Closing Cycles: An integrated approach to winery wastewater treatment and CO_2 capture using microalgae technology

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INTRODUCTION

- Mediterranean climate zones face increasing **water shortages**.
- The Industrial Ecology concept of **closed loop systems** promotes waste valorization and thereby reduced environmental impact. This concept can be applied to water.
- By requiring large quantities of water and by generating emissions with global warming potential (ex. CO_2) industries contribute to water scarcity, and should be the target of innovative closed loop solutions.
- **Wine production**, a prominent industry in Mediterranean climate zones, is a particularly interesting case. Wineries require up to 14L of water per bottle of wine, and generate one ton of CO_2 for every 10 tons of fermenting mash.

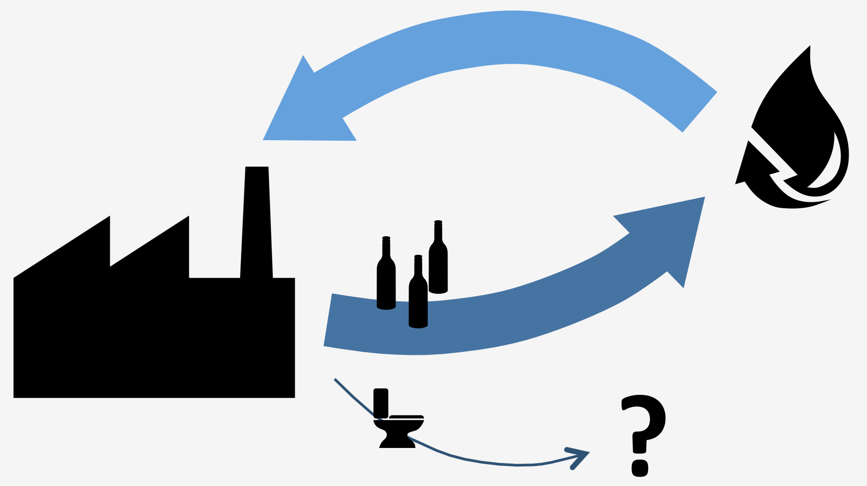


Figure 1: Strides have been made in treatment of winery process wastewater. However the need remains for creative solutions to treatment of winery sewage, which often cannot be directed to municipal treatment facilities due to issues of proximity.

Microalgae provide a promising approach to winery sewage treatment:

1. Efficiently **remove nutrients** in municipal sewage wastewaters.
2. **Growth is promoted by CO_2** supplementation. Sourcing CO_2 from fermentation would **mitigating overall winery CO_2 emissions** and therefore also global warming potential.
3. Microalgae are photosynthetic, grow rapidly, and can be a **source of value added products** such as biogas or nitrogen rich compost.
4. Implementation can be **onsite**, is not energy intensive and is relatively affordable.

METHODOLOGY

The **goal** of this study is to explore the potential of further closing winery water, nutrient, and emission cycles via an **integrated microalgae wastewater treatment and CO_2 capture system**. To this end we explore the growth and nutrient removal efficiency of an algae/bacteria consortium grown in winery sewage wastewater, and evaluate the impact of CO_2 supplementation.

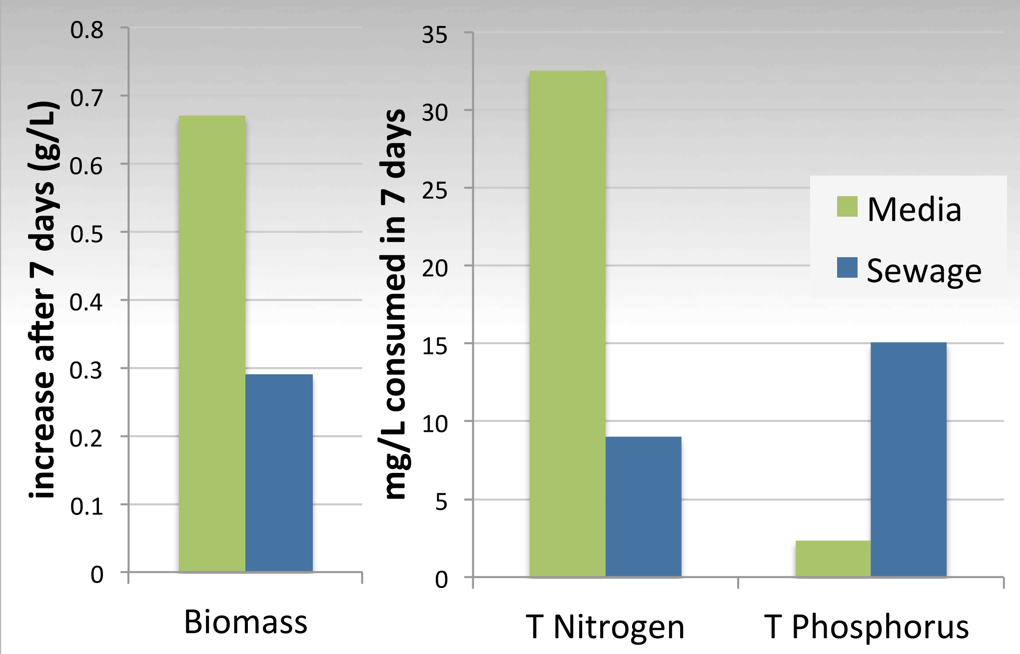
The project's initial experiments—presented here—were conducted at laboratory scale in volumes of 125mL. Cultures were grown for 7 days at controlled temperature (20±1°C), subject to 12-hour light/dark cycles, and agitated manually once daily. Algal growth was determined by dry weight analysis on days 0 and 7; water quality was evaluated on days 0 and 7.

CONCLUSIONS & FUTURE DIRECTIONS

- Preliminary results are promising and suggest that treatment of winery sewage wastewater is likely to be possible using an algal consortium approach.
- Subsequent experiments will be performed to explore the impact of CO_2 supplementation on growth and effluent quality.
- In order to be scalable in the winery context, water quality and consortium composition will need to be evaluated as conditions such as temperature, light and influent vary over the year. Compatibility of fermentation sourced CO_2 will also need to be established.
- Similar algae based approaches could be explored for winery process wastewater at small enterprises

PRILIMINARY RESULTS

Fig. 2: GROWTH AND NUTRIENT CLEARANCE FOR ALGAE GROWN IN SYNTHETIC MEDIA OR SEWAGE



Algae grown in winery sewage produced 0.29g/L biomass in 7 days compared to 0.67g/L in synthetic medium. While total P clearance is higher in the sewage, the reverse is true for N clearance. N remains higher than acceptable in sewage effluent.

Fig. 3: N:P RATIOS VS NUTRIENT CLEARANCE AND GROWTH (7 DAYS)

Nutrient ratios are shown to be important for algal growth. Here we explore the role of sewage water N:P ratio. Ratios 10:1 and 21:1 are two different 100% winery sewage samples. The results suggest that a N:P ratio of 25:1 promotes highest N removal. At higher ratios both N and P consumption is reduced, and at low ratios N becomes limiting. Growth does not appear to be directly related to N:P ratio. In this case adjusting Carbon content may have a greater effect.

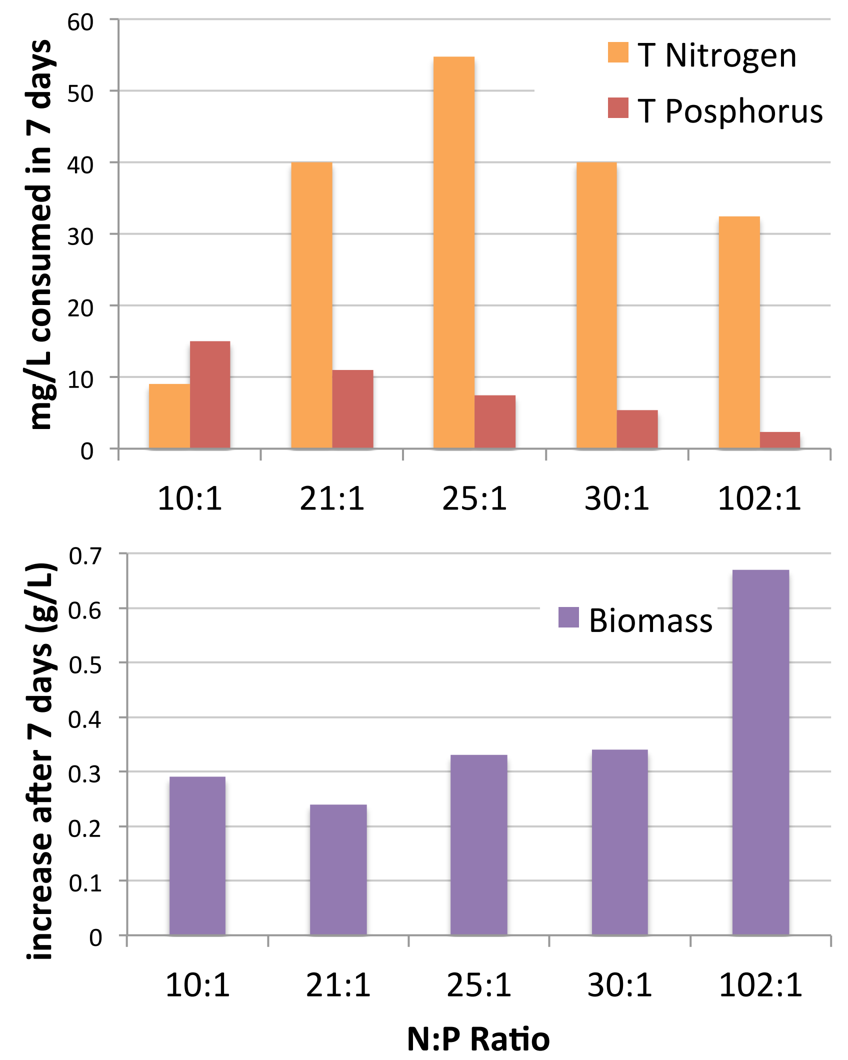
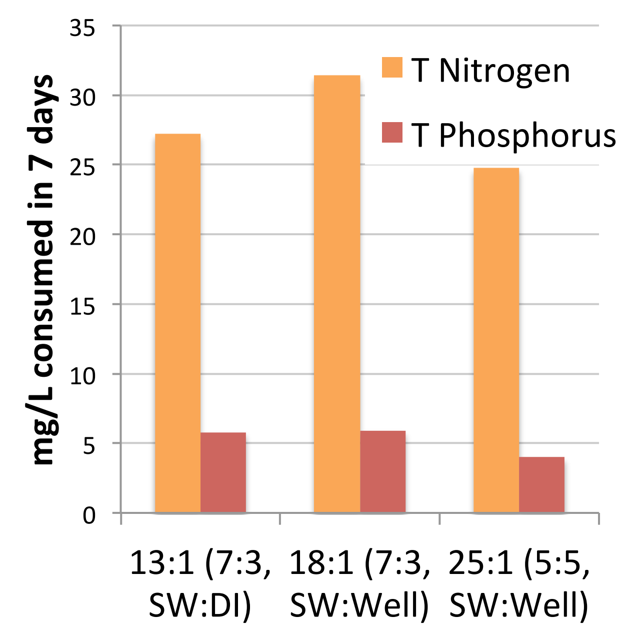


Fig. 4: CONTRIBUTION OF DILUTION FACTOR TO NUTRIENT CLEARANCE



Results shown in fig. 3 do not rule out the contribution of dilution in algae nutrient consumption. Here we recreate the optimal ratio of 25:1 with a new dilution factor, and compare nutrient clearance in samples diluted with well water vs. distilled water. The results show that dilution may play a role as in this case 25:1 no longer outperforms other ratios in N removal.

Fig. 5: WATER ANALYSIS FOR SAMPLE GROWN IN 70/30 SEWAGE/WELL WATER AND N:P RATIO 25:1

	Parameter							
	pH	TSS	COD	TOC	TIC	TC	TN	TP
Unit		mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}	mg L^{-1}
Initial	7.8	60.0	78.5	101.8	19.1	120.9	92.8	8.3
Final	9.0	35.0	74.0	23.9	48.0	71.8	38.0	0.7
Target	6.5-9	≤35	≤125				≤15	≤2

*Initial: influent day 0, Final: effluent day 7

Water quality targets are reached within 7 days with the exception of nitrogen levels. We will address this in subsequent extended time course, and CO_2 supplementation experiments.

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