The experiment performed will be carried out in three stages with the intent of taking dissolved orthophosphate at 20 ppm in CAFO waste water and converting it into a useful fertilizer. The initial solution given by WERC is 20 liters at 20 ppm of orthophosphate. The proposed fertilizer end product is a compound called struvite with the chemical formula $MgNH_4PO_4 * 6H_2O$. The three stages of the process are reverse osmosis which runs in batch to concentrate the 20L solution at 20 ppm to 1L between 200 and 300 ppm. To this solution, ammonium chloride will be added at a molar ratio of 1.5 to 1 of ammonium to orthophosphate and sodium hydroxide will be added to bring the solution to a pH of 8.5. The next stage is electrochemical precipitation using sacrificial magnesium electrodes which act to create an alkaline solution via water electrolysis at the cathode to a pH of 8.5 and 10.5 to drive struvite formation. This will also supply the needed magnesium ions from the anode. The last stage is simply gravity filtration into filter paper.

2, 3) The following chemical reactions and their respective heats of reaction that are expected to take place in the reactor:

Struvite formation: $Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O \rightarrow MgNH_4PO_4 * 6H_2O$

Reaction at the Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

Reactions at the Anode: $2Mg \leftrightarrow 2Mg^+ + 2e^-$

$$2Mg + 2H_2O \rightarrow 2Mg^{2+} + 2OH^- + H_2$$

Overall Electrochemical Reaction: $2Mg + 2H_2O \rightarrow 2OH^- + H_2 + 2Mg^{2+}$

Table 1: Reactions

Reaction	Balanced Equation	ΔH_R (kJ/mol)	Moles in 20L of Solution	Total Enthalpy (kJ)
Crystallization Reaction	$Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O \rightarrow MgNH_4PO_4 * 6H_2O$	98.83 [1]	0.0016	0.158
Overall Electrochemical Reaction	$2Mg + 2H_2O \rightarrow 2OH^- + H_2 + 2Mg^{2+}$	-350.2 [2]	0.0016	-0.560

[1] Bhuiyan MI; Mavinic DS; Beckie RD. A solubility and thermodynamic study of struvite. *Environmental Technology.* [Online] Sept 2007, 9, 1015-26 https://www.ncbi.nlm.nih.gov/pubmed/17910254 (accessed Feb 27, 2019).

[2] *Enthalpy of Formation for Various Compounds*. (n.d.). Retrieved February 25, 2019, from http://nshs-science.net/chemistry/common/pdf/R-standard_enthalpy_of_formation.pdf

3. As seen from the Table in part 2 above, the heats of reaction are so small that there are no thermal dangers associated with this process.

4. Chemicals used and produced:
- Orthophosphate
- Ammonium Chloride - NH_4Cl
- Sodium Hydroxide - NaOH
- Water - H_20
- Struvite - $NH_4MgPO_4*6H_20$
- Magnesium ions - Mg^{2+}

5. Equipment used in process:
- Centrifugal Pump
- Reverse Osmosis Unit
- Holding Tank
- 2 peristaltic pumps
- Electrochemical Plug Flow Reactor
- Vacuum filter with Filter Paper
- Sacrificial magnesium electrodes
- Adjustable Power Source

6. Timeline:
- Set up: 40 minutes
- Reverse Osmosis: 35 minutes
- Reactor: 60 minutes
- Emptying reactor: 15 minutes
- Filtration: 20 minutes
- Process Total: 2 hours 10 minutes
- Clean up: 15 minutes
- Total: 3 hours 5 minutes

Operation of the experiment will be monitored by the team or a member of the team onsite during all facets of the experiment, including; experimental set-up, experimental operation, and experimental clean up. There will be no hazardous disposal techniques utilized following the conclusion of the experiment.