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Special Method for CO_2 Addition to Recarbonation Chamber Significantly Cuts CO_2 Usage; Provides More Consistent pH Readings

Alternative to Diffusers for Lime Softening Plant; Carrier Stream is Process Water
Benefits Continuing and Enhanced after 12 years in Use

*by Cliff Lebowitz****

2013 pilot proprietary CO_2 dissolution and injection system had delivered typical CO_2 dose of 15 mg/L, while treating an average flow of 30 MGD (113,562 m³/day), and a range of 25-54 MGD (94,635-to-204,412 m³/day). Reduction in CO_2 delivery rate vs. diffusers was 21% to 57%, av. 40%, for projected annual savings in 2013 CO_2 cost and 2013 dollars of $48,800 @ target pH 9.8, and $124,000 @ target pH 8.5.

Table 1

2013 Pilot CO_2 Dissolution: Diffusers vs. Proprietary Innovation

Reduction in CO_2 Delivery Rates:
21% to 57%; av. 40%

(for projected annual savings, in 2013 CO_2 cost and 2013 dollars, of $48,800 @ target pH 9.8, and $124,000 @ target pH 8.5)

Control of existing diffusers had been achieved by manual adjustment of the CO_2 pound per hour (pph) delivery rate, requiring plant operators to constantly monitor pH in the recarbonation basins and adjust diffuser delivery rates accordingly. With pilot installed, operators could now know if the pH was right, on the spot, and maintain a set point. Benefit continues with permanent unit.

Water quality management at a 120 MGD (454,250 m³/day) lime softening plant in Minneapolis, MN reports 12 years of continuing, and enhanced, major benefits from the successful full-scale use of a special method for delivering pH-reducing carbon dioxide (CO_2) to a recarbonation chamber.

The use of the patented method was originally reported in 2014* as a one-month successful pilot project in 2013, when plant management was seeking an alternative to less effective and more costly CO_2 addition using diffusers. The full-scale installation was promptly installed, and the results and service availability have continued through changes in the vendor's ownership and their service model.**

"The pilot did exactly what we were hoping it was going to do," stated George Kraynick, in a recent interview. He is the manager of water quality and laboratory services in the Minneapolis Public Works Department's Water Treatment and Distribution group.

"The installation of the permanent unit, now on three skids instead of one, has been working amazingly well. It's continued to be a set-it-and-forget it kind of operation for us," Kraynick continued.

"We wanted to get more consistent pH readings in the recarbonation chamber, which we could rely on for process control, while giving us a more efficient method for re-carbonating. It's continued to do that, while also allowing us to use process water as the carrier stream for the CO_2 solution, so that we did not need to use finished house water, which continues to be in short supply here."

Kraynick said the month-long pilot operation of the proprietary system, which continues to be patented, manufactured, and represented by BlueInGreen® LLC, showed the capability for reducing CO_2 costs by 40%, while ending the problem of having inconsistent pH readings, ranging from 9 to 10.5, in the piloted recarbonation chamber.

He added that the 3 ft. x 5 ft. x 9 ft. pilot skid had been readily installed by plant plumbers and electricians, and that "when they came to take the pilot away, the operators were very unhappy, because it had made their lives so much easier. The higher ups readily approved the permanent version."

"The permanent, three skid installation, two in service and one standby," Kraynick noted, "is each about the same size as the pilot version, and the

CO_2 had previously been added through round-plate diffusers to form bubbles that were hopefully small, but sometimes reached golf ball size. The piloted alternative method, and its permanent replacement, combines a side stream of water with carbon dioxide gas, in a pressurized saturation tank containing a gas head space,that is designed to create conditions ideal for dissolving carbon dioxide.

installation took about a day, including the vendor's service team coming out and readily educating us on it."

"They've been promptly responsive for any issues since then, but there haven't been many. The last time was in early 2022, when they tweaked the PID loop so it would jibe with a plant software update."

"Meanwhile, the cost savings benefit has been considerably enhanced since 2013, with carbon dioxide now costing about four times as much."

Plant Operation

The use of diffusers for CO_2 addition dates to the origin of the plant in 1940, when it was built to soften water in order to minimize scaling for the utility's industrial customers, while minimizing washing soap requirements for residential users.

Raw water from the Mississippi River is pumped to a venturi room in the lime slaking (softening) plant, where alum is added at 15-25 mg/L for coagulation. The pretreated raw water moves to mixing chambers for addition of recycled lime sludge and lime, and then enters a main flume for addition of powder activated carbon (PAC) before proceeding to precipitators.

After appropriate detention time in the precipitators, the stream enters two 1 million gal. (3,785 m^3) recarbonation chambers for CO_2 addition, as well as potassium permanganate ($KMnO_4$) for taste and odor when needed. Recarbonated water leaving one chamber proceeds to conventional filtration, while the treated stream from the other proceeds to an ultrafiltration (UF) membrane plant.

The lime softening and recarbonation processes are utilized both for hardness control and total organic carbon (TOC) removal.

CO_2 Addition

CO_2 was previously added through round-plate diffusers to form bubbles that were hopefully small, but sometimes reached golf ball size. Design feed rate is 1,800 lbs/hr/chamber, and averages 1,300-1,500 lbs/hr total, 24/7.

"Round-plate diffusers worked, but not very efficiently," Kraynick said. "CO_2 cost us $64/ton in 2013, which was inexpensive as chemicals go, but we needed to optimize treatment wherever we could to reduce costs, so we needed to upgrade there."

The need for CO_2 addition derives from the lime addition, which raises pH from the river from 8 to 8.5 up to 10.8-11.2 exiting the precipitators.

"At that pH level the calcium carbonate would plate out everywhere in the plant," Kraynick noted, "so we needed it lower. We knew the CO_2 addition through diffusers is inefficient, but we also knew that while we were getting fairly consistent pH readings of 10 +/- 0.4 at various locations in one recarbonation chamber, in the other chamber readings were very inconsistent, ranging from 9 to 10.5. And we only adjusted pH at one point in our process."

"To both improve efficiency and provide more consistent pH readings, we could have sought better diffusers, but instead sought to take advantage of new technology we knew was out there, and which we had used on our wastewater side, where CO_2 gas is forced into solution, so that a super-saturated CO_2 solution got injected bubble-free."

"We chose to pilot the system from BlueInGreen, in our chamber where the pH readings were too inconsistent," he continued. "The system we piloted was oversized. It could feed about 3,000 lbs/hr. We could have pushed all our water through the piloted chamber if we needed to."

The existing CO_2 feed line for the diffusers was tapped to supply the gas to the pilot. Recarbonated water from the other chamber was used as feedwater for the pilot, instead of using already-burdened finished (house) water for that purpose. Tapping the house water instead would not only have limited the supply, but also required the installation of a new main, adding to the capital cost.

Initially, CO_2 was injected near the diffusers, but pH readings were still too variable using that location.

"BlueInGreen found that injecting before water entered the recarbonation chamber solved that problem, in effect bypassing limitations deriving from its 1940 design," Kraynick recalled.

"After that, we had stable pH readings regardless of where we took them."

Readings are taken "every couple of hours," depending on slaker operation. The pilot system's operation was connected to the plant's SCADA system. Any pH swings caused by slaker feed issues could be addressed right away by the pilot's control system, through autocorrection of CO_2 or feedwater rates.

Control of the existing diffusers was achieved by manual adjustment of the CO_2 pound per hour (pph) delivery rate, requiring plant operators to constantly monitor pH in the recarbonation basins and adjust diffuser delivery rates accordingly.

"With the pilot installed, we could now know if the pH was right, on the spot, and maintain a set point," Kraynick concluded. "That has continued with the permanent installation."

Special CO_2 Addition Method and Results

The proprietary CDOX® CO_2 dissolution and injection system is manufactured by BlueInGreen LLC of Fayetteville, AR. During the testing, it delivered a typical CO_2 dose of 15 mg/L, while treating an average flow of 30 MGD (113,562 m^3/day), and a range of 25-54 MGD (94,635-to-204,412 m^3/day).

Carbon dioxide gas forms carbonic acid when it is dissolved in water, in the first two of four steps that occur in carbonic acid equilibrium. The formation of bicarbonate and carbonate follow.

The special system combines a side stream of water with carbon dioxide gas, in a pressurized saturation tank containing a gas head space that is designed to create conditions ideal for dissolving carbon dioxide.

As the water is introduced through the head space, carbon dioxide dissolves into the carrier water stream, creating a water solution that is saturated with carbon dioxide. Because of the high rate at which the system can dissolve carbon dioxide into water, only a small carrier side stream is needed.

During the test period, the existing diffusers were monitored to determine a baseline of performance, and they showed highly varied fluctuations in pH. Data showed the automatic response of the CDOX® system to changes in recarbonation basin flow rate and influent pH.

The pH values resulting from the patented system's operation, for days where there were multiple changes in flow rate in the test basin, showed effective control of pH at three different basin flow rates. Separate jar testing was effective in establishing that in all cases tested, over 85% of pH change occurred within 5 minutes of CO_2 injection.

With the previous diffuser system, the plant operator had to frequently check and manually adjust the diffuser output. In contrast, the special test system maintained the pH with no input or attention required.

After the test system was decommissioned, pump disassembly showed no accumulation of scaling on the impeller during the pump's one month service with process water.

In addition, CO_2 delivery rates required with the test system were compared to those required with the existing diffusers. Data used in the comparison had the same basin flow rate, influent pH, and basin pH.

The average reduction in CO_2 delivery rates required with the CDOX® ranged from 21% to 57% and showed an average of 40 percent. Consequent yearly savings, in 2013 CO_2 prices and 2013 dollars, were projected to be $48,800 for a target pH of 9.8, and $124,000 for a target pH of 8.5.

*In 2014, the successful pilot project, conducted in 2013, was reported in in the January/February 2014 Government Engineering Journal; the December 2014 Water/Wastewater Processing supplement to Processing magazine; and the January 20-14 Carbon Dioxide Injection newsletter.

**BlueInGreen LLC was purchased by Chart Industries (NYSE: GTLS) in 2020, with BlueInGreen being one of four ChartWater™ companies. In a statement describing its treatment-as-a-service (TaaS) model, the Company noted that the proven innovation in combination with a monthly equipment and services model provides a "low-risk/high-reward" means of solution adoption that is ideally suited to the risk-averse cultures of regulated water treatment, and other environmental, health, and safety compliance functions."

"Equipment and Operational Engineering service contracts help customers implement a fast-follower approach to adopting proven innovations. Operational staff value remote access of equipment and guidance from engineers and operators experienced with the technology and processes to effectively and efficiently transfer the insights and know-how from (hundreds of) previous installations and applications to the adopter's operations."

"To facilitate the adoption of technology, we developed a Treatment-as-a-Service (TaaS) business model to complement capital sales: a monthly equipment and services contract where we supply the technology and operational expertise to the customer."

The CDOX® technology can be applied either in-basin or in-pipe, and can be customized to minimize total cost of installation. The proprietary process, which includes a fully integrated control scheme, is designed to provide excellent mass transfer capabilities, and near 100% utilization of vaporized gas. For further information, contact BlueInGreen LLC, 1201 W Sunchase Ct. Fayetteville, AR 72701, 479-527-6378, www.chart-water.com.

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