Pairing of Anaerobic and Aerobic Treatment of Petroleum Wastewater

UtahState University SYNTHETIC BIOMANUFACTURING INSTITUTE

SWBEC

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UWRL

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Objectives

Develop a novel treatment strategy for petroleum wastewater that meets the following State of Utah effluent guidelines:

- 25 mg/L BOD (38 mg/L COD)
- 25 mg/L TSS

Secondary objectives would include, but are not limited to:

- Reduction of nitrogen to at or below 10 mg/L
- Reduction of phosphorus to at or below 1 mg/L
- Production of value-added products

Background and Methods

Wastewater derived from petroleum refining accounts for 33.6 million barrels per day globally. Currently, few wastewater treatment strategies exist to produce value-added products from petroleum refining wastewater, while successfully reducing nutrients, total suspended solids (TSS), and biological oxygen demand (BOD).

Figure 1. RABRs after 5 days of treating petroleum refining wastewater.

The theory behind RABR wastewater treatment is that a 40% submerged rotating drum with appropriate substratum, allows phototrophic microalgal biofilms to be exposed to two growth stimulating environments: 1) nutrients in the wastewater and 2) light and carbon dioxide in the air. As the biofilm grows, macro and micronutrients from the wastewater can be converted to biomass in the biofilm. The biofilm is then easily removed from the system through mechanical scraping, allowing for removal of these nutrients.

The Rotating Algae Biofilm Reactor (RABR) has demonstrated the ability to effectively remove macronutrients and produce various bioproducts including biodiesel, bioplastics, acetone, ethanol, and protein feed for livestock.

Anaerobic digestion has been shown to produce methane rich biogas for energy, heat, and power production. Ideally, these technologies can be used synergistically as seen in Figures 2 and 3.

In this study, triplicate 1L RABR units and suspended growth lagoons were continuously fed with petroleum refinery wastewater at retention times of 24 and 48 hours.

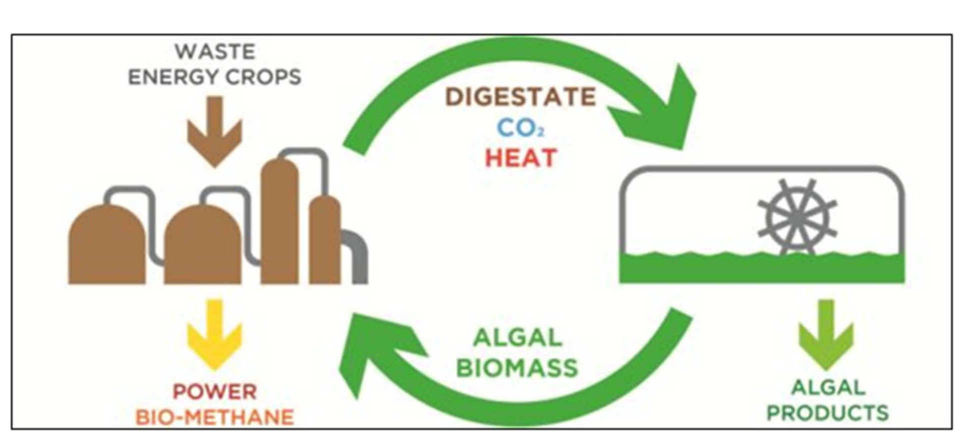

Figure 2. Algae-Based Energy Bioproduction.

RABR and suspended growth lagoon units were operated for 15 weeks and total nitrogen, total phosphorus, total suspended solids (TSS), and chemical oxygen demand of the influent and effluent wastewater were measured weekly.

Biomethane potential assays were operated for 50 days and the anaerobic production of methane was measured through gas chromatography.

Final Design

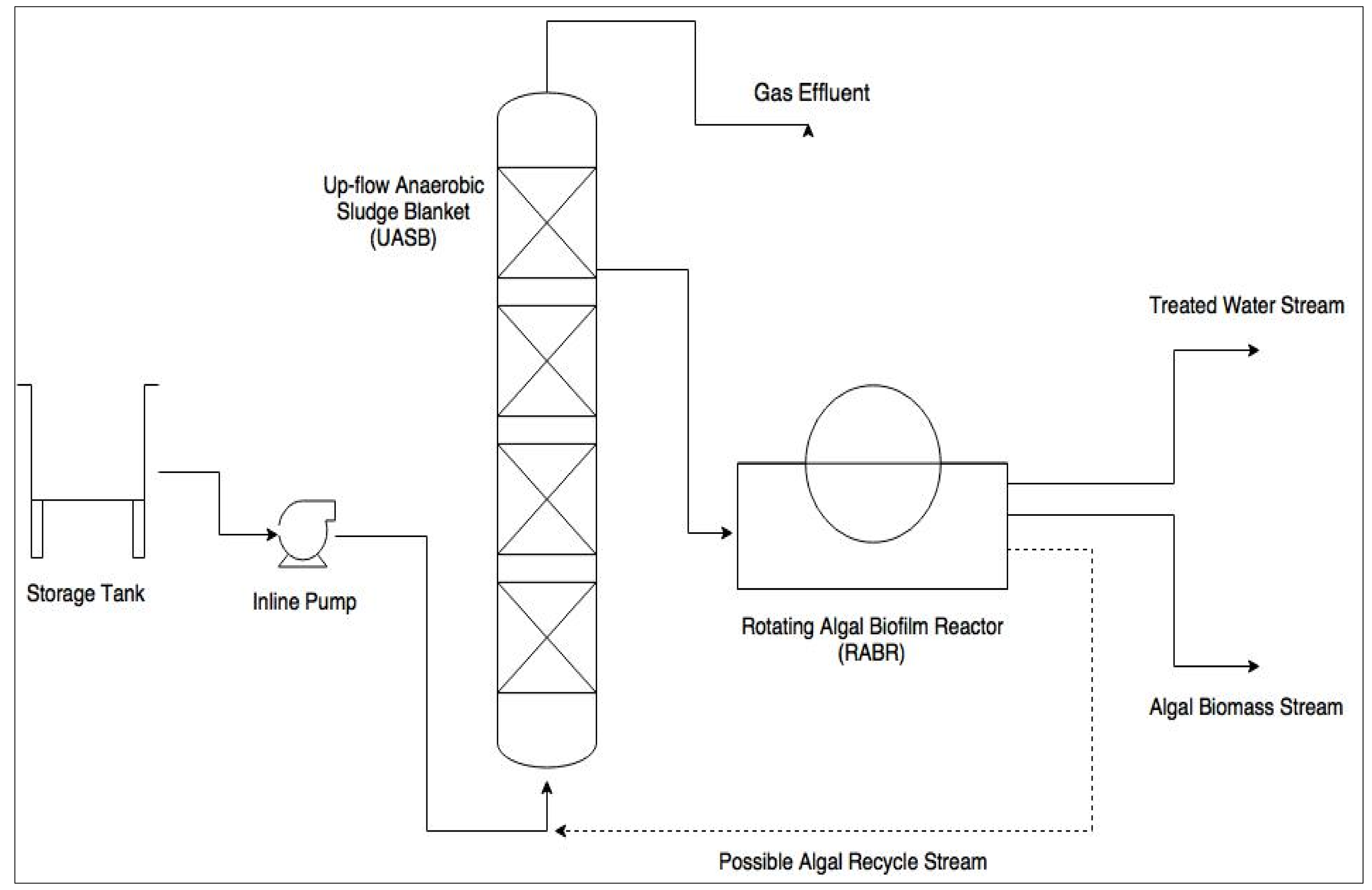

Figure 3. Process of UASB and RABR for remediation of petroleum wastewater.

Aerobic Treatment

Continuous-flow RABR technology demonstrated significant reduction of nitrogen and phosphorus as compared to suspended growth controls (Figure 4A-B).

Average decreases in effluent concentrations are as follows:

- **Nitrogen:** 18.1 mg/L, 17.7 mg/L, and 3.47 mg/L, for 24-hr HRT RABR, 48-hr HRT RABR, and control lagoon
- **Phosphorus:** 0.90 mg/L, 1.04 mg/L, and 0.34 mg/L, for 24-hr HRT RABR, 48-hr HRT RABR, and control lagoon
- **TSS:** 20.9 mg/L and 23.9 mg/L for 24-hr HRT RABR and 48-hr HRT RABR

An increase in suspended solids concentration of 18.3 mg/L was observed in the simulated lagoon treatment group as a result of suspended microalgal growth. There was no significant reduction in COD, as expected.

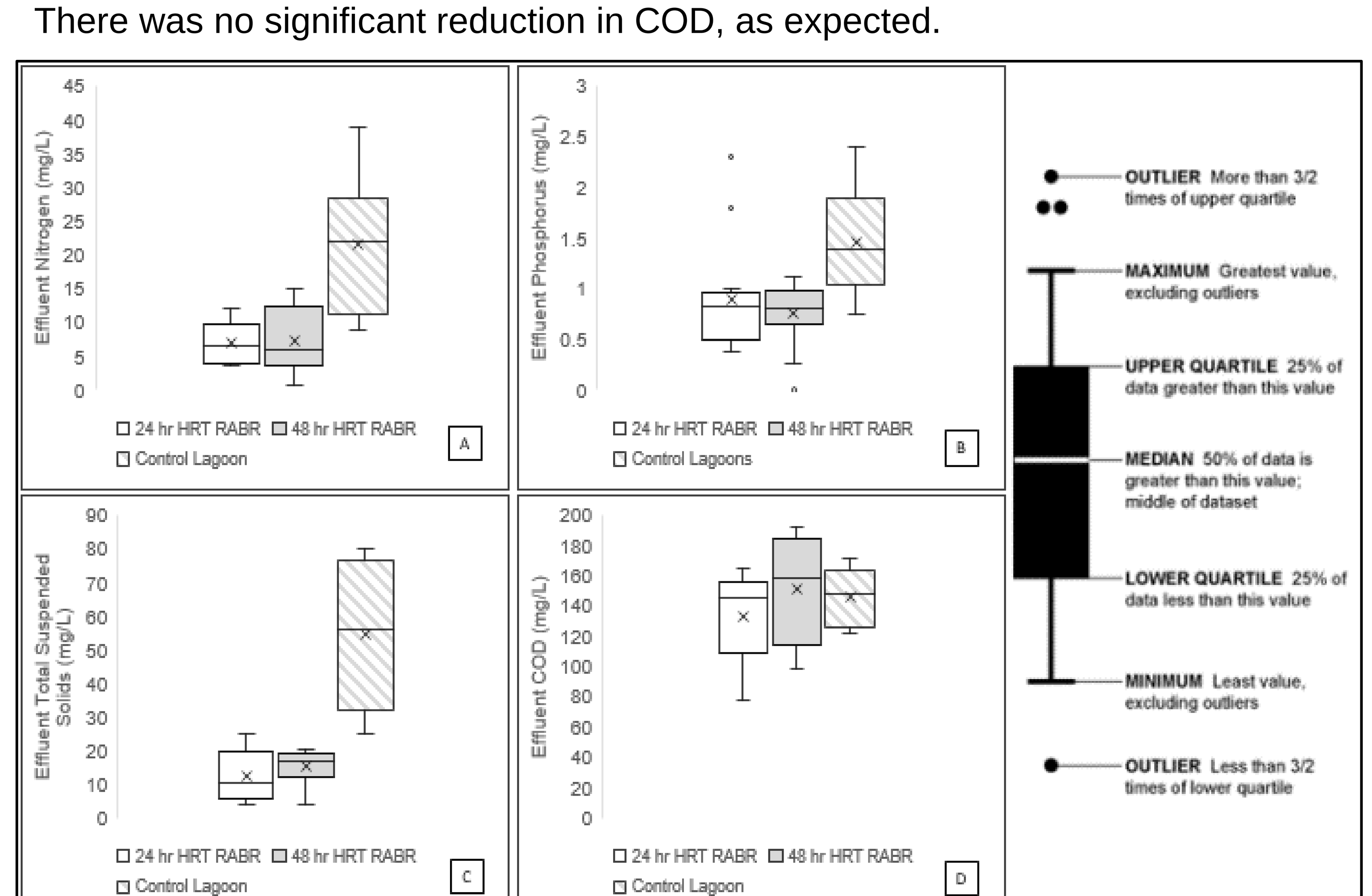

Figure 4(A-D). Effluent wastewater characteristics. Figure 4A Effluent nitrogen concentration. Figure 4B Effluent phosphorus concentration. Figure 4C Effluent total suspended solids concentration. Figure 4D Effluent COD.

Anaerobic Digestion

Anaerobic digestion was evaluated using biogas generation in bio--methane potential (BMP) assays.

Anaerobic digestion of the wastewater demonstrated successful reduction of organic chemicals in the wastewater as measured by the chemical oxygen demand (COD) assay reduction and as measured by biogas production.

Anaerobic digestion demonstrated the following:

- **Decrease in COD by an average of 89 mg/L**
- **Methane (CH_4) production of 727 mL of methane per liter of wastewater**

Results of BMP assays highlight the potential for anaerobic digestion to be used to both reduce COD and produce the valuable byproduct of methane gas (Figure 5, Table 1).

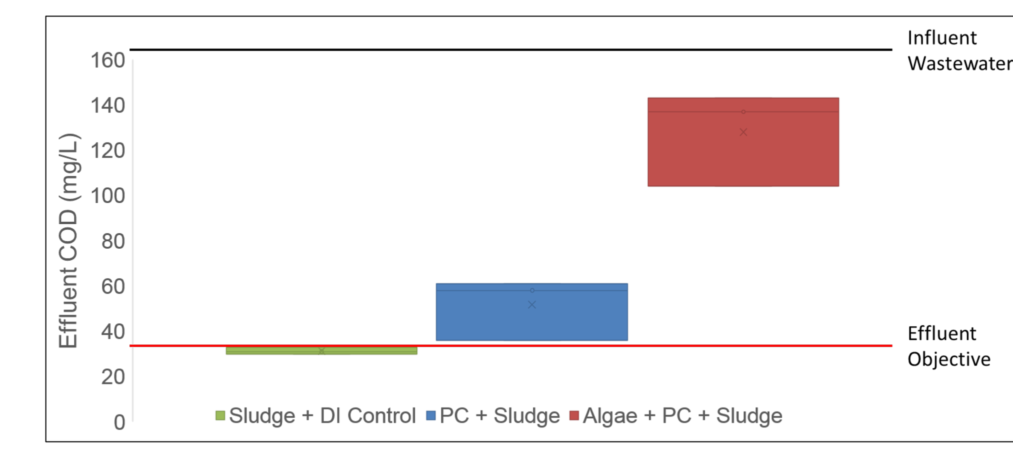

Figure 5. COD remediation through anaerobic digestion.

Table 1. Gas production during Biomethane potential testing.

Sample Set	Initial COD	Final COD	% COD Reduction	Biomethane Produced (mL)	g CH4 / g COD
Algae-Amended Wastewater	193.20	128.00	32.98	218.11	0.34
Wastewater	141.00	51.67	63.36	0.03	0.00

Conclusions

The pairing of aerobic and anaerobic treatment was shown to be a possible strategy for remediation of petroleum wastewater. When compared to a negative control of evaporative lagoons, aerobic RABR treatment not only produced biofilm algae that could be used downstream for value added streams, but was shown to be statistically significant for reduction of soluble nitrogen, soluble phosphorus, and total suspended solids.

Table 2.Objective completion.

Constituent	Objective Effluent	Average Observed Effluent	Method of removal
BOD	25	15.67	BMP/UASB
TSS	25	16.85	RABR
Nitrogen	10	6.7	RABR
Phosphorus	1	0.85	RABR

Pairing the two treatment strategies discussed creates a novel treatment strategy for petroleum wastewater that meets all of the primary and secondary objectives described.

References/Acknowledgements

1. Figure 2: ABG project diagram by AlgEN and KOTO

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