitrification is observed in the BDP process, making TN removal more efficient. Compared with full chemical reactions for nitrogen removal, shortcut nitrification/ denitrification refers to reactions in which ammonia is oxidized directly to nitrite (NO_2^-) without nitrate (NO_3^-) as the intermediate, followed by reducing it to nitrogen gas (N_2) and into to the atmosphere directly. The mixed liquor suspended solid (MLSS) is kept high at approximately 8,000 mg/L; therefore, a high sludge concentration with a low food/ microorganisms ratio helps to maintain smaller sludge flocs that can sustain just enough aerobic activity in the low dissolved oxygen environment. The high MLSS also enables the BDP process to double its treatment capacity with the same footprint when compared to the conventional process.

Facility process design

For the process design of the SECCO water reclamation facility in Shanghai, the domestic wastewater and the acrylonitrile wastewater are first conveyed into separate regulating basins and then pumped into a mixing basin for blending. The alkalinity of the mixed wastewater is adjusted by adding caustic. The mixed wastewater stream is then introduced to the BDP system and immediately diluted by recirculated MLSS and lifted by an airlift device into the aeration zone for treatment. The concentration of dissolved oxygen (DO) in the aeration zone is automatically regulated to facilitate the removal of chemical oxygen demand (CODCr), ammonia nitrogen (NH_3-N), TN, and CN^- components by microorganisms. Wastewater leaving the aeration zone flows into the fast clarification zone by gravity, where effluent exits the BDP basin, and mixed liquor is returned to aeration zone. Excess waste activated sludge (WAS) is collected by the sludge scrapper and then pumped to a solids handling facility for further treatment and disposal. A flowchart of the BDP process is provided in Figure 2. Figure 3 shows the entire treatment process flow of this facility, using BDP as the main biological treatment process for enhancing suspended solids, COD, and TN removal.

SECCO's full-scale design treatment capacity of BDP is 150 cubic meters per hour (m^3/hr), including 60 m^3/hr of acrylonitrile wastewater and 90 m^3/hr of domestic wastewater, respectively. Table 1 shows the daily average and annual treatment flows.

Operating since November 2014, the full-scale BDP system has a treatment capacity of 3,600 cubic meters per day (m^3/d) and meets discharge requirements while significantly reducing estimated operation and maintenance costs. Table 2 shows the consistently high removal rates achieved by the BDP process for COD, NH_3-N, TN, and CN-.

Figure 2. BDP System Treatment Flow Diagrams

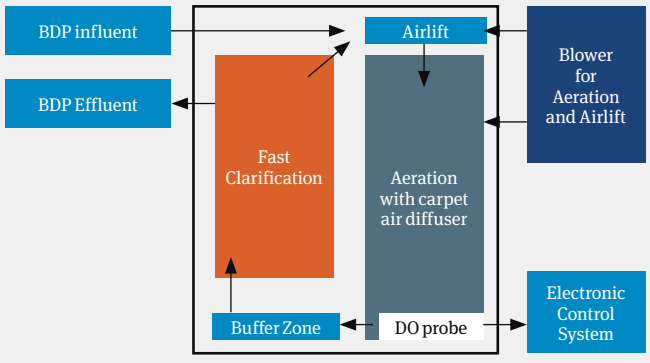


Table 1

Parameter	Units	Values
Flow Rate	million liters per day	360
Annual Treatment Capacity	million liters per year	1,317
Annual Operation Time	hours/year	8,760

Treatment Capacity of BDP® Biological Treatment System in SECCO project

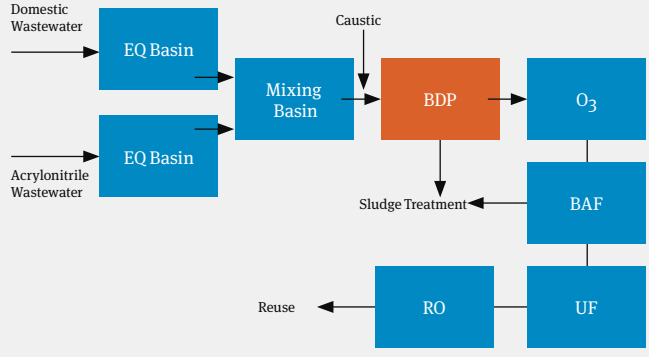
Table 2

Parameters (mg/L)	CODCr	TN	NH3-N	CN-
Influent after Mixing	≤ 1,500	≤ 250	≤ 50	≤ 5
BDP Effluent (6 months average)	93	18	2.5	0.3
BDP Effluent Requirement	≤ 150	≤ 25	≤ 10	-
Removal Rate	94%	93%	95%	94%

Note: The data represents the performance of the BDP secondary treatment process only.

Full-scale BDP Performance at SECCO Acrylonitrile Wastewater Reclamation Plant

Figure 3. Process Flow Chart for SECCO Wastewater Reclamation Facility



Conclusion

SECCO's Shanghai water reclamation facility has become a flagship model for the petrochemical industry worldwide. The BDP system reduces 50 percent of the volume of air necessary for aeration compared to conventional technologies; it eliminates separated secondary clarifier structure and substantial energy required for onsite pumping in conventional RAS process; and it combines anaerobic and aerobic process into one bioreactor to achieve an excellent nutrients removal rate. The plant recycles 100 percent of the wastewater and saves approximately US$4.5 million dollars annually from industrial water supply purchasing, energy consumption, and wastewater discharge.

Authors' Note

CEO Eric Li and project manager Ben Chow work at BDP EnviroTech LLC, based in Laguna Hills, California.