new options in nutrient removal

By John Shepherd

The continuously sequencing reactor (CSR) is a process modification of a continuous-flow, complete-mix activated sludge system. With the CSR, air is operated intermittently to allow the reactor to sequence through aerobic (oxic), anoxic and anaerobic phases, thus accomplishing biological nutrient removal (BNR) in a single reactor. Because aeration is not allowed during the anoxic and anaerobic phases, the key requirement for such a cyclical operation is that the reactor mixing must be independent of the aeration (i.e., separation of aeration and mixing).

Separation of aeration and mixing in a continuously sequencing reactor

ARTICLE SUMMARY

Challenge: End-users may not realize the benefits of a CSR aeration process.

Solution: Among many benefits of CSR is its ability to more effectively monitor nutrient removal and a simple and efficient operating process.

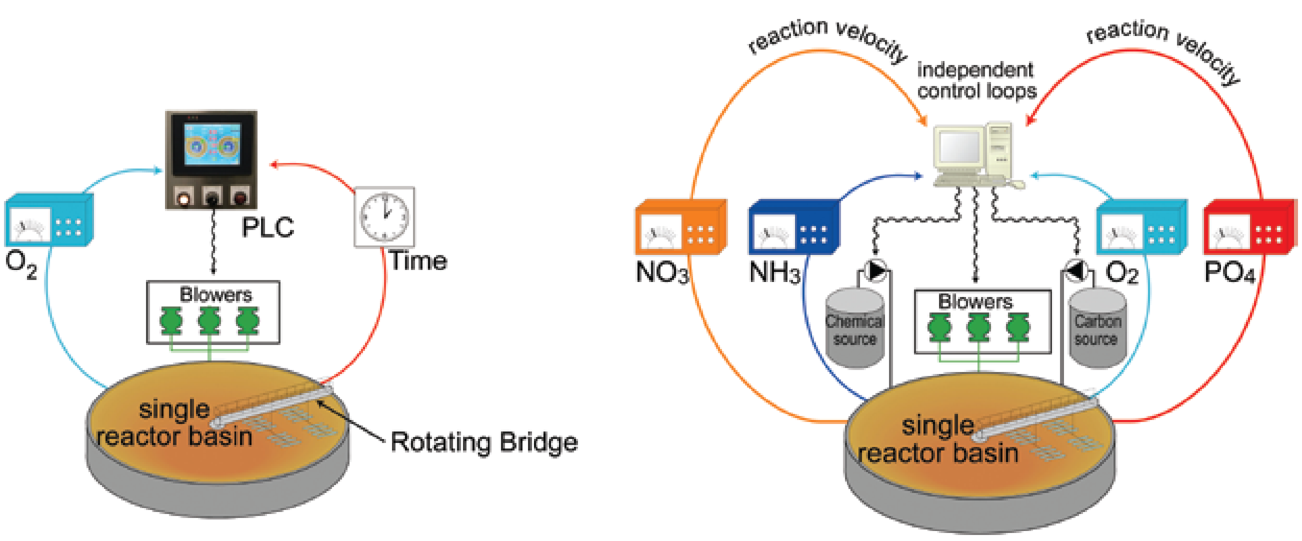
Conclusion: CSR offers basic operations simplicity and a robust process stability, translating to a highly stable system capable of reliable operation throughout its service life; it also allows for a lower-operating-cost facility.

Schreiber's aeration system is a natural fit for the CSR. In the system, a rotating aeration bridge provides all required basin mixing: The diffused aeration system is free to be operated strictly for aeration purposes alone. Subsequently, the aeration function is totally independent of the low-hp mixing function, resulting in large energy savings.

While flow is continuously routed through the basin, the mixed liquor is first aerated to allow nitrification of ammonia to nitrates, which requires oxygen and alkalinity. Once this nitrification is complete, the air is turned off and denitrification commences. As denitrification is completed, the basin becomes anaerobic, generating a phosphorus (P) release. When aeration is resumed, the same bacteria rapidly reabsorb P from solution and take up several times the amount of P that they released—a process commonly known as "luxury" uptake. The reactor then resumes aeration and continues to cycle, or "sequence," through the three process phases of aerobic, anoxic and anaerobic—hence the term CSR.

There are several basic concepts to keep in mind when considering the CSR process. First, the three process phases occur in the same basin, but not at the same time. Second, the entire basin experiences each process phase fully. So, when the CSR is in the aerobic phase, the entire basin is aerobic. As the process enters the anoxic phase, the entire basin becomes anoxic. When the process is in an anaerobic phase, the entire basin experiences the anaerobic conditions. Third, the process phases occur sequentially and always in the same order of aerobic, anoxic and anaerobic—followed by aerobic, anoxic and anaerobic, followed by aerobic, anoxic, anaerobic, etc. And finally, although the process phases occur over and over, the time duration of each phase can vary from cycle to cycle depending on the loading and the degree of treatment desired.

Figure 1. CSR nutrient removal takes place in a single reactor basin; the need for various recycle streams is eliminated completely.



Stable & Economical

The CSR offers many more benefits due to its single basin process. Because the denitrification process recovers oxygen and alkalinity, this process is more economical to operate than a conventional activated sludge facility. Also, the CSR process is more stable, as the nitrogen cycle is completed, rather than terminated, at the end of the nitrification phase. In the CSR, nutrient removal is accomplished in a single reactor basin, so the need for the various recycle streams characteristic of most other BNR systems is eliminated completely. Because the entire CSR basin is subjected to the separate process phases, the "recycle" is internal and the additional equipment, energy and operating effort required by other processes is not necessary.

The basic equipment components required to operate a CSR are the same as those needed for any normal activated sludge process facility: aeration, mixing and solids separation (e.g., clarifier/filter). When compared to the more common plug-flow type of BNR systems, however, the CSR is surprisingly simple and efficient to operate.

The only two decisions required of the operator (or by an automatic controller) are when to turn the air off and how long to leave it off. Such control can be implemented by a PLC-based system or something as simple as a time clock that switches the aeration blowers "on" and "off" for set periods of time. Usually the time periods are on the order of one hour off and two hours on. Using no more than a simple timer as the controller, CSR plants processing typical municipal-type influents can achieve total nitrogen (TN) effluents of roughly 6 mg/L.

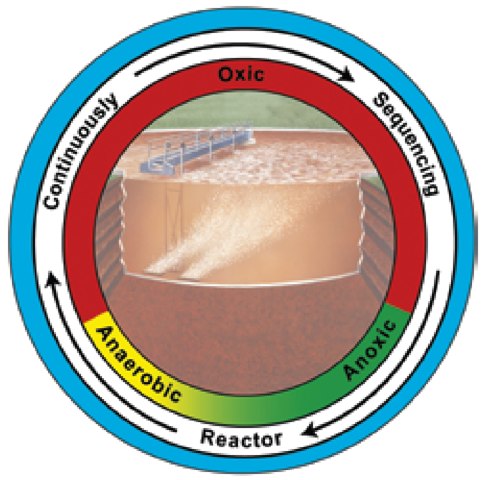
With the CSR, as higher degrees of nutrient removal are required, more elaborate control systems can be employed to increasingly monitor the nutrients in the reactor. Recent improvements in instrumentation technology have resulted in reliable analyzers and ion-specific electrode probes that can be installed directly in the basin. Such components allow the direct and continuous measurement of the ammonia, nitrate and phosphate concentrations in the mixed-liquor suspended solids.

Armed with the real-time knowledge of what is occurring in the reactor, the CSR operator can determine the optimum length of each of the aerated and nonaerated phases. By tracking ammonia in the aerobic phase, the operator can determine when nitrification is essentially completed and when further aerobic time will be nonproductive. At that point, the aeration is stopped. As denitrification commences, during anoxic phase, nitrates are monitored. The nitrates that were produced during the nitrification phase are converted to nitrogen gas during the denitrification phase.

Once nitrate concentrations reach their lower levels and all oxygen recovery from the destruction of the nitrates cease, the anaerobic phase begins. With the start of the anaerobic phase, P concentrations are monitored; they increase sharply as the poly-P bacteria are stressed and release the P from their cell mass. This release, typically completed within 20 minutes, is indicated by a peak in soluble P. At that point, aeration is resumed, returning the CSR basin to the aerobic phase, in which luxury uptake will occur again.

The SchreiberFlex control system incorporates nutrient monitoring as well as dissolved oxygen (DO) control for the aerobic phase. The data is evaluated continuously and used to control the entire process. By evaluating the various parameters, the system automatically determines when to terminate aeration and initiate the anoxic phase.

Figure 2. CSR is a cyclical, simple operation.



The system also recognizes the initiation of, as well as the completion of, the anaerobic phase (by P release). It then calls for the resumption of aeration and the return to the aerobic phase. During the aerobic phase, the system relies on the DO control components of the system to maintain the reactor within set DO levels. This reduces the system operating cost by allowing the aeration system to supply only the amount of oxygen required by the process.

The system continuously evaluates reaction rates in each phase to determine when the current phase is still productive and when to transition to the next phase. The effect is to optimize the total reactor time into the most productive ratio of phases. Because TN removal is strictly biological, whereas P can be removed biologically or chemically, the system is geared primarily to nitrogen removal with P removal as a secondary goal. By utilizing the CSR process with the control system, municipal facilities typically can achieve effluent TN levels of less than 3 mg/L and effluent P levels of 0.5 to 1 mg/L without chemical addition.

Clarification is usually sufficient to achieve an effluent P of 1 mg/L, while tertiary filtration generally is required to reach lower P levels. Chemical addition can be incorporated into the CSR process to supplement the biological P uptake and trim the remaining P to achieve lower limits. Both the biological and chemical processes are converting soluble P into the solid form, in which it can be physically separated by clarification and filtration.

While for many locations nutrient removal may not be of concern presently, the CSR provides an attractive alternative to conventional treatment by providing a lower-operating-cost facility than a conventional activated sludge plant at no additional capital cost. The CSR offers basic operations simplicity and a robust process stability, translating to a highly stable system capable of reliable operation throughout its long service life. WWD

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