MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

MAGYARORSZÁG KORMÁNYA

Európai Unió
Európai Strukturális és Beruházási Alapok

BEFEKTETÉS A JÖVŐBE

SZÉCHENYI 2020

Nutrient Removal By Microalgae from Pre-treated Municipal Wastewater

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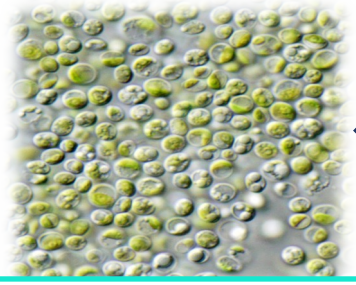
A kutatás a Technológiai és Ipari Minisztérium „A körforgásos gazdaságra történő átállás előkészítési feladatai a mezőgazdasági és zöldhulladékok esetében” című, KEHOP-3.2.1-15-2021-00037 azonosítószámú Környezet és Energiahatékonysági Operatív Program támogatásával valósult meg.

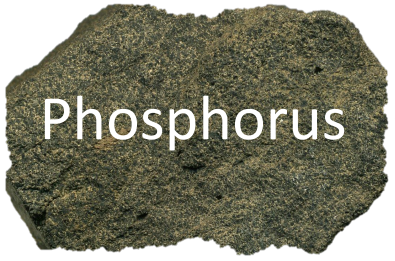
I. Wastewater Treatment Issues & Phosphorus

- Conventional wastewater treatment plants → struggle to remove nutrient after physical treatment → struggling with strict pollutant limitation → methods are efficient but expensive → chemical P removal makes it unavailable for plants uptake.
- Microalgae could be applied on soils (which are deficient in organic matter and nutrients) & also could be used for biofuel ; fix CO_2 ←→ but its production demand a lot of nutrients
- Phosphorus is finite and non-renewable for intensive agriculture → limited phosphate rock reserves → Critical mineral for global food security

Sustainable Phosphorus fertilizer



Phosphorus demand for growth



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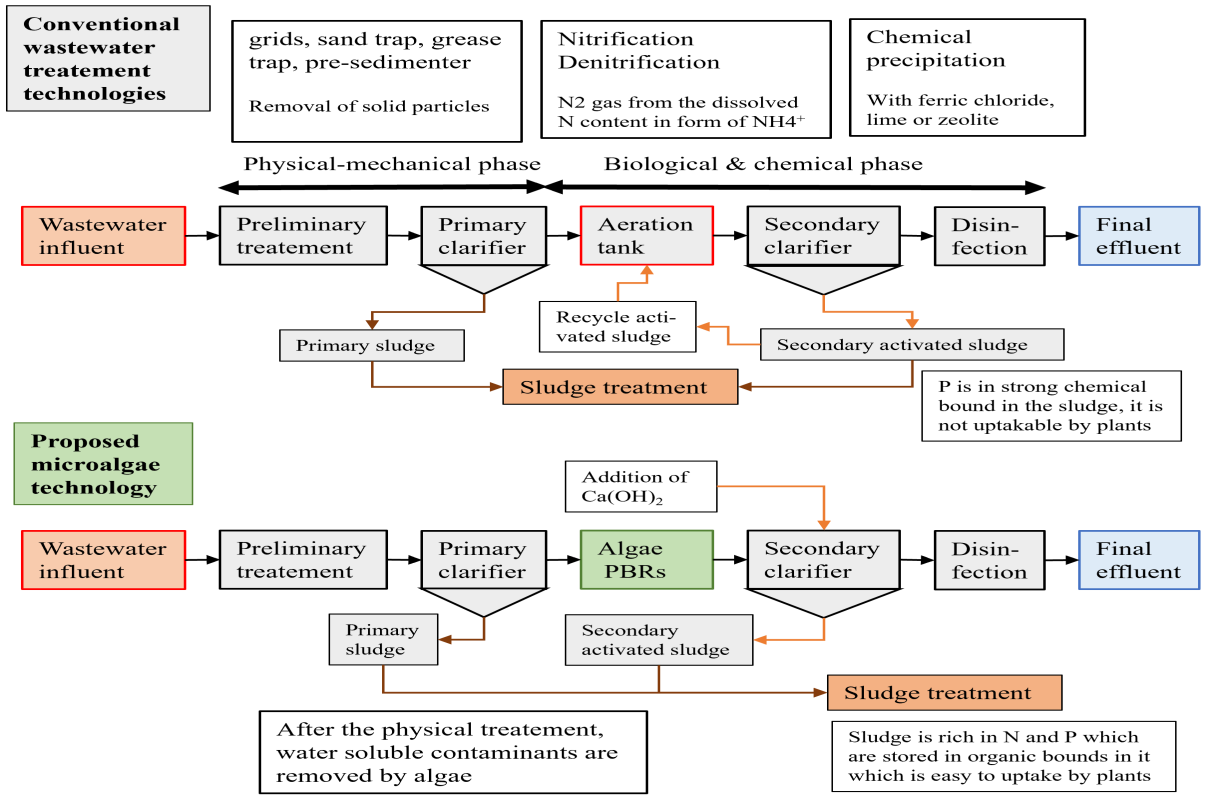
Proposed Solution & Objectives

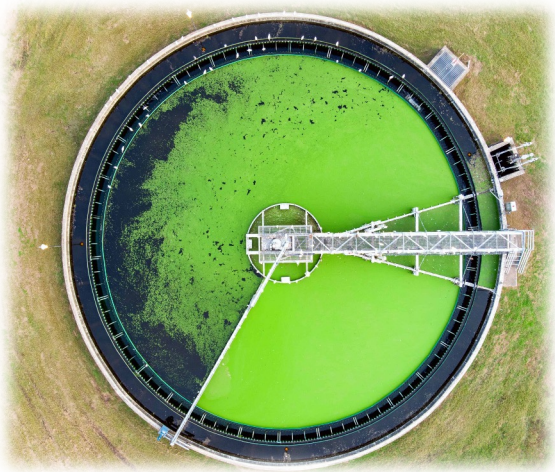
General Objective

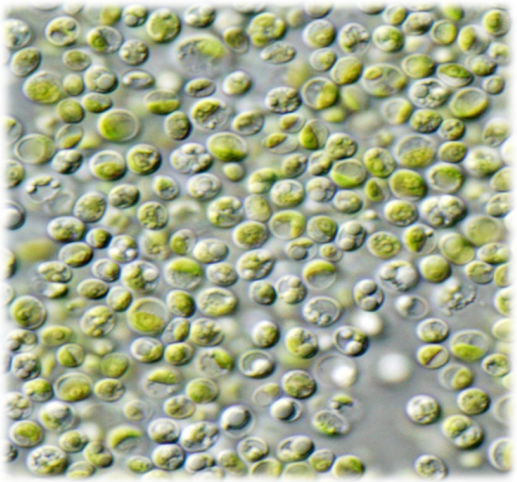
To determine the efficiency of nutrient uptake from municipal wastewater and to evaluate the most efficient harvesting technique of the microalga biomass.



Specific Objectives

- To explore the cultivation of the *Chlorella vulgaris* in municipal wastewater under applied treatment of dilution ratios and investigate the potential value of the biomass obtained.
- Investigate the efficiency of microalgal removal of nitrogen and phosphorus from pre-treated municipal wastewater.
- To assess the most efficient harvesting technique of the microalga suitable for water quality restoration, biofertilizer and biofuel production.





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Experimental Settings

I. Algae culturing in wastewater

- Wastewater sample was collected from the primary settler at Gödöllő treatment plant.
- *Chlorella vulgaris* was cultured in a 500mL Erlenmeyer flask and was tightly corked.
- Respiration tubes provided continuous aeration (CO_2) to the culture.
- Cultures were placed in a phytotron (20-25℃)
- Illumination by 4 Osram biolux lamps; 12h/12h dark/light cycles

Comp (ml)	Control	Algae 1	Algae 2
Wastewater	200	200	200
Algae stock	0	30	100
Distilled Water	100	70	0

Measured Parameters

- Daily: optical density → algal biomass
  (with spectrophotometer at 682nm)
  pH, Electrical conductivity
- Initial, 1 day, 7 day: N, P concentrations – LCK 138, LCK 349 cuvette tests
- Data subjected to ANOVA; Fisher's Protected LSD at significance level of 95%

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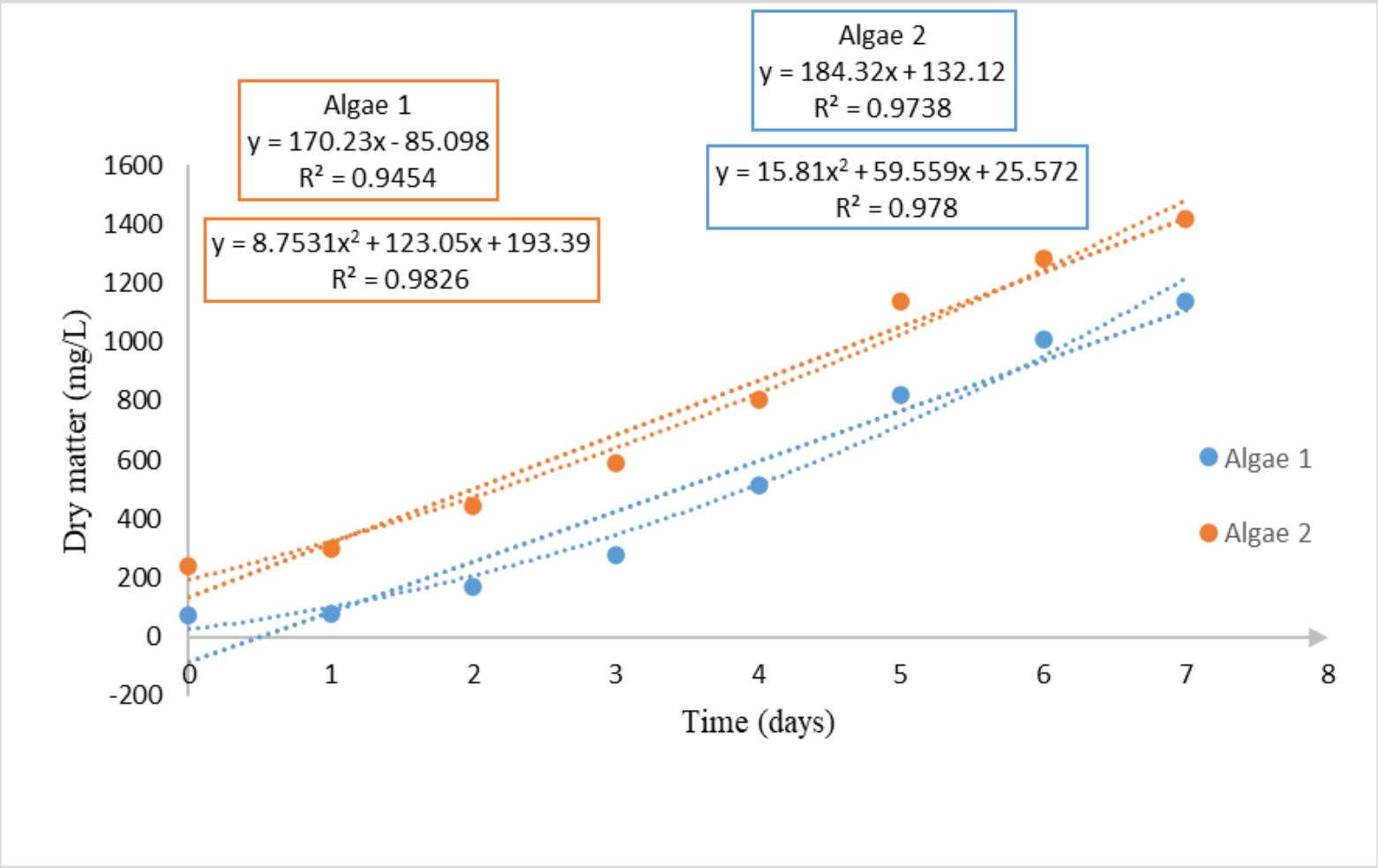
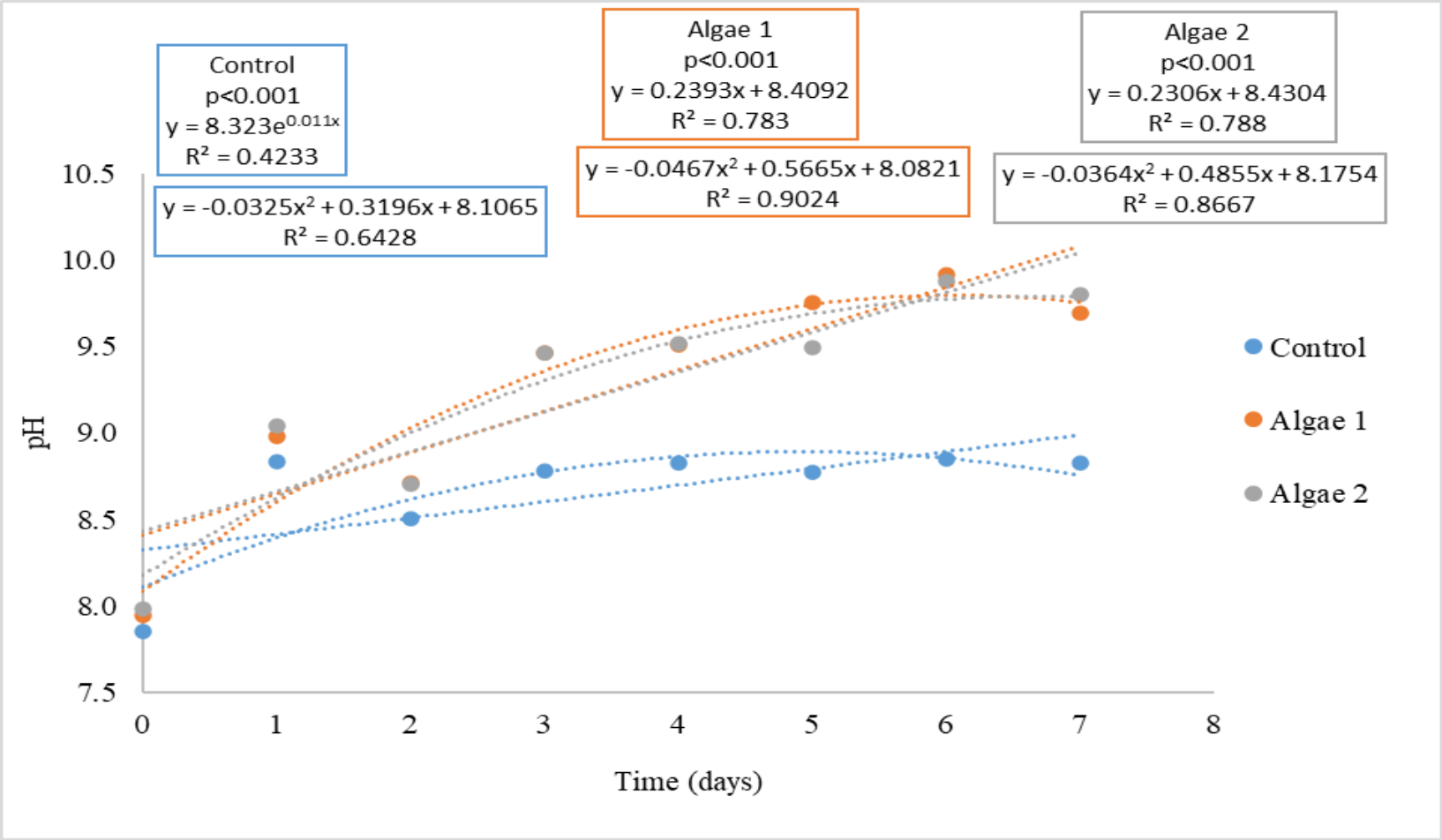
Results I. Biomass Growth of *Chlorella vulgaris*



Algae 1 = 30mL Algae stock
Algae 2 = 100mL Algae stock

- Increase in dry matter of both cultures overtime.
- Algae 2 demonstrated a faster growth rate.
- Higher dry matter weight in Algae 2.
- Stationary phase in Days from Day 6 to 7.

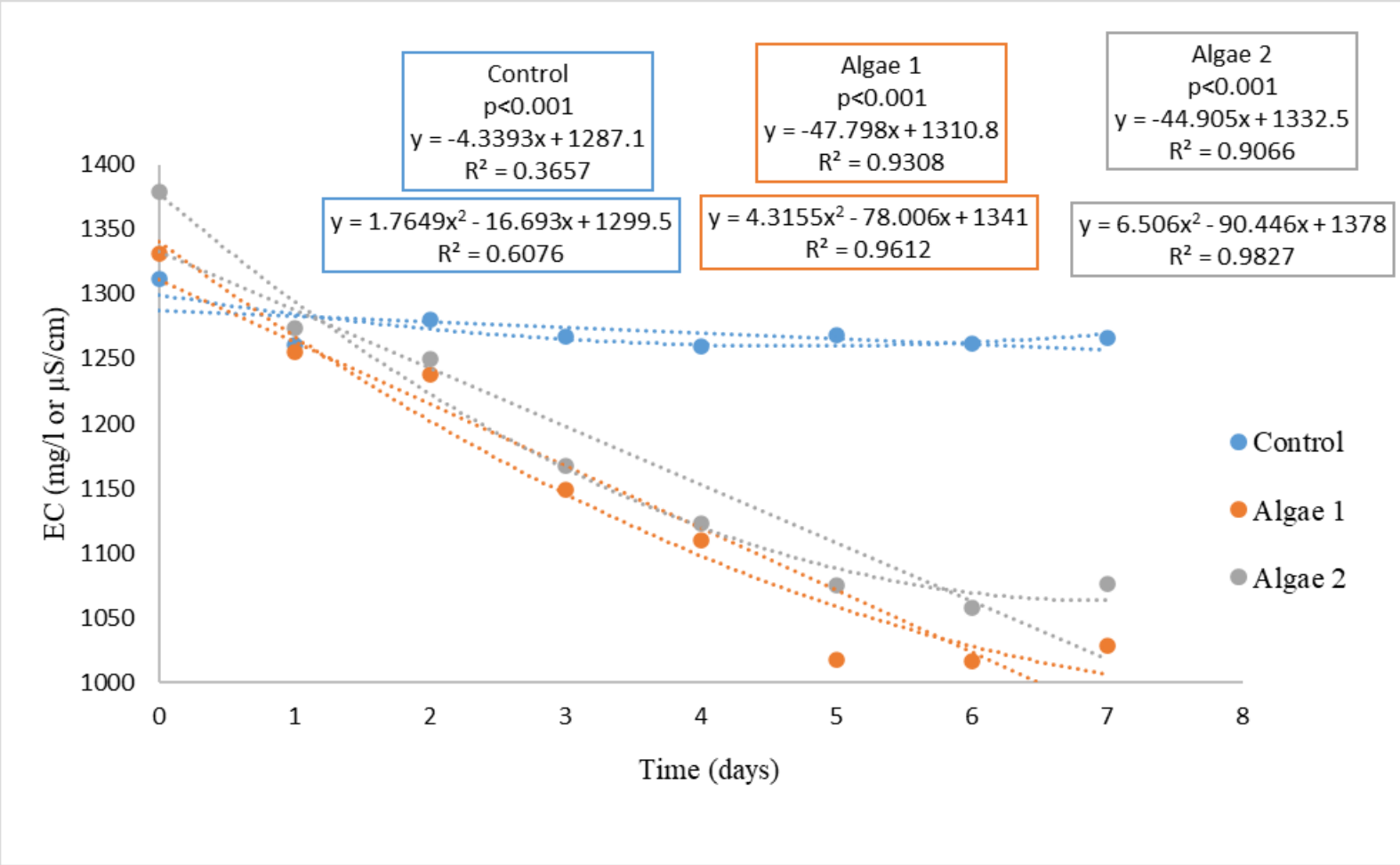
Results II. Changes in pH of the media



Control = No Algae
Algae 1 = 30mL Algae stock
Algae 2 = 100mL Algae stock

- Increase in pH of Algae 1 & 2 overtime.
- Relatively stable pH in Control from Day 3 to 7.
- CO_2 consumption by photosynthetic microalgae

Result III. Changes in Electrical Conductivity of the media



- Decrease in EC of Algae 1 & 2 overtime.
- Relatively stable EC values in Control from Day 3 to 7.
- Utilization of dissolved salts, nutrients and ions by photosynthetic microalgae

Control = No Algae
Algae 1 = 30mL Algae stock
Algae 2 = 100mL Algae stock

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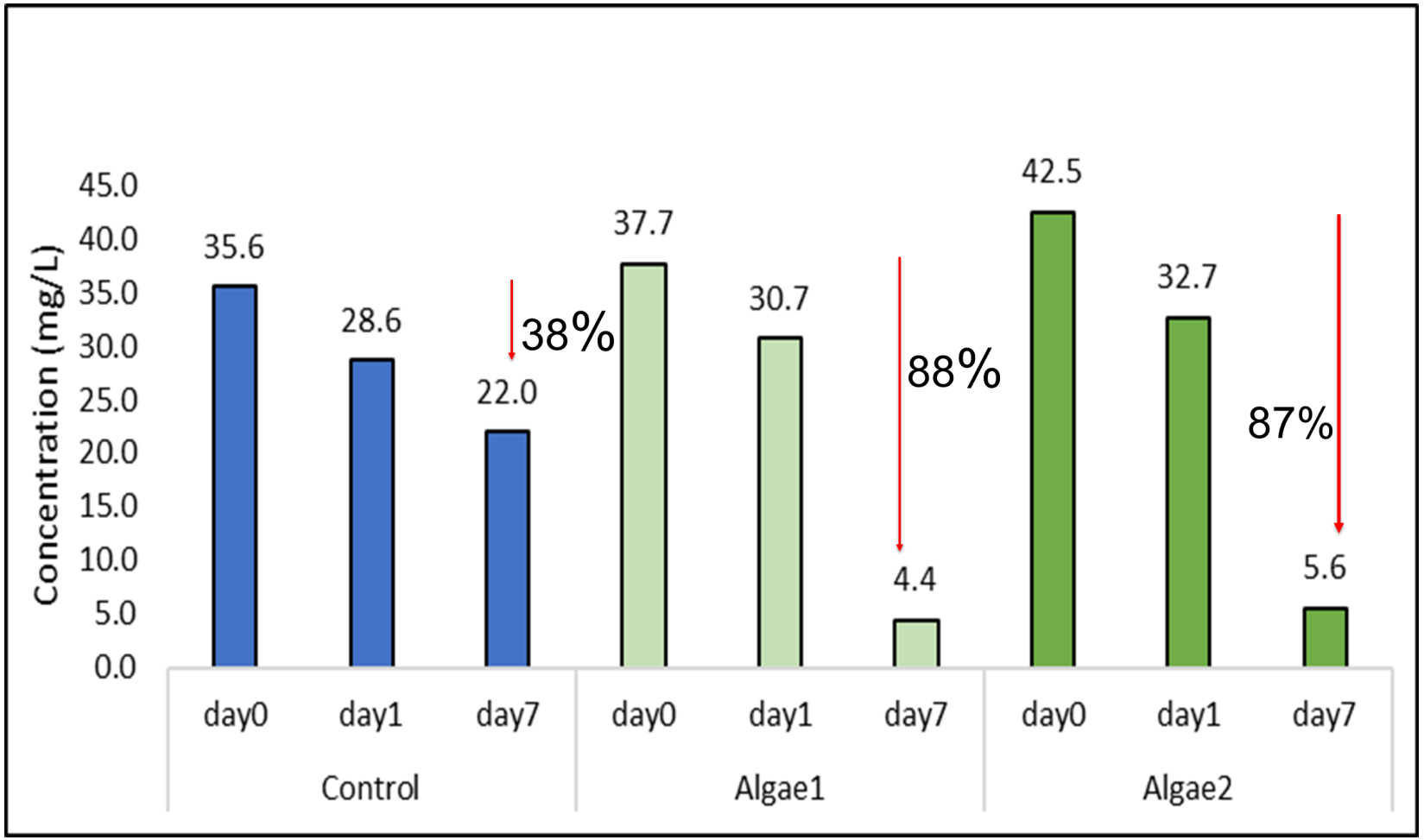
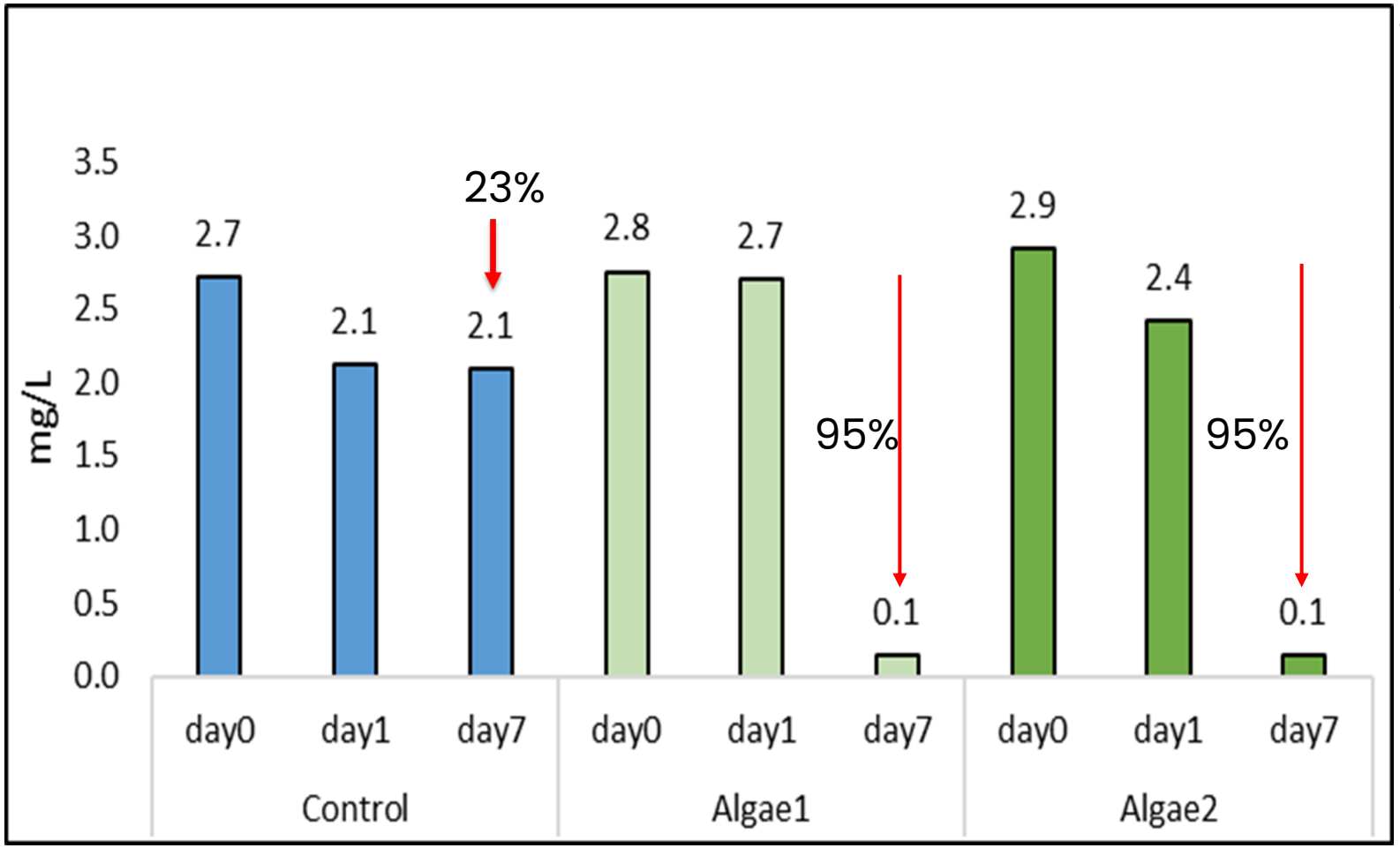
Changes in Total Nitrogen of the media



Control = No Algae
Algae 1 = 30mL Algae stock
Algae 2 = 100mL Algae stock

- After 7 days, significant difference was measured between N removal of control & algae treatment.
- Best removal was the lower initial algae concentration (Algae 1).
- Nitrogen probably was not the limiting element

Changes in Total Phosphorus of the media



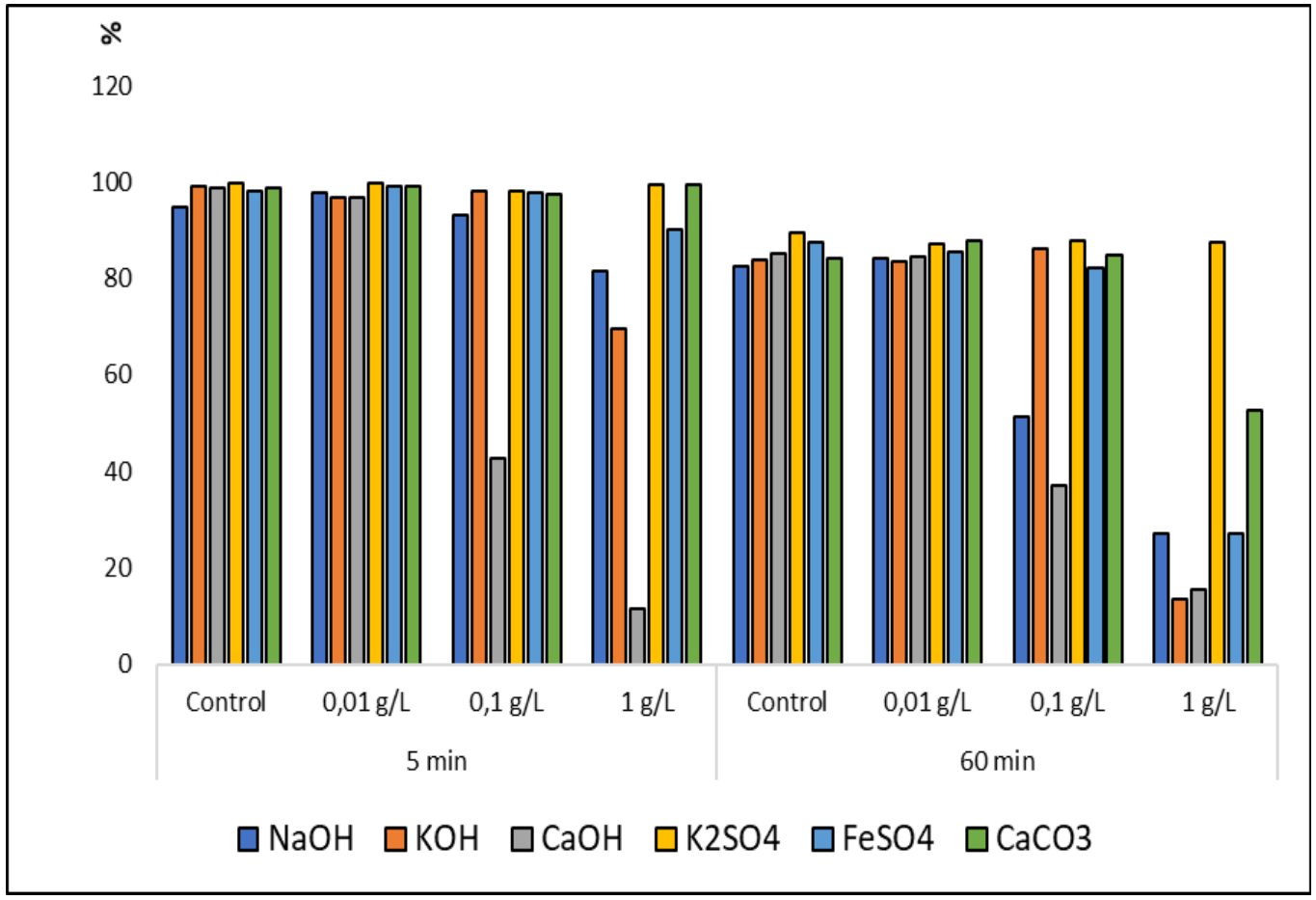
Control = No Algae
Algae 1 = 30mL Algae stock
Algae 2 = 100mL Algae stock

- After 7 days, significant difference between P removal of control & algae treatment
- Both algae treatment observed almost complete P removal (minimal detection = 0.05)
- P was probably the limiting element of algae growth

MICROALGAE HARVESTING BY SEDIMENTATION (Gravity)

- Added chemicals: Control (no chemical addition)
  + 6 flocculants: NaOH, KOH, $Ca(OH)_2$, K_2SO_4, $FeSO_4$ and $CaCO_3$.
- 3 concentrations: 0.001g/L, 0.01g/L and 1.0 g/L
- Mixing: magnetic motion stirrer at 350 rpm for 2minutes
- Measuring time : 0, 5 & 60 minutes of settling
  - Turbidity levels were determined by UV/VIS spectrophotometry (Hach Lange, DR600 at 550nm wavelength according to ISO 7027-1:2016)
  - Images were taken with Fujifilm X30 12 MP Digital Camera
- pH changes were determined

VII. Comparison of Effectiveness & Changes in pH



Comparison of sedimentation effectiveness of all concentrations in 5 & 60 minutes

	Control	0,01 g/L	0,1 g/L	1.0 g/L
NaOH	5,6	8,8	11,3	12,4
KOH	4,4	7,3	9,9	11,9
$Ca(OH)_2$	4,1	7,3	10,7	12,3
K_2SO_4	4,9	5,0	4,9	5,0
$FeSO_4$	5,7	5,1	5,0	4,3
$CaCO_3$	5,9	7,4	8,9	8,7

Changes in pH during sedimentation process

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Conclusion & Recommendation

- Pre-treated municipal wastewater contains sufficient levels of N and P, providing adequate nutrients for microalgae growth and removal of nutrients
- Growth of microalgae increased pH of culture media due to photosynthetic use of CO_2.
- Electrical conductivity values decreased significantly in algae cultures, indicating high nutrient consumption for growth and metabolism.
- *Chlorella vulgaris* displayed high nitrogen removal efficiency of 88% and phosphorus utilization efficiency of 95% after seven days.
- Hydroxide-based flocculants were found to be more effective with $Ca(OH)_2$ appearing to be the most effective flocculant for sedimentation of microalgal cells.
- $Ca(OH)_2$ was able to reduce turbidity in short and long periods, relatively cheap and environmentally friendly in moderate concentrations.

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References

- Al Hattab, M., Ghaly, A., & Hammouda, A. (2015). Microalgae harvesting methods for industrial production of biodiesel: critical review and comparative analysis. J Fundam Renew Energy Appl, 5(2), 1000154.
- Al-Jabri, H., Das, P., Khan, S., Thaher, M., & AbdulQuadir, M. (2020). Treatment of wastewaters by microalgae and the potential applications of the produced biomass—A review. Water, 13(1), 27.
- Choi, H. J., & Lee, S. M. (2012). Effects of microalgae on the removal of nutrients from wastewater: various concentrations of Chlorella vulgaris. Environmental Engineering Research, 17(S1), 3-8.
- Figler, A., B-Béres, V., Dobronoki, D., Márton, K., Nagy, S. A., & Bácsi, I. (2019). Salt tolerance and desalination abilities of nine common green microalgae isolates. Water, 11(12), 2527.
- Kamyab, H., Din, M. F. M., Tin, C. L., Ponraj, M., Soltani, M., Mohamad, S. E., & Roudi, A. M. (2014). Micro-macro algal mixture as a promising agent for treating POME discharge and its potential use as animal feed stock enhancer. Jurnal Teknologi, 68(5).
- Kaosol, Thaniya, and Vicheka Keo. "Effect of Salinity on Chlorella vulgaris for Increasing Lipid Content." Thai Environmental Engineering Journal 34, no. 2 (2020): 11-21.
- Larsdotter, K. (2006). Wastewater treatment with microalgae-a literature review. Vatten, 62(1), 31.
- Li, B., Boiarkina, I., Young, B., Yu, W., & Singhal, N. (2018). Prediction of future phosphate rock: a demand based model. J. Environ. Inform, 31, 41-53.
- Pandey, B. C. & Gupta, S. (2022). Effectiveness of Algae in Wastewater Treatment Systems. Ijraset Journal For Research in Applied Science and Engineering Technology, 10(VIII). https://doi.org/10.22214/ijraset.2022.46241.
- Ruiz, J., Alvarez, P., Arbib, Z., Garrido, C., Barragan, J., & Perales, J. A. (2011). Effect of nitrogen and phosphorus concentration on their removal kinetic in treated urban wastewater by Chlorella vulgaris. International journal of phytoremediation, 13(9), 884-896.
- Wang, C., Li, H., Wang, Q., & Wei, P. (2010). Effect of pH on growth and lipid content of Chlorella vulgaris cultured in biogas slurry. Sheng wu gong cheng xue bao= Chinese journal of biotechnology, 26(8), 1074-1079.
- Wu, Z., Zhu, Y., Huang, W., Zhang, C., Li, T., Zhang, Y., & Li, A. (2012). Evaluation of flocculation induced by pH increase for harvesting microalgae and reuse of flocculated medium. Bioresource technology, 110, 496-502.
- Liu, Y., Zhang, Y., Zhang, X., & Wang, Q. (2020). Microalgal-bacterial interaction and its effect on nutrient removal and microbial community structure in wastewater treatment systems. Microbiology and ecology, 75(1), 156-165.
- Santos, E. B., Nascimento, E. S., & Sawaya, A. C. (2019). Microalgae as tools for wastewater treatment: a review. Frontiers in Energy Research, 7, 83.
- Wang, J., Liu, Q., & Li, X. (2021). Nutrient removal and microalgal community structure in a pilot-scale municipal wastewater treatment system using Chlorella vulgaris. Algal Research, 60, 102261.

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