A NEW SPIN ON LIQUID CHLORINATION

Michael Braden$^1$ and James W. Weishuhn$^2$

Abstract

Liquid chlorination has historically utilized excess energy of an effluent pump to power a venturi to introduce sodium hypochlorite into a treated wastewater stream. A new innovation utilizes a peristaltic pump, directly driven by a paddle wheel that gains energy from the effluent flow into an effluent pump tank and provides for a more precise flow paced dose of disinfectant resulting in more consistent chlorine residuals.

The innovation utilizes a paddle wheel similar in nature to those utilized by water powered mills of by gone eras and a modern day peristaltic pump, without the electric motor. Water discharging over the paddlewheel rotates a shaft, directly driving the peristaltic pump resulting in a proportional flow of sodium hypochlorite to the wastewater flow, and provides for an application proportional to time. No wastewater flow results in no sodium hypochlorite flow and increased wastewater flows results in increased sodium hypochlorite flow, accomplished without electricity or instrumentation. Current liquid chlorination devices dose when the effluent pump is energized which yields inconsistent chlorine contact times.

Analytical monitoring has demonstrated chlorine residuals consistently at about two milligrams per liter, utilizing 8.25 percent sodium hypochlorite as the disinfectant on the effluent of an aerobic treatment unit operating at about 300 gallons per day.

Introduction

The objective of this paper is to document and present the effectiveness of an innovative disinfection device that utilizes sodium hypochlorite as a disinfectant chemical, but requires no other inputs other than the flow requiring treatment.

This innovative device offers a new spin on chlorination. Historically, the small flow business has relied on tablet chlorinators or venturi based devices that rely on the energy from an effluent pump to disinfect wastewater streams. The tablet chlorinator relies on the wastewater stream for the mass transfer of chlorine fixed in a tablet to the wastewater stream. The venturi based chlorinators utilize sodium hypochlorite, but must have the energy of a pump to induce the sodium hypochlorite flow.

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The Revolution Liquid Bleach Chlorinator (REVLBC) device, patent pending, utilizes the potential and kinetic energy of a wastewater stream to rotate a paddle wheel that directly drives a very small peristaltic pump. The peristaltic pump doses the sodium hypochlorite into the wastewater stream. Accordingly, the dosing is precisely flow paced which typically is not done in the small flow applications. Flow paced dosing provides for a more accurate disinfection process that applies the chemical as the flow occurs, resulting in a more effective disinfection process because of consistent contact times.

Sodium hypochlorite is commonly known as bleach, is available at grocery stores, it is an effective disinfectant and is inexpensive. Sodium hypochlorite disinfection is characterized as follows:

\[
\text{NaOCl} + \text{H}_2\text{O} \rightarrow \text{HOCI} + \text{NaOH}^-
\]

The HOCl (hypochlorous acid) further disassociates as follows:

\[
\text{HOCl} \rightarrow \text{H}^+ + \text{OCl}^-
\]

The free available chlorine is the quantity of HOCl and OCl\(^-\) (hypochlorite). HOCl is 40 to 80 times more efficient than OCl\(^-\). The distribution of hypochlorite increases, as hypochlorous acid decreases, as pH increases in the solution.

The unit operation does not attempt to manipulate the speciation of hypochlorous acid or hypochlorite in the solution to improve disinfection. It provides a flow paced application of sodium hypochlorite to disinfect wastewater streams.

**Materials and Methods**

The device is a six blade paddle wheel fabricated from high density polyethylene. A metal shaft is friction fitted transversely through the paddle wheel and connected to a peristaltic pump. The water wheel’s shaft rotates the peristaltic pump rotor. Rotation of the pumps rotor creates negative pressure in the pump tube inducing flow of the disinfectant from a reservoir into the pump tube and then discharge into the wastewater tank. A process flow diagram for the unit as tested is provided as Figure 1.
The chlorinator was installed on the influent pipe of a pump tank receiving flow from an aerobic treatment unit. Current industry standards utilize effluent pumps and chlorine applied by venturis. Accordingly, application of the device does not represent a change from current standards and current pumps and equipment are suitable for use with the device.

The aerobic treatment unit was rated for 600 gallons per day. The source of the wastewater was a four bedroom home with a living area of about 3,000 square feet. The home was occupied by six residents and the daily flows ranged from zero to approximately 300 gallons per day.

A dose of 9.5 drops of 8.25% sodium hypochlorite per gallon of wastewater was estimated to provide a resulting total chlorine concentration between 1 to 4 mg/L in the treated wastewater stream. There are 20 drops in a milliliter, or 0.05 milliliters per drop. The dose in milliliters of sodium hypochlorite per gallon applied to the wastewater stream is calculated as follows:

\[
\text{Dose (ml per gallon)} = 9.5 \text{ drops per gallon} \times 0.05 \text{ milliliters per drop} = 0.475 \text{ ml of sodium hypochlorite per gallon of wastewater.}
\]

A dose of 11 mg of chlorine per liter of wastewater is estimated by interpolating from Solvay Chemicals International’s *Diluted Sodium Hypochlorite Correlation Between Various Concentration Units* table. Typically a dose of 8 mg / L of Cl₂ is a recommended dose for activated sludge treatment plants.

The REVLBC paddle wheel diameter, shaft diameter and the peristaltic pump capacity are sized to provide a proportional dose of 9.5 drops per gallon of water crossing the paddle wheel.

The National Pollution Discharge Elimination System (NPDES) program requires a 20 minute chlorine contact time on most systems discharging to surface water as a benchmark for assessing...
chlorine contact times. Historically, a chlorine contact time is not required for small flow systems. In this pilot test, the pump tank receiving the disinfected wastewater stream was a 500 gallon tank with level controls installed for three doses of a hundred gallons with the first dose occurring at midnight. Assuming that the last flow of wastewater into the system occurs at 11:00 p.m., the minimum chlorine contact time is about 60 minutes, which exceeds the NPDES requirement for surface water discharges.

The unit was tested for a period of one month under the aforementioned real-time operating scenario. Samples were collected for analysis weekly by the analytical laboratory on the Tuesday of each week.

**Results**

Wastewater samples were field analyzed for select parameters and submitted to an analytical laboratory, to assess the chlorinator’s effectiveness. The samples were collected weekly during a one month period. Field analysis was performed by the laboratory’s technician and the samples were transported directly to the laboratory by the technician. Laboratory analysis focused on chlorine residual, however typical wastewater parameters including the following were analyzed to characterize the wastewater and the treated wastewater stream:

- Five day Biochemical Oxygen Demand (BOD₅);
- Total Suspended Solids (TSS);
- Ammonia as Nitrogen;
- Chlorine Residual; and
- E. Coli.

Samples were collected from the aerobic treatment unit’s clarifier effluent (prior to chlorination) and chlorinated effluent (following chlorination) as shown on Figure 1. The clarifier effluent was the treated wastewater discharge from the aerobic treatment system and the chlorinated effluent was collected from the pump tank following addition of sodium hypochlorite with the unit. Analytical results are provided in the following tables.

**Table 1. Treated Wastewater Prior to Disinfection (Clarifier Effluent)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Average</th>
<th>Median</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>mg/L</td>
<td>12*</td>
<td>9</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>23</td>
<td>12</td>
<td>3</td>
<td>62</td>
</tr>
<tr>
<td>NH₃N</td>
<td>mg/L</td>
<td>3.1</td>
<td>2.3</td>
<td>1.18</td>
<td>6.68</td>
</tr>
</tbody>
</table>

*Average of 4 samples.
Table 2.  REVLBC Disinfected Wastewater Results (Pump Tank)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Average</th>
<th>Median</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>mg/L</td>
<td>10*</td>
<td>8</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>21</td>
<td>11</td>
<td>7</td>
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<tr>
<td>NH₃N</td>
<td>mg/L</td>
<td>2.73</td>
<td>2.16</td>
<td>1.09</td>
<td>5.53</td>
</tr>
<tr>
<td>Cl₂</td>
<td>mg/L</td>
<td>3.1</td>
<td>3.2</td>
<td>2.3</td>
<td>3.7</td>
</tr>
<tr>
<td>E. Coli</td>
<td>MPN/100 mL</td>
<td>2.4**</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>5.2</td>
</tr>
</tbody>
</table>

*Average of 4 samples.  
**Average of 3 samples

Discussion

Preliminary testing of the unit has demonstrated consistent chlorine residuals ranging from two to four milligrams per liter of chlorine residual in a real time treated wastewater setting. NSF testing of the device is being completed and appears to demonstrate acceptable disinfection in terms of colony forming units remaining in the treated wastewater stream. The innovative approach provides for flow paced sodium hypochlorite disinfection without the need for flow meters, programmable logic controllers, or pumps. The simple concept of a paddle wheel utilizing the potential and kinetic energy of the treated wastewater stream, directly driving a peristaltic pump to convey sodium hypochlorite from a reservoir to a pump tank provides the equipment for this disinfection alternative.

The 8.25% sodium hypochlorite demand is about one gallon per month for a residence generating 240 to 300 gallons of wastewater for a disinfectant cost ranging from about $3 to $4 per month or about $50 per year. The cost utilizing chlorine tablets is about $350 per year. The mass of chlorine applied using the Revolution Liquid Bleach Chlorinator is about one-half of the mass applied to the environment using chlorine tablets. The Revolution Liquid Bleach Chlorinator appears to offer an effective chlorination system with a low operating cost and is more environmentally conscious than other alternatives. The capital cost of the unit is estimated to be less than $100.

Literature Cited

