Three-step Ammonia Removal System

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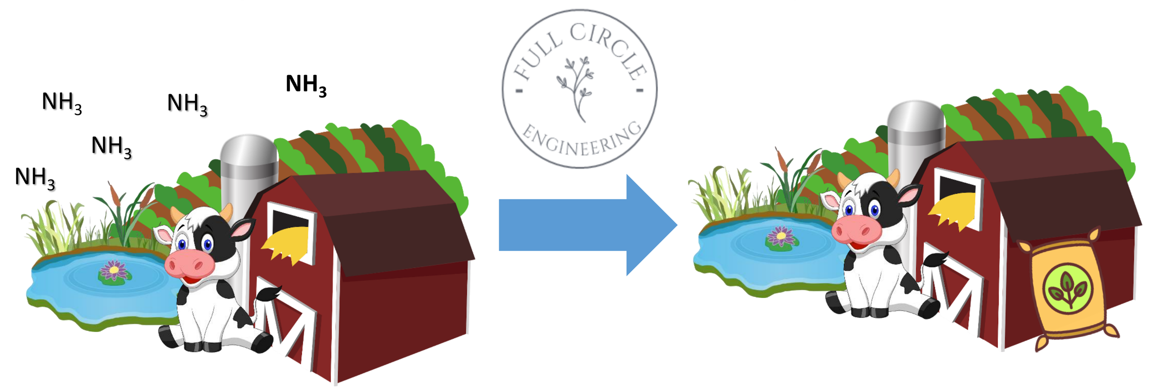
United States Environmental Protection Agency

U.S. EPA P3 PEOPLE PROSPERITY PLANET

FULL CIRCLE ENGINEERING

Project Goal

Full Circle Engineering (FCE) is fully dedicated to using the principles of green engineering to remediate harmful ammonia (NH_3) emissions from the environment using a three-step NH_3 removal system. The system centers around the full circle mentality by using biochar, a sustainable and accessible filtration medium, which can be repurposed as an effective soil amendment upon saturation. Currently, FCE is working to create a full scale model of the three-step NH_3 removal system at Scott Brothers' Dairy Farm located in Moreno Valley, California.



Absorption
- Collection and subsequent scrubbing of gaseous NH_3 from agricultural point sources
- Conversion of gaseous NH_3 to aqueous phase NH_4^+
- Clean air is released as a byproduct of this process

Adsorption
- Aqueous NH_4^+ pumped into a biochar column where NH_4^+ is removed from the water
- Biochar serves as a granular medium which effectively adsorbs NH_4^+ from aqueous phase

Recycle
- Water from biochar column is recirculated back into the scrubber column for further absorption
- Biochar enriched with adsorbed NH_3/NH_4^+ can be used a soil amendment to propagate increased crop yield

Supporting People, Planet & Prosperity

Since the original three-phase scrubber project design proposal, FCE has improved the design dramatically to truly encapsulate the full circle mindset and better protect people, planet, and their prosperity.

People
- Reduced NH_3 related health issues like lung irritation, asthma, and pulmonary ailments
- Better air quality for workers near NH_3 sources

Planet
- Reduced eutrophication caused by high nitrogen loading in surface waters
- Reduced particulate matter formation which is regulated by the EPA's Clean Air Act

Prosperity
- Improved welfare
  - Reduced odor from agricultural operations
  - Less haze and smog formation
- Cost effective atmospheric NH_3 removal solution

References

[1] Agency for Toxic Substances and Disease Registry (2004). Toxicological Profile for Ammonia. Atsdr.cdc.gov.

[2] "CDC - NIOSH Pocket Guide to Chemical Hazards - Ammonia." *Centers for Disease Control and Prevention*, Centers for Disease Control and Prevention.

[3]Admin. "Conserving Ammonia in Manure." *Center for Agriculture, Food and the Environment*, UMassAmherst, 24 Jan. 2017

[4] Pinder, Robert W, and Natalie J Anderson. "Ammonia Emissions from Dairy Farms: Development of a Farm Model and Estimation of Emissions from the United States ." *Department of Civil and Environmental Engineering Carnegie Mellon University*, p. 14.

Results and Developments

Bench-Scale Design

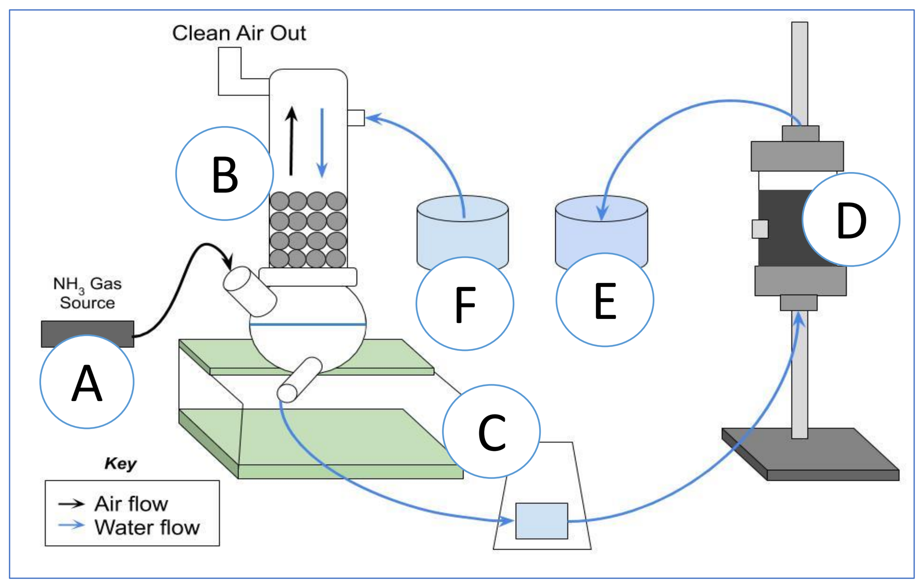


Figure 1: Bench-scale schematic

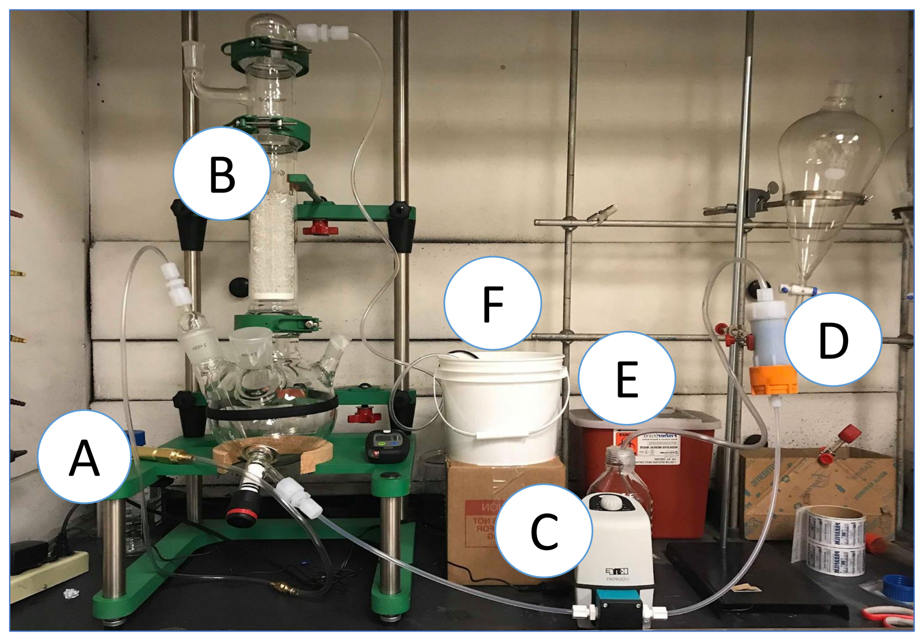


Figure 2: Bench-scale prototype

- **A** *NH_3 Gas Permeation Tube:* emits gas at a constant rate of 290 ng/min
- **B** *Chemglass Absorption Column:* packed with 8x8mm rasching rings and a 3L reservoir
- **C** *Water Transfer Pump:* Pumps water into the biochar column at a consistent rate
- **D** *Biochar Column:* Biochar adsorption column filled with 22 g of pine based biochar and perlon filter fibers
- **E** *Glass Bottle:* collects biochar filter effluent for sampling
- **F** *Clean Water Source:* Filled with deionized water and a submerged water pump to refill absorption column

Allows FCE to optimize NH_3 removal by varying:
- Biochar influent flow rate
- Biochar particle size
- Biochar volume

Two valuable waste products are generated:
- Clean water which is recycled back into the scrubber
- NH_4^+ saturated biochar which is recycled into a sustainable soil amendment

Biochar as an Ammonia Adsorbent and Soil Amendment - Results

Biochar as an NH_3 Adsorbent - Removal Efficiency

The overall effectiveness of the biochar in removing ammonia (as NH_4^+) from the absorption column effluent was tested in a series of lab experiments. The initial ammonia concentration was determined from samples collected at the reservoir and the final concentration in the biochar filter effluent. Removal efficiency was determined using an ammonia phenolate analysis method. The water flow rate and biochar particle size were optimized, producing the results shown in **Figure 3** and **Table 1**. The maximum ammonia removal efficiency was found to be 78% with an average of 60% ± 14% over multiple trials.

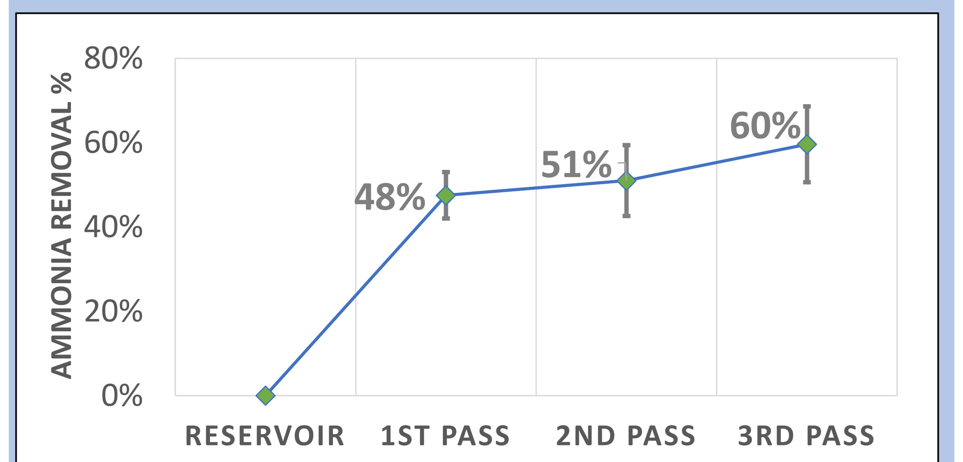


Figure 3: NH_3 removal efficiency with subsequent passes

Table 1: Summary of controlled parameters and resultant average removal rate

Parameter	Value	Units
Biochar Particle Diameter	<1/20	inch
Biochar Volume	100	mL
Initial [NH_3]	3	mM
Average Flow Rate	4.77 ± 0.73	mL/s
Average Retention Time	152 ± 30	seconds
Average Removal Rate	0.0213 ± 0.008	g NH_3 / g biochar

Biochar with NH_3 - Soil Amendment Properties

The ability of NH_3/NH_4^+ saturated biochar to serve as a soil amendment was also tested using 3 other soil types for comparison. The results are summarized in **Table 2**. Romaine lettuce was used for its short maturation period of 3 weeks. The average leaf weight (**Figure 4**) and average number of leaves on each plant (**Figure 5**) were recorded over a 12 week period to allow for a robust statistical analysis.

Table 2: Summary of 4 different soil types used in study

Soil Type	Description
Control	No soil amendments added
Commercial Fertilizer	Soil with Dr. Earth's all purpose fertilizer with 2-2-2 N-P-K ratio
Biochar	Soil with raw biochar
Biochar with Ammonia	Soil with biochar saturated with 0.1 M of NH_3

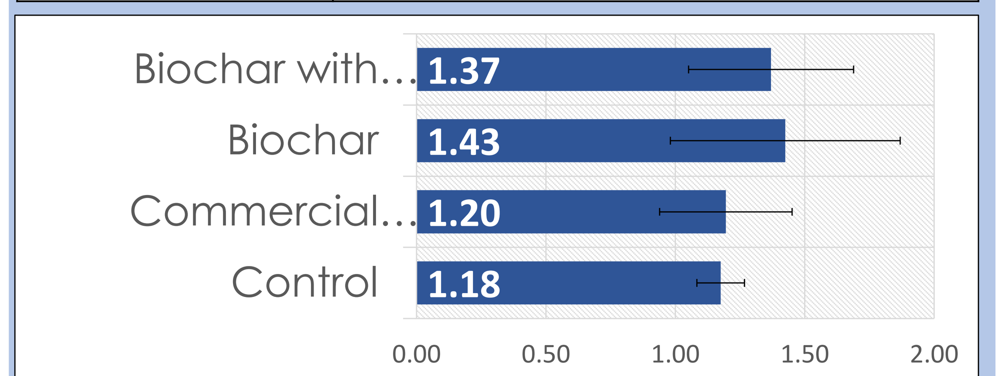


Figure 4: Average weight of lettuce leaf in 4 soil types

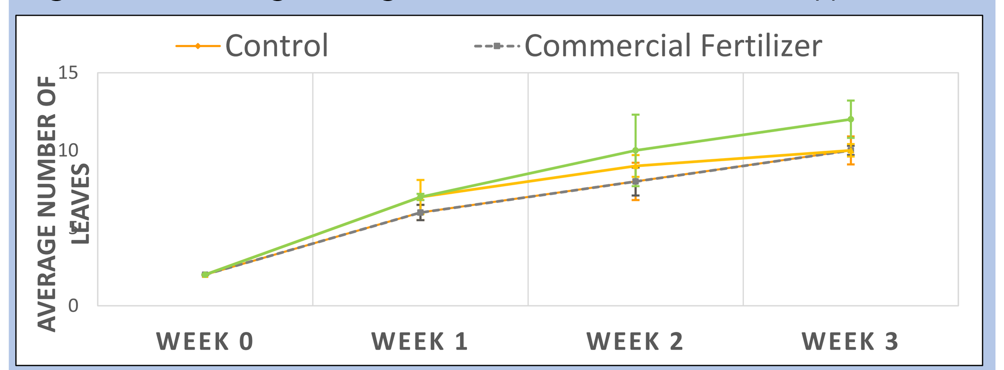


Figure 5: Average number of lettuce leaves on each plant

Summary of Anticipated Outcomes

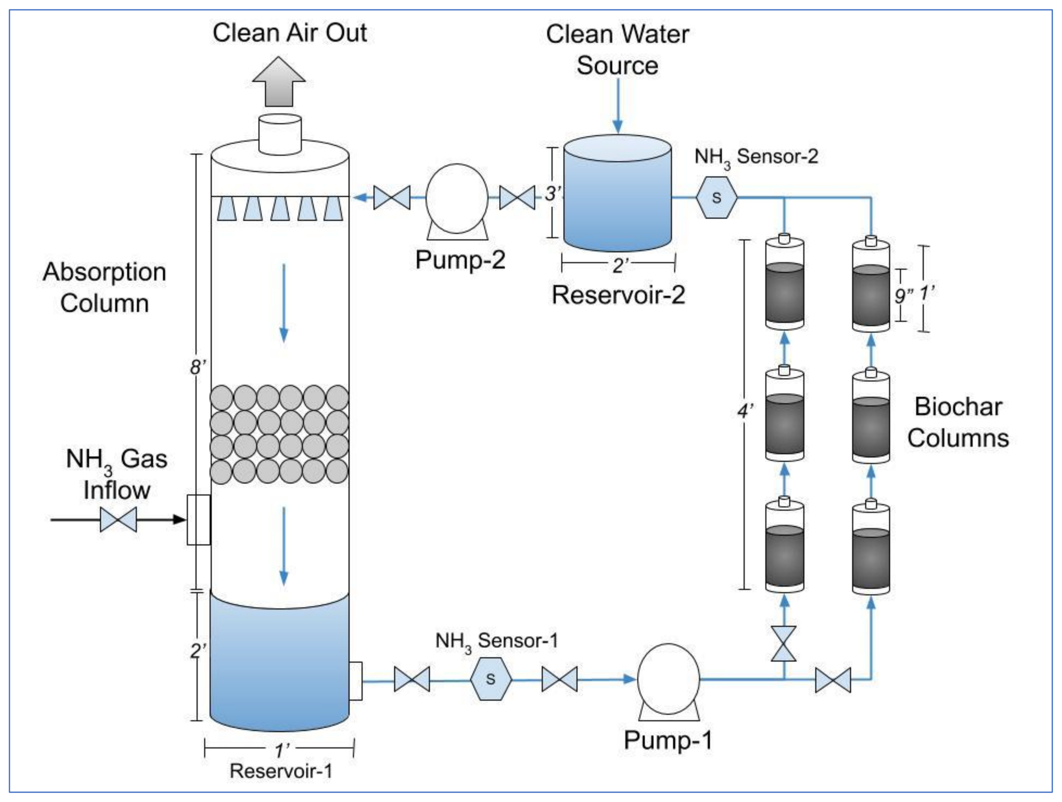


Figure 6: Proposed design flow chart

- The proposed design (Figure 6) is optimized to remove daily loading of 0.064 to 0.32 lbs NH_3/ ft³ of water (800 – 1700 cows)
- Versatile placement options connecting barn ventilation systems to scrubber
- Improved system design with addition of third column in series and switching out columns at saturation point
- Biochar becoming widely used not only as a waste-removing soil amendment but also for carbon sequestration

Anticipated Conclusions

Ultimately, this process encompasses the full circle mentality by converting hazardous waste into a valuable soil amendment for agricultural operations throughout the world. By remediating ammonia from farms, FCE will safeguard human health, preserve worker safety, improve community welfare, and protect the natural environment while boosting soil health, crop yield, and agricultural profits, while also reducing water use.

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worldwaterforum

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