Shifting the Energy Balance – Driving toward Energy Neutral WWTPs

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INTRODUCTION

Over the last decade, the wastewater treatment industry has rapidly advanced in the development of technologies to enhance conventional primary treatment. The term carbon diversion has been adopted by the industry and researchers.

Carbon diversion technologies have the ability to capture more organics from the inlet wastewater stream, resulting in more raw biochemical oxygen demand (BOD) load diverted to the biosolids line in lieu of aerobic oxidation. This shifts the typical energy balance in a wastewater treatment plant by:

1. reducing the aeration energy demand in the activated sludge process
2. diverting more organics to anaerobic digestion to capitalize on renewable energy opportunities by generating more biogas.

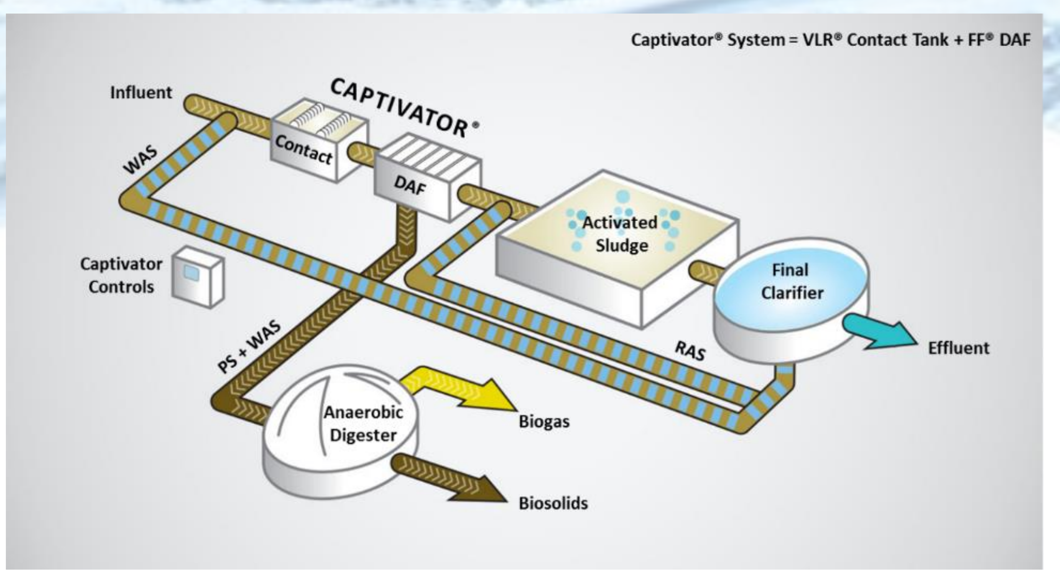

Figure 1. Captivator® System Schematic

Evoqua's Captivator® System (Figure 1) works under the principles of biosorption and carbon diversion. WAS from the downstream secondary process is blended with raw wastewater in a mildly aerated contact tank which activates rapid biosorption of soluble organics (Ding et al., 2015). Colloidal BOD is also adsorbed onto flocs in this tank from which flows pass to a high-rate dissolved air floatation (DAF) process which separates the solids from the liquid stream while also functioning as a thickener.

Floated solids with high BOD concentration are sent to digestion without further thickening. The effluent stream from the DAF unit is directed to the activated sludge process which now operates with a significantly reduced organic load, reduced aeration demand and potentially smaller volumes.

Captivator is unique in that it incorporates well established equipment in an innovative configuration to achieve carbon diversion with a reliable, simple and sustainable approach.

CAPTIVATOR: A COMBINATION OF PROVEN PROCESSES

A Vertical Loop Reactor (VLR®) performs as the Aeration Contact Tank (Figure 2). Biosorption takes place here where biomass in the WAS stream is contacted with incoming raw water, absorbing the majority of soluble, colloidal and particulate organic matter.

- Disc aerators provide mixing and oxygen transfer which helps biomass absorb soluble BOD.
- Hydraulic residence time in the VLR tank is typically 30-40 minutes.

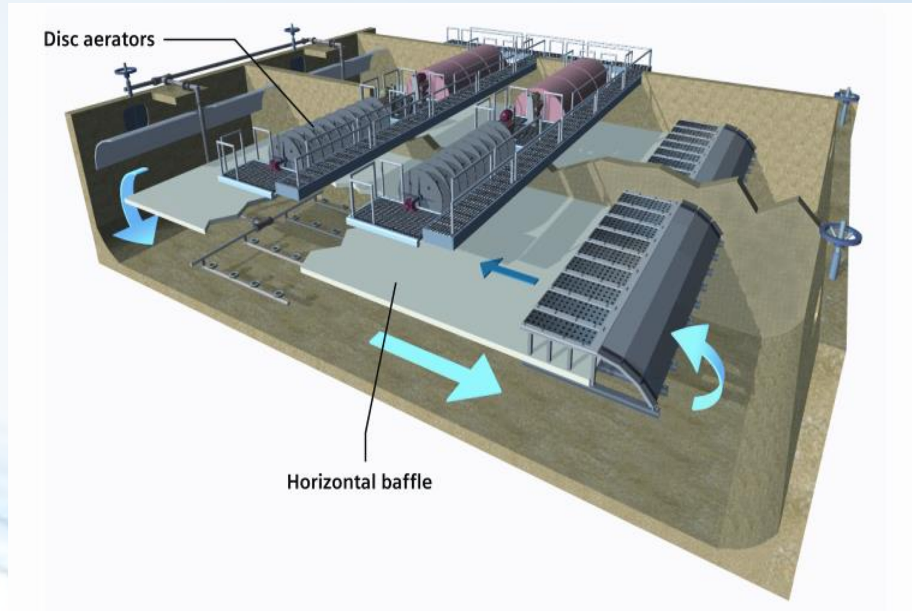

Figure 2. Vertical Loop Reactor (VLR®)

A Folded Flow® DAF (Figure 3) efficiently removes and thickens the majority of the biomass and incoming suspended solids.

- Conventional sedimentation processes are limited to rise rates of approximately 1.2 m/h. In contrast, the floating rise rate of the DAF is as high as 12 m/h.
- The result is the DAF footprint is typically less than 20% of an A-stage clarifier with an HRT of several minutes rather than hours.
- No chemical required to achieve high dry solids concentration in the float (4-6%)
- Can achieve 85% suspended solids removal
- Low energy – 1.2 kW/ML

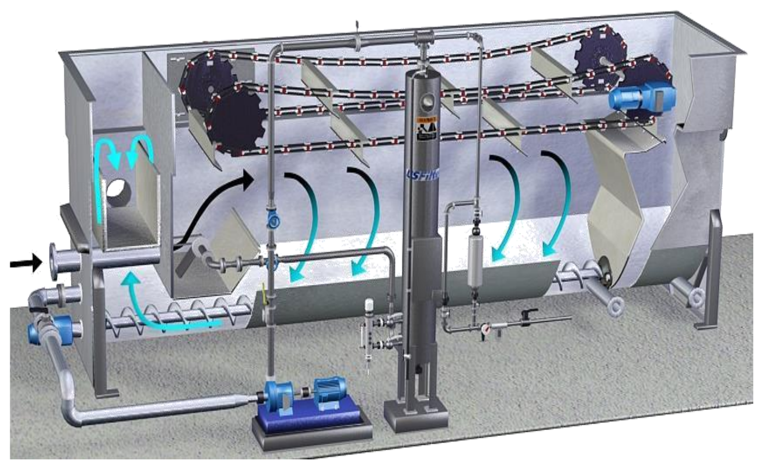

Figure 3. Folded Flow® DAF

Integrated controls enable the system to perform as one process, allowing for automatic adjustment to diurnal flow and load patterns while maximising transfer of BOD load to the digester.

CASE STUDY – ULU PANDAN, SINGAPORE

- A 200 m3/d pilot test conducted at PUB's Ulu Pandan Water Reclamation Plant in 2012-2013.
- The pilot could be configured as a conventional system with primary clarifier, or with Captivator as a BEPT unit operation.
- A baseline conventional activated sludge (CAS) system and Captivator process were evaluated using the same aeration tanks but different primary unit processes. Figure 4 shows the process PFD for both configurations.

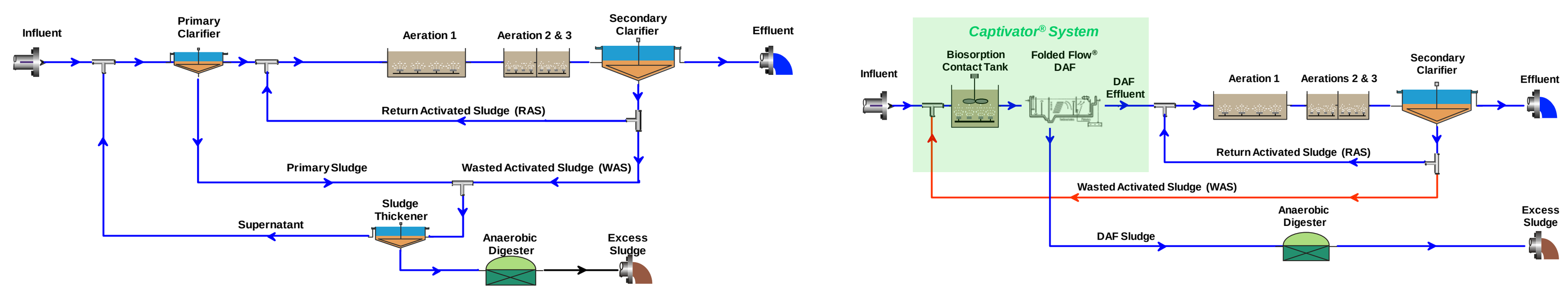

Figure 4. Process Flow Schemes for baseline CAS and Captivator

- The CAS process was examined first to establish baseline data for comparison purposes. Overall performance was evaluated on liquid treatment efficiency, biogas production and final excess sludge generation.
- The average biogas production for the CAS system was 8.3 m^3/d compared to 15 m^3/d for the Captivator system. This shows the effect of capturing raw wastewater organics that would normally escape primary clarification and diverting to the anaerobic digester. Figure 5 shows comparative biogas production data collected during the trial.
- Captivator captured over 70% of the primary wastewater volatile suspended solids (VSS) compared to 43% for the CAS process
- Digester VS destruction was 55% in the Captivator System compared to 42% for the CAS process.

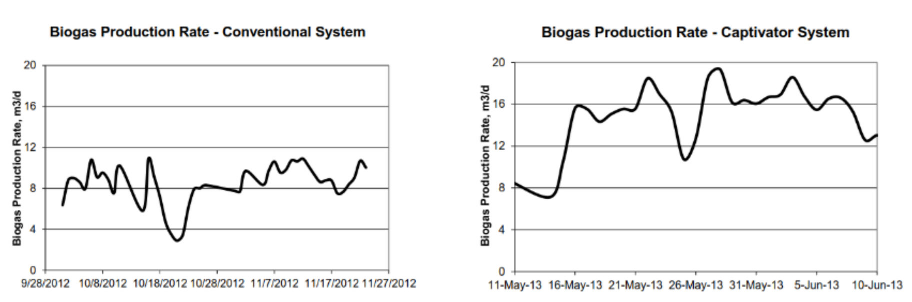

Figure 5. Comparative Biogas Production – CAS and Captivator

- Daily results were collected and used to perform a COD balance for both the CAS and Captivator processes as shown in Figure 6 and summarised in Figure 7.

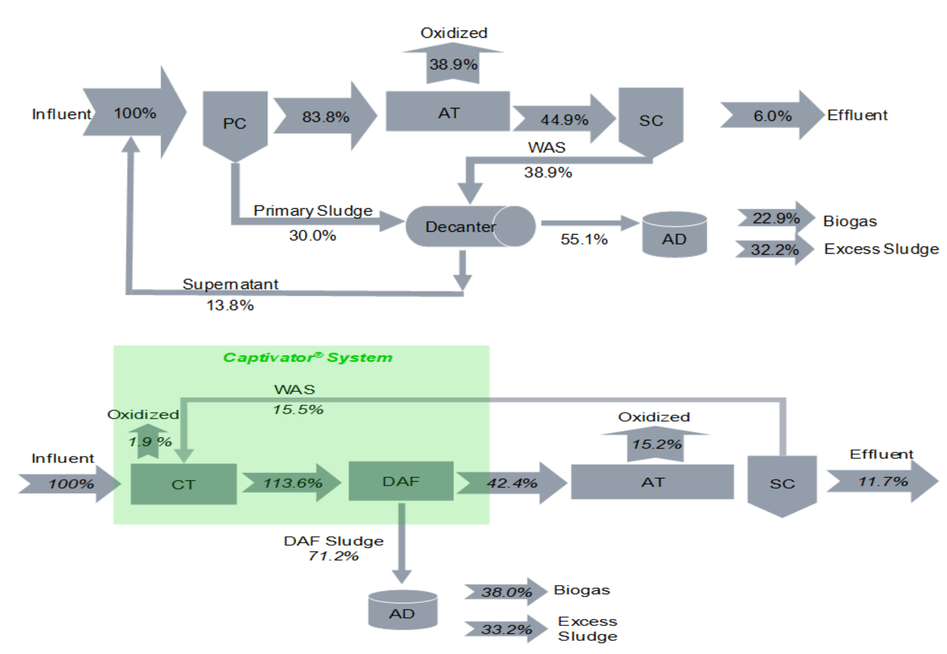

Figure 6. COD Balance for CAS and Captivator Processes

Summary COD balance of CAS Process vs. Captivator System

	CAS	Captivator System
Final Effluent	6%	12%
Oxidized	39%	17%
Biogas	23%	38%
Excess Sludge	32%	33%

Figure 7. COD Balance Summary

CASE STUDY – AGUA NUEVA WATER RECLAMATION FACILITY

The first full-scale plant using the Captivator System came online in January 2014 at the 121,000 m³/d Agua Nueva Water Reclamation Facility in Pima County, Arizona. The Agua Nueva plant (shown in Figure 8) uses six Folded Flow DAF tanks, each 18 m x 6 m with a design overflow rate of 7.5 m/h.

Figure 8. Agua Nueva Water Reclamation Facility, Pima County, Arizona

The Captivator biologically enhanced primary treatment (BEPT) process was selected based on a net present value analysis of primary treatment vs. no primary treatment, and comparison to conventional primary clarification, chemically enhanced primary clarification, and micro-screening. The footprint reduction of the BEPT process compared to primary clarifiers is approximately 65% as well.

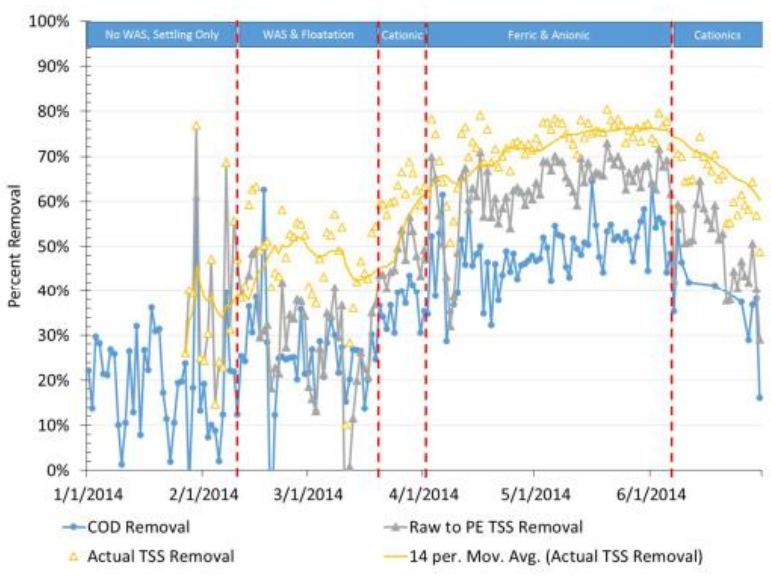

Figure 9. Folded Flow DAF Operating Data, Agua Nueva WRF

- The BEPT process has typically achieved 25-30% soluble BOD removal and 65% TSS removal.
- Under full load operating conditions this system has achieved 75% TSS removal and up to 35% sCOD removal with little drop off noticed during peak stormflow events .

Figure 9 shows FF DAF operating data from the early phase of operation.

Additional information on the design and operation of the Agua Nueva WRF is provided in Johnson et al., 2014.

Toward Net-Zero Energy Use

The Captivator System, offers a biologically enhanced primary treatment system in which a higher proportion of carbon can be diverted through anaerobic digestion than can be achieved with conventional or alternate enhanced primary treatment options. This diversion is capable of increasing biogas production by more than 40% while simultaneously reducing the amount of carbon oxidized in the mainstream CAS process by 40%. This combination offers a fundamental shift in the energy balance of a typical wastewater plant and offers a clear route for utility owners to move toward an energy neutral wastewater treatment system.

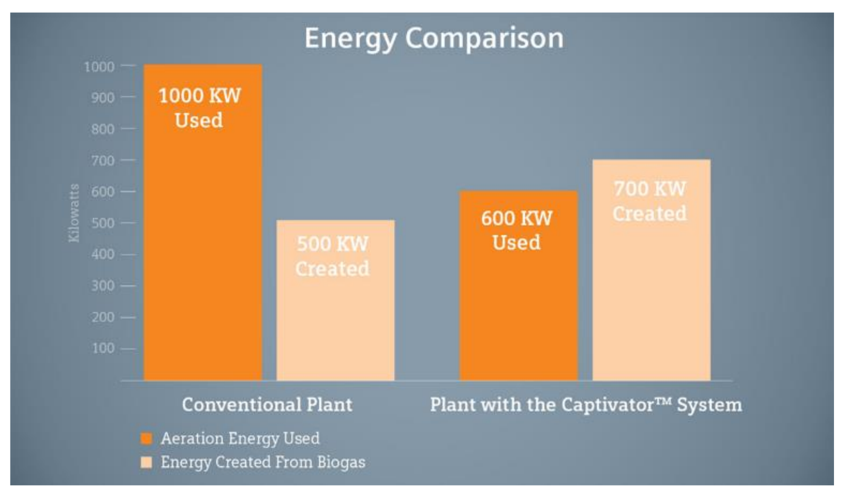

Figure 10. Energy Comparison.
Where a 110 ML/d CAS plant might use 1000 kW of electricity in aeration and only produce 500 kW from biogas, a plant with a Captivator System would only need 600 kW for aeration and could generate 700 kW from biogas.

References: [1]Ding H-H., Doyle M., Erdogan A., Wikramanayake R., Gallagher P (2015). "Innovative Use of Dissolved Air Floatation with Biosorption as Primary Treatment to Approach Energy Neutrality in WWTPs". *Water Practice and Technology,* **10** (1) 133 [2] Johnson B., Phillips J., Bauer T., Smith G., Smith G., Sherlock., (2014). "Startup and Performance of the World's first Large Scale Primary Dissolved Air Floatation Clarifier". *Proceedings of the Water Environment Federation,* **6** 712-721 [3] Waul C., Doyle M., Smith G., Pino-Jelcic S., Erdogan A. (2016). "Shifting the Energy Balance with Biologically Enhanced Primary Treatment – How Carbon Diversion Makes Sense". *Proceedings of the Water Environment Federation Residuals and Biosolids* (**16**) 945-960

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