Novel intervention strategies and technologies for food safety assurance in pork supply chain

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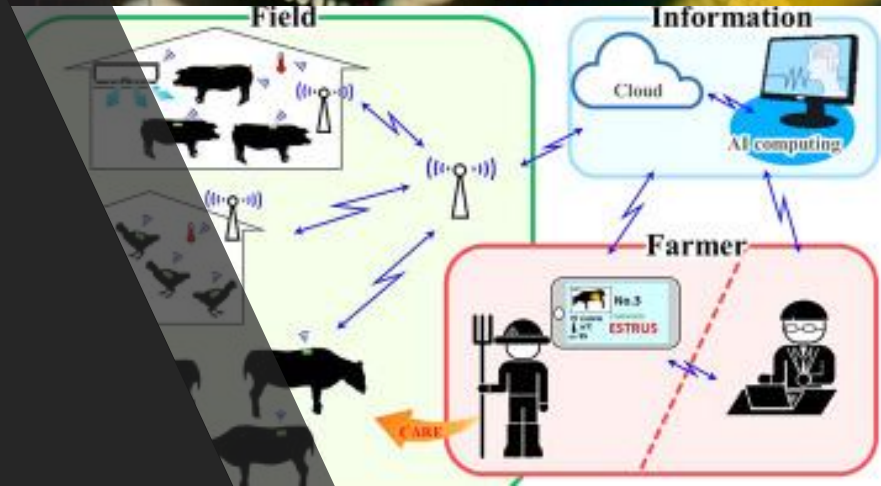
A vision and technology for a sustainable smart pork production system

Sustainable Smart Production System

Smart production systems

- Sensing
  - Pathogens
  - Air conditions and quality
  - Water contamination
  - Feed usage
  - More ……
- Data collection/transmission/analysis/IoT
  - Extract actionable information from synthesizing large amounts of multi-source data through Big Data Analytics
  - Real time/automatic actions/intervention to control the environment/conditions for animal health/welfare and optimal growth



Smart Ventilation Systems for Hog Housing

Traditional goal of ventilation

- **to remove the excess heat and moisture that buildup in the facility in order to maintain an appropriate temperature and humidity level for pig health and performance**
- **to remove excess gas that is harmful to pigs and humans**

Emerging goal/strategy

- **to sanitize air and improve air quality in order to ensure biosecurity and animal safety and health**

Trend

There is a trend in intensive hog farming using indoor facilities including multi-floor buildings/vertical hog farming.

This presents many problems associated with high density of pigs

It also presents opportunity for designing well controlled ventilation systems.

Several companies in China have already built this kind of hog production facility and are moving to increase this practice.

Some of them are using big data to control the environment and feeding.

Conceptual design of a smart ventilation system for a smart production system to ensure biosecurity using latest techniques

Design principles:

- Enclosed environment with minimal intermittent air exchange to reduce the energy consumption
- The incoming (inlet) air is treated to eliminate airborne pathogens
- The air inside the facility is monitored, circulated through a treatment center where airborne pathogens are inactivated and ammonia/ hydrogen sulfide, and other odorous and hazardous gases, decomposed and utilized, temperature/RH conditioned, and the treated air is circulated back inside the facility.
- The outgoing (exhaust) air are treated to remove pathogens and odorous compounds before discharge. The amount of outgoing air may depend on the need to remove heat and moisture in the air.

Cleaning facilities and equipment with ozonated/NTP activated water

Washing live animals with ozonated/ NTP activated water

- Catalytic NTP/Low temperature microwave-based air sanitation
- NTP based odor removal

Decontaminated and reconditioned air

Treatment Center B

Decontaminated & deodored air

SENSORS

Micros CO_2 H_2S NH_3 RH T

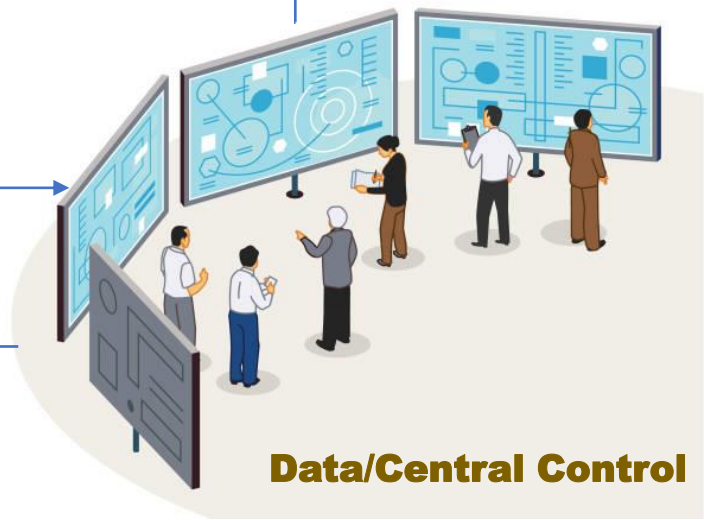
Indoor dirty air

Incoming air

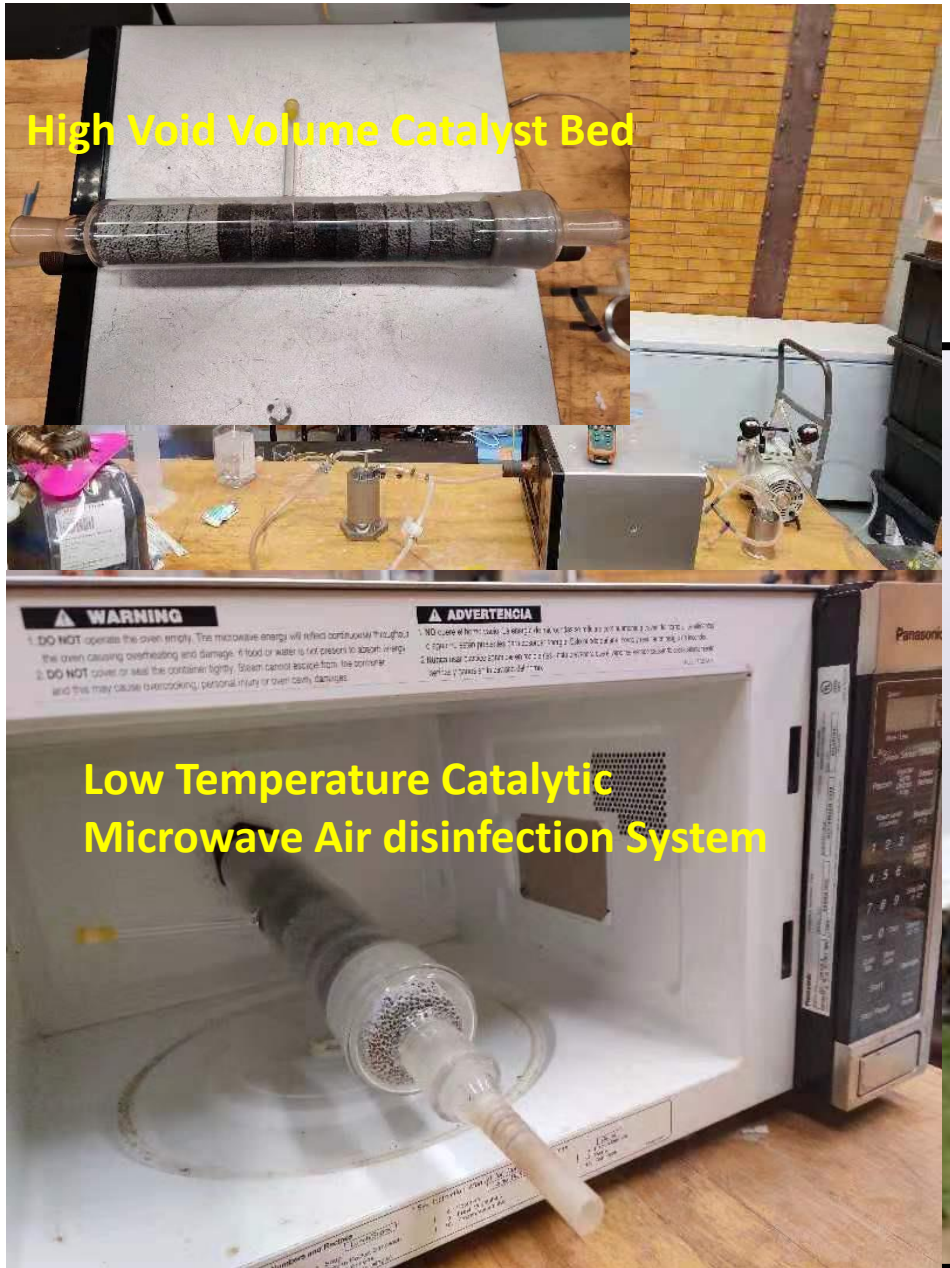
Treatment Center A

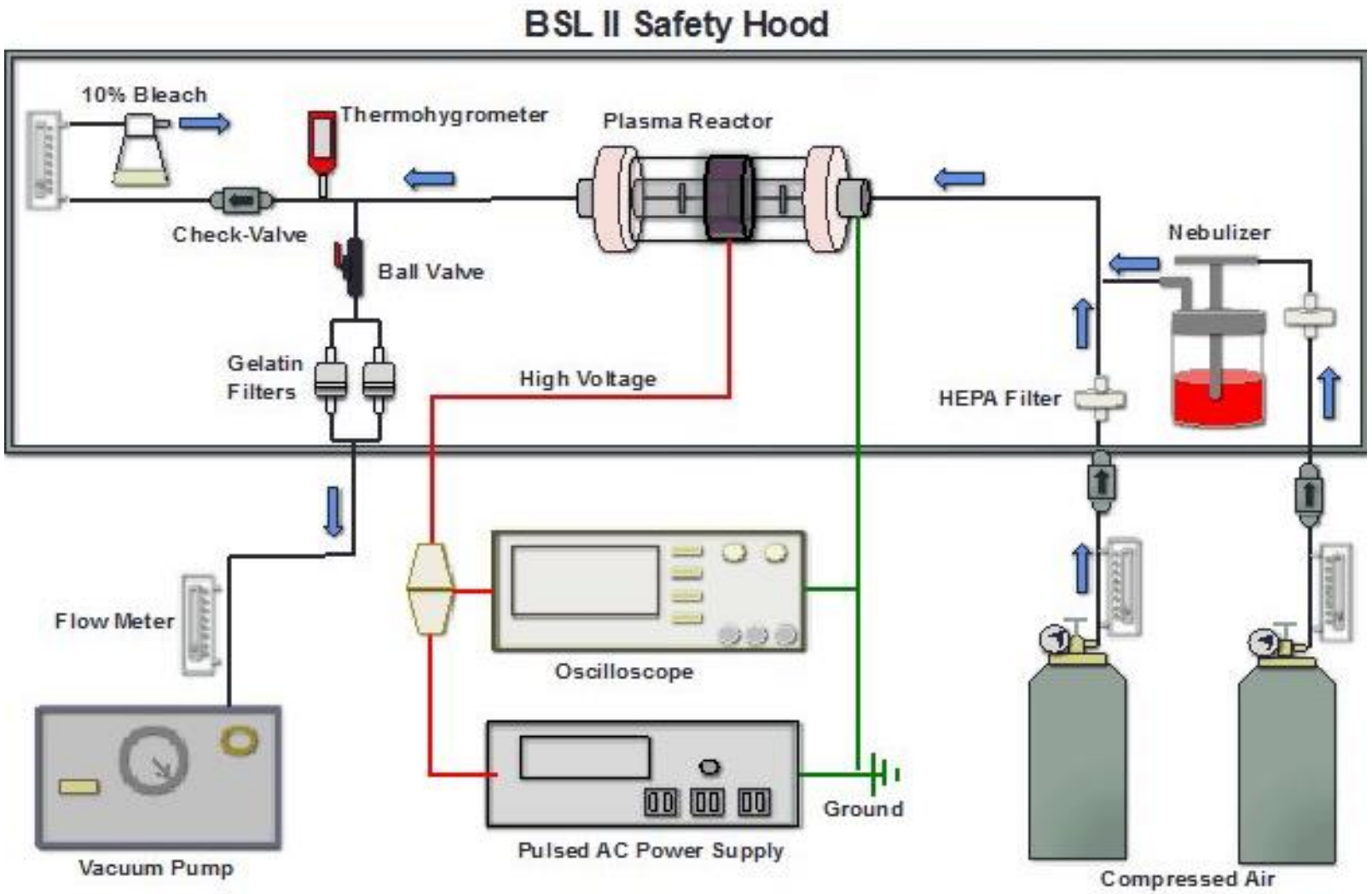
Decontaminated air

- Catalytic NTP/Low temperature microwave-based air sanitation



Intervention technologies and systems by UMN Researchers



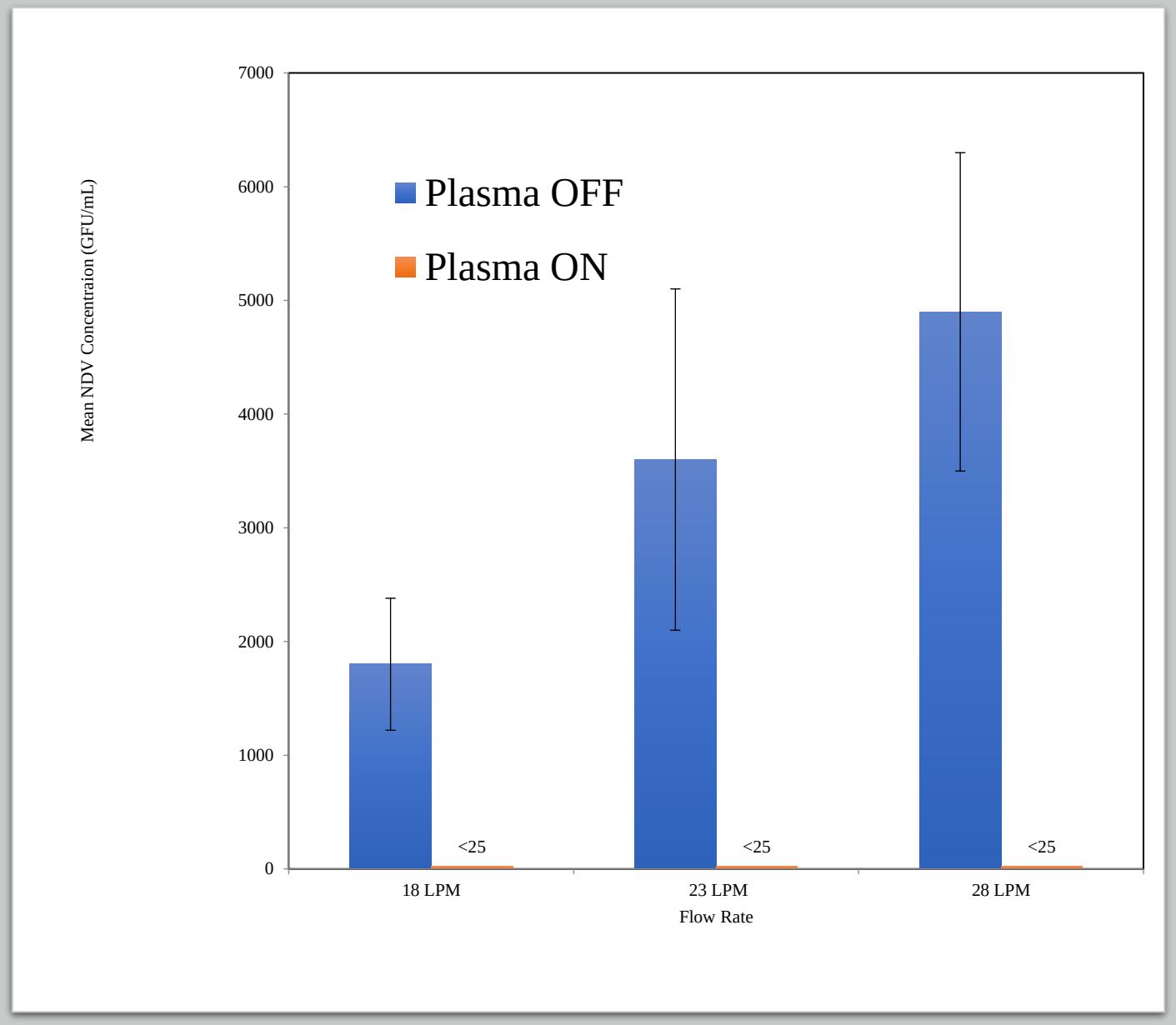


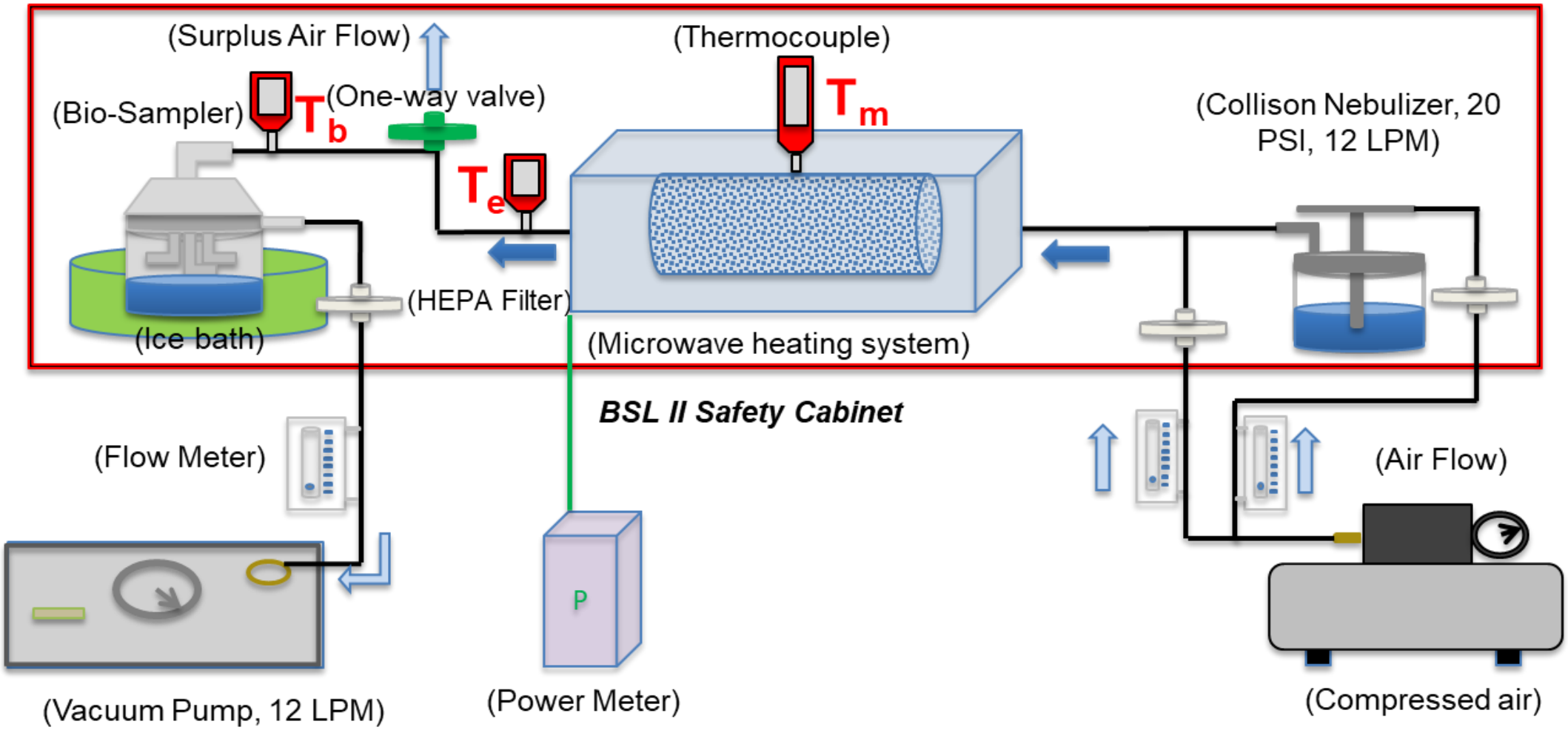
Non-thermal plasmas (NTP) technique

Experimental setup for inactivation of aerosolized Newcastle disease virus

Non-thermal plasmas (NTP) technique

- **Plot of mean NDV concentration vs. flow rate for treated and untreated samples. Treated samples (plasma on) were below the limit of detection (<25 GFU/mL).**
- **Plasma reactor power input of 80 W.**

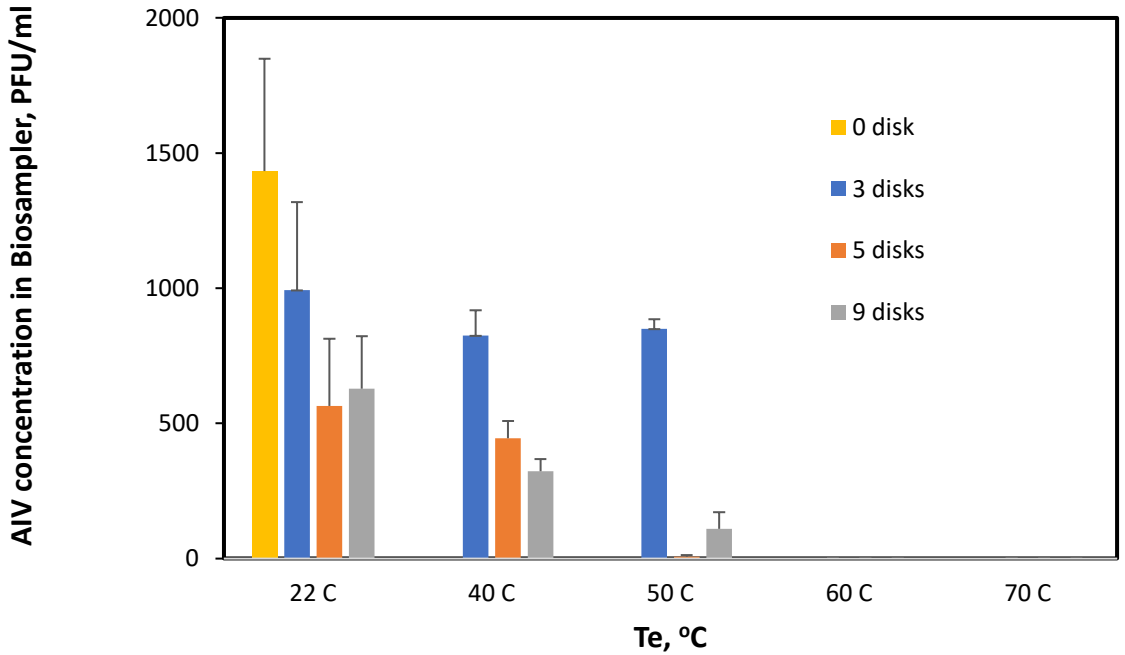


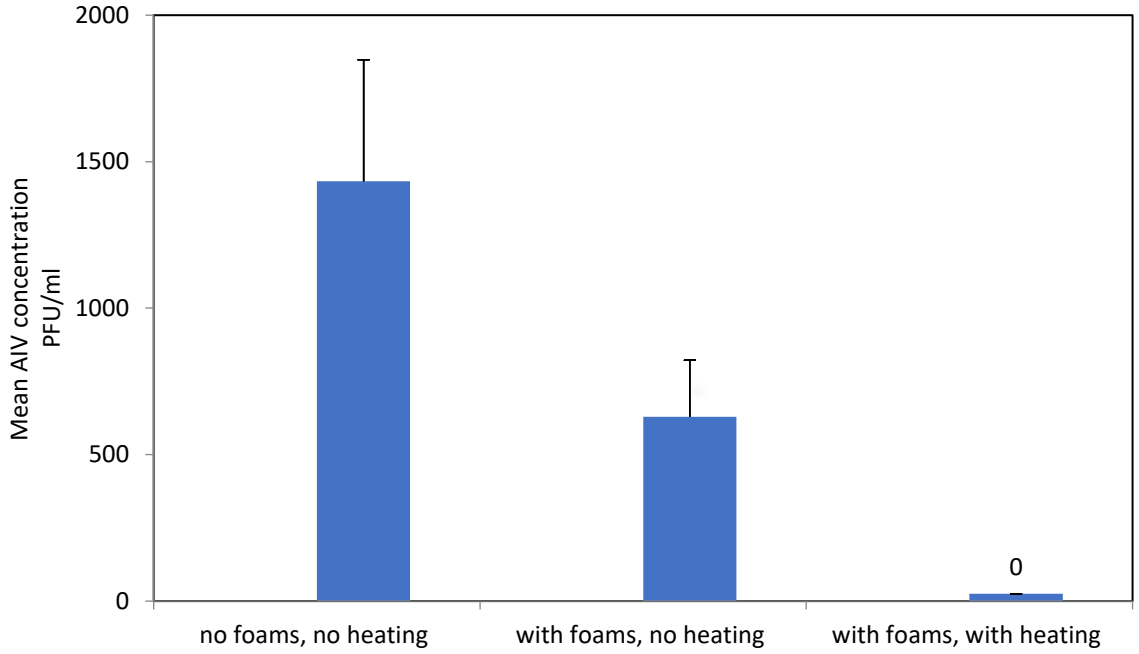


Catalytic low-temperature Microwave based techniques

- **Diagram of the experimental setup for microwave assisted air sanitation.**

Viral titers detected at the Biosampler at different exit air temperatures





H5N2 virus concentrations in liquid samples collected from aerosol experiments under different conditions. For treatment, air was heated to 60ºC by microwave heating assisted by SiC foam filters.

$$H_2S + O_3 \rightarrow H_2O + SO_2$$
$$OH + SO_2 \rightarrow HSO_3$$
$$OH + HSO_3 \rightarrow H_2SO_4$$
$$2NH_3 + H_2SO_4 \rightarrow 2(NH_4)_2SO_4$$

$$VOCs + O \text{ (or } OH \text{ or } O_3, \ldots) \rightarrow CO_x + H_2O + \text{byproducts}$$

Planar NTP Reactor Prototype for Air treatment and Odor Control

Ma, H., Chen, P. & Ruan, R. H2S and NH3 Removal by Silent Discharge Plasma and Ozone Combo-System. Plasma Chemistry and Plasma Processing 21, 611–624 (2001).

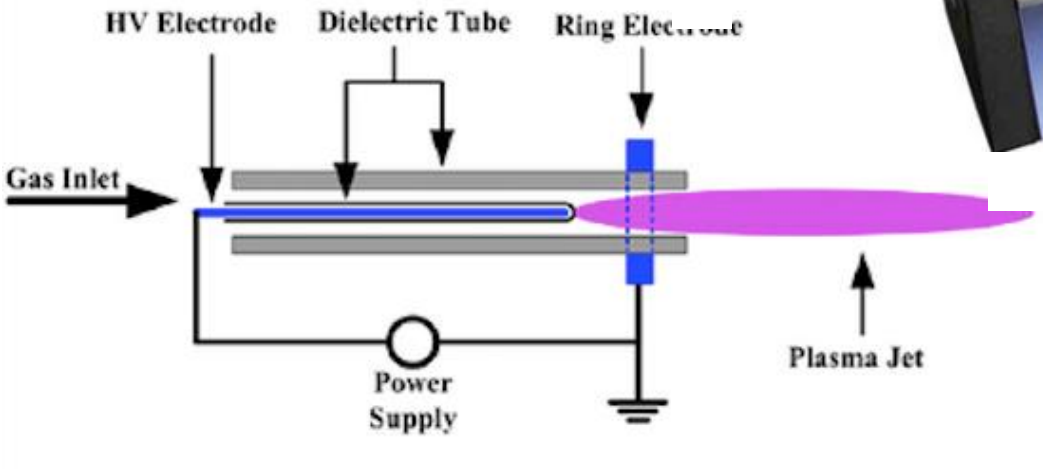
Planar NTP Reactor for Air Treatment and Odor Control

Planar NTP Reactor for Air Treatment and Odor Control

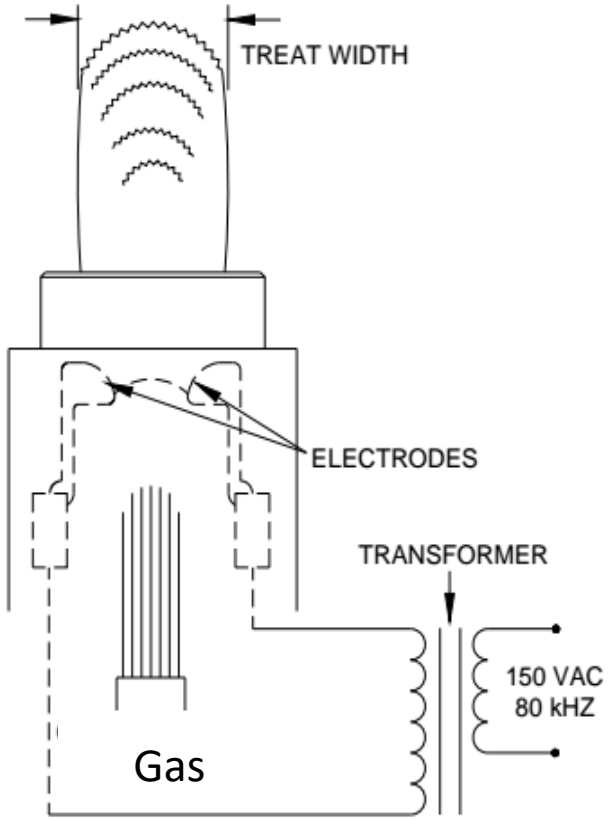
Ozonized Water Generation and Treatment System

Ozonized Water Generation and Treatment System

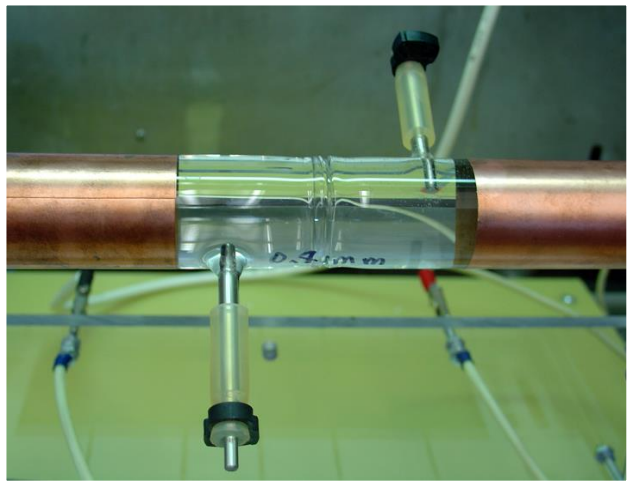
Nonthermal Jet Plasma Surface Treatment

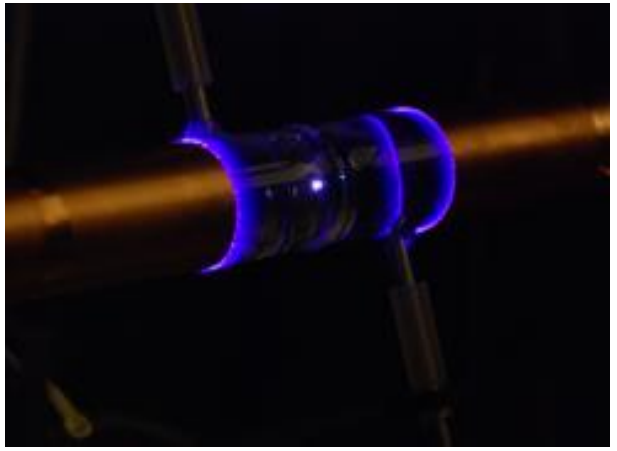


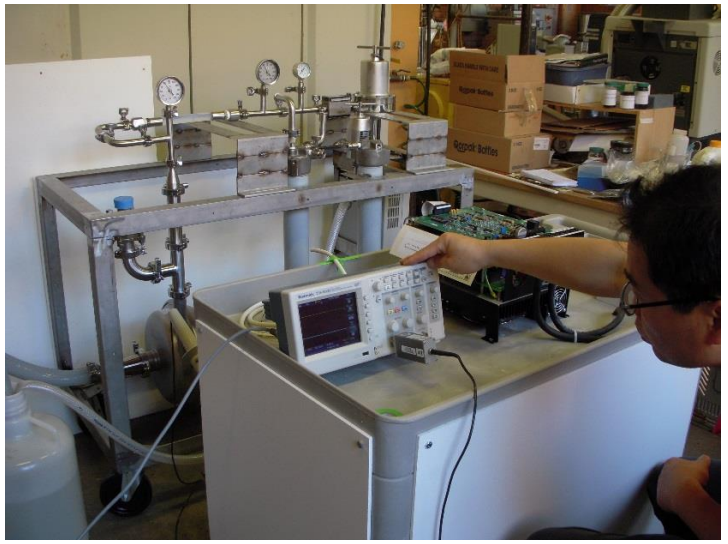
- Ionized local gas flows, generated under normal pressure
- High gas velocity

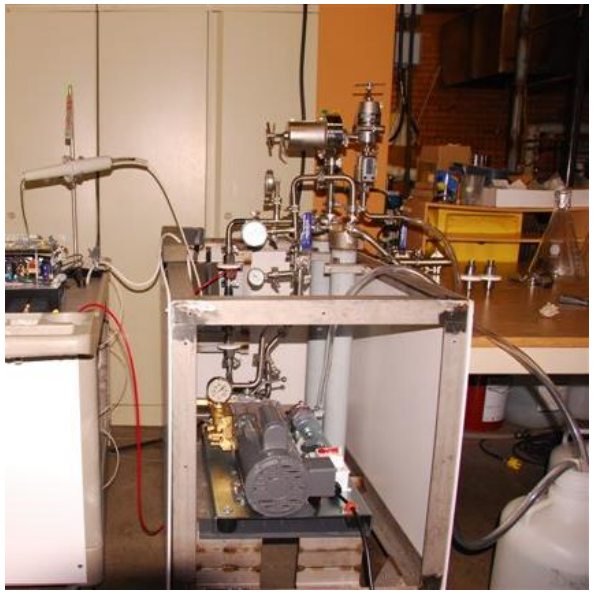


NTP generation in liquid

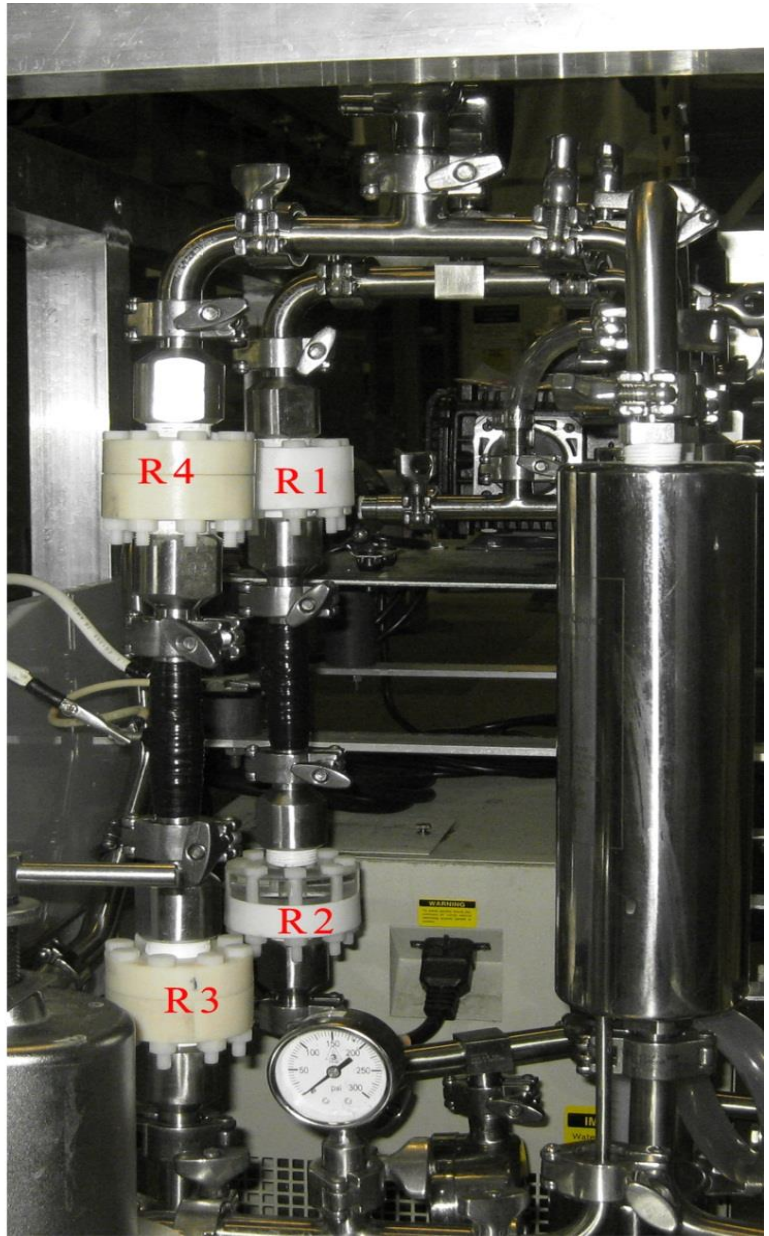








Pilot CHIEF/NTP Water Treatment System



Liquid CHIEF/NTP Food Pasteurization Systems

YN-1

YNK-1

YNK-2

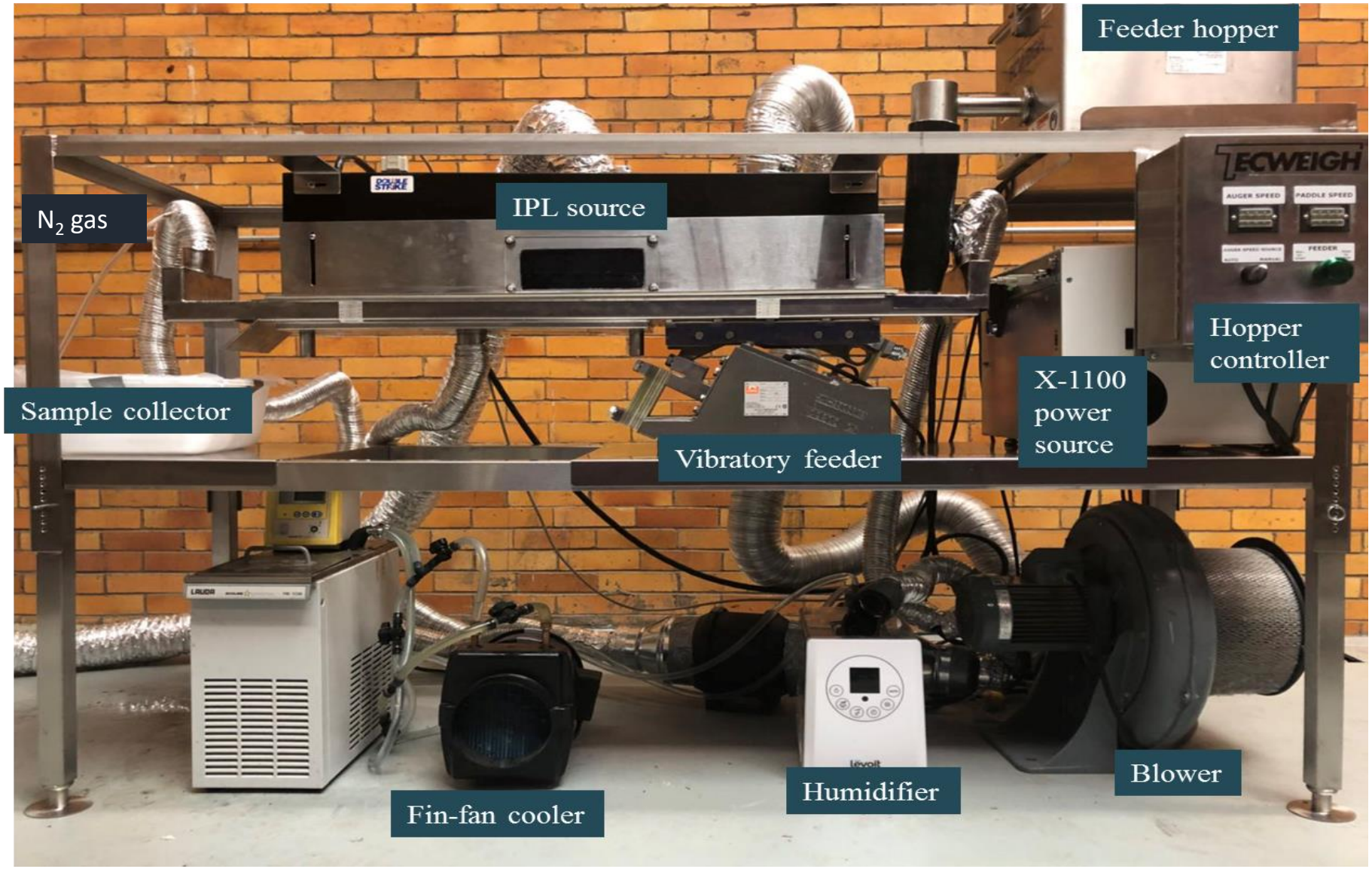
NTP Solid Disinfection System

The continuous automatic solid treatment prototype system

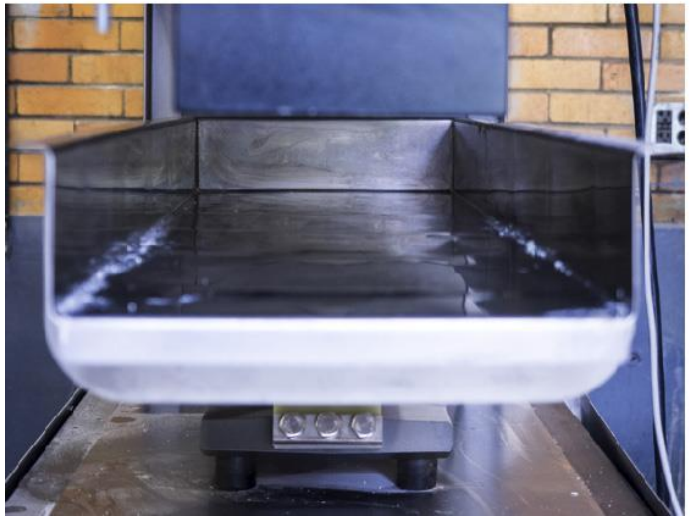
Potential application of intensive pulsed light (IPL) - based techniques in pork production/ processing

- **IPL illumination of carcasses**
- **IPL illumination of packaged meat products**
- **IPL illumination of packaging materials**
- **IPL illumination of processing equipment**

Photocatalytic IPL Prototype System



Photocatalytic Intense Pulsed Light (cIPL)



Sustainability

Automatic and precision farming through smart systems to improve material and energy efficiency and eliminate air and water pollutions

Waste treatment and utilization/recycling to improve hygiene/safety, reduce chemical and biological pollutants, and add value

Smart ventilation system

Ozonated water wash of facility and pigs

Drinking water treatment

Production facility

Washing processing equipment surfaces with ozonated water

Washing carcasses with ozonated water

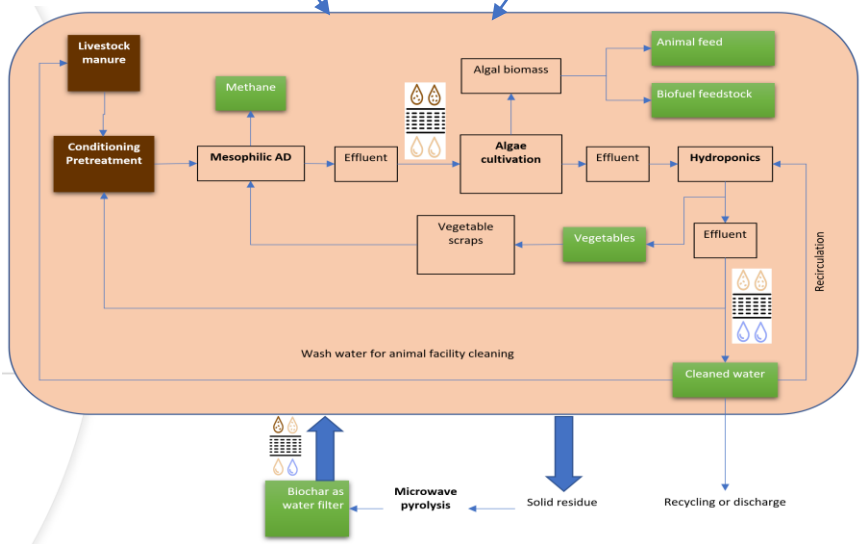
Treatment of drinking water and recycling cooling water through ozonation

Disinfecting surface of packaged products using ozonated water

Coat facility surface with catalyst and apply intense pulsed light for surface disinfection

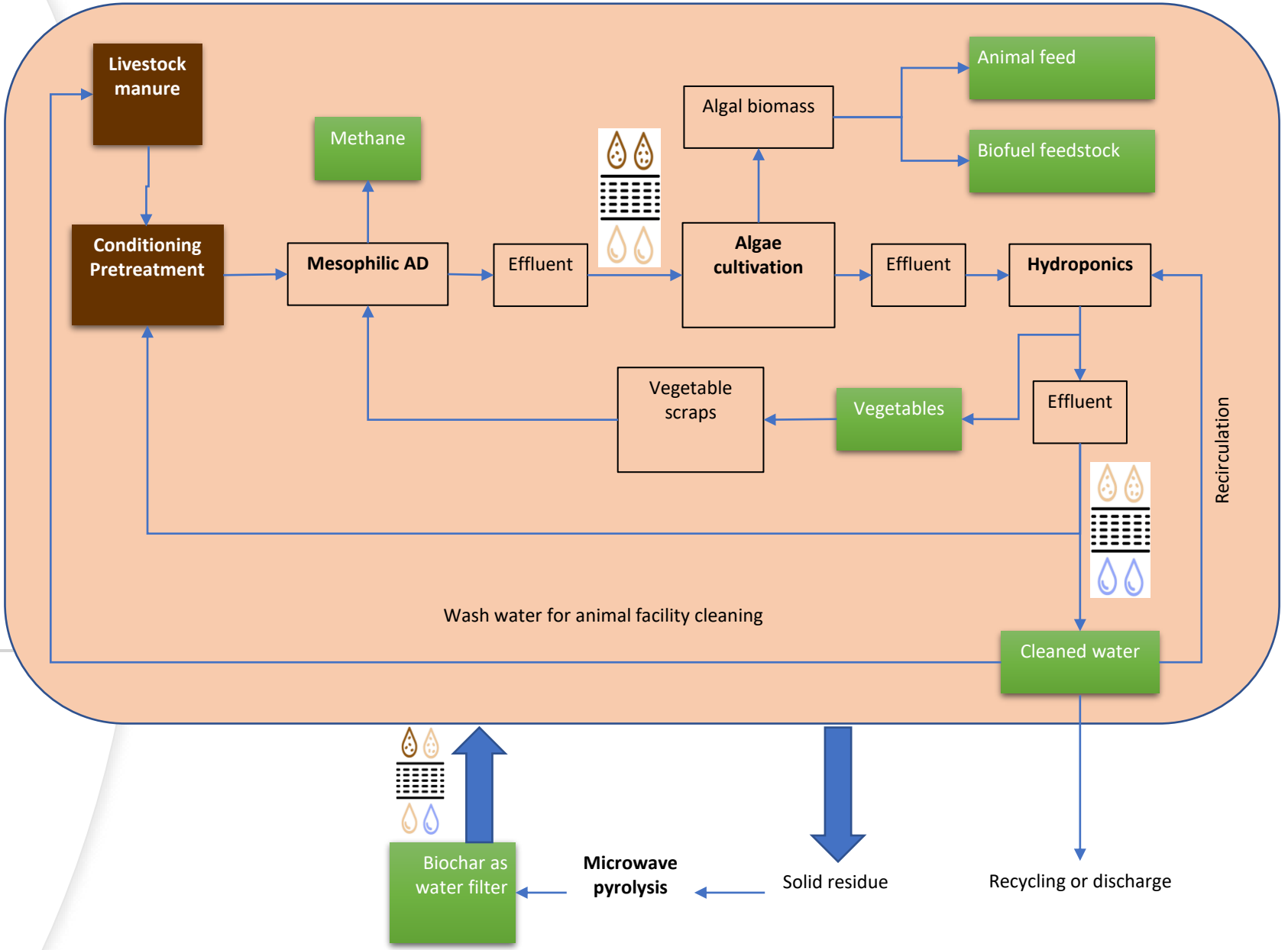
Processing facility

Wastewater

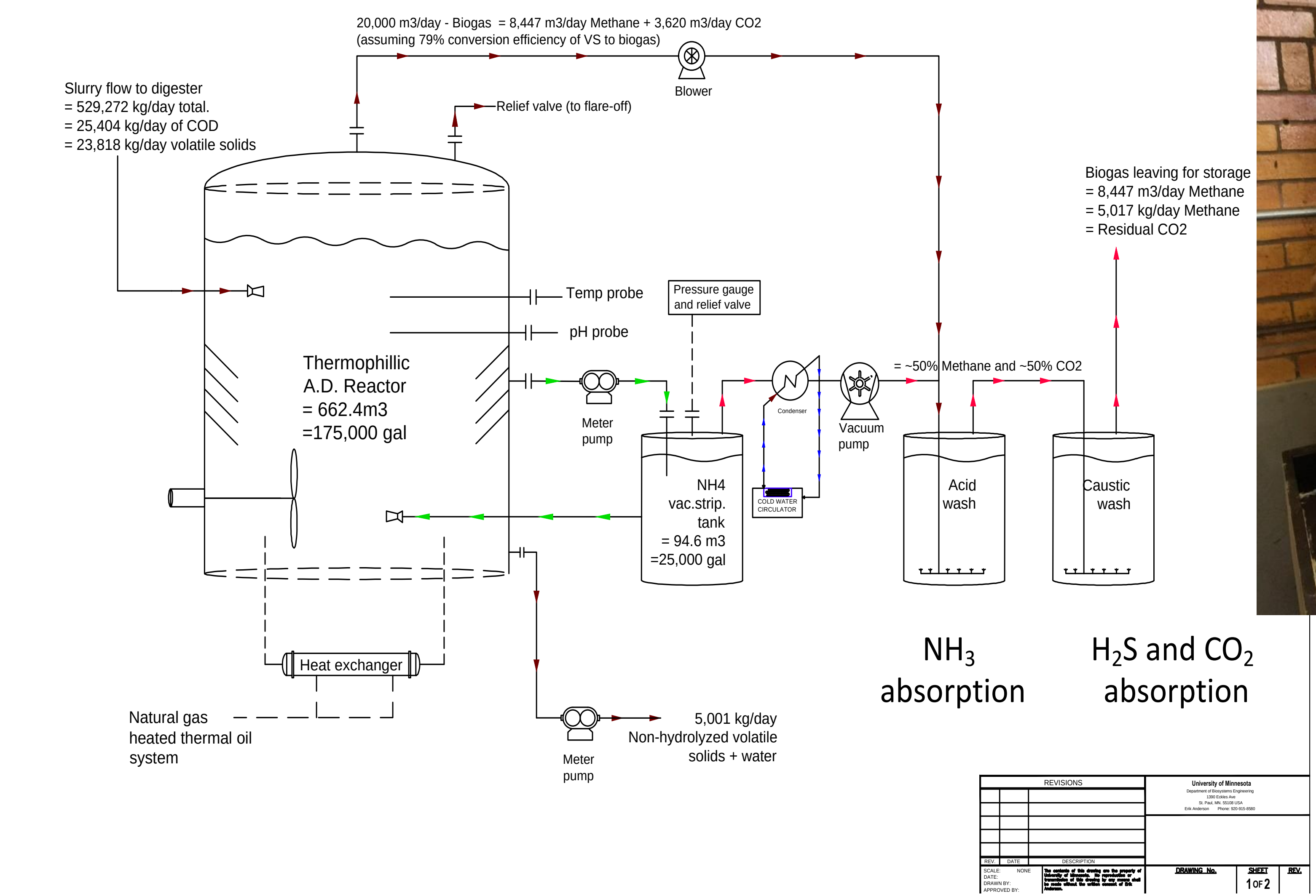


Integrated wastewater treatment and utilization facility

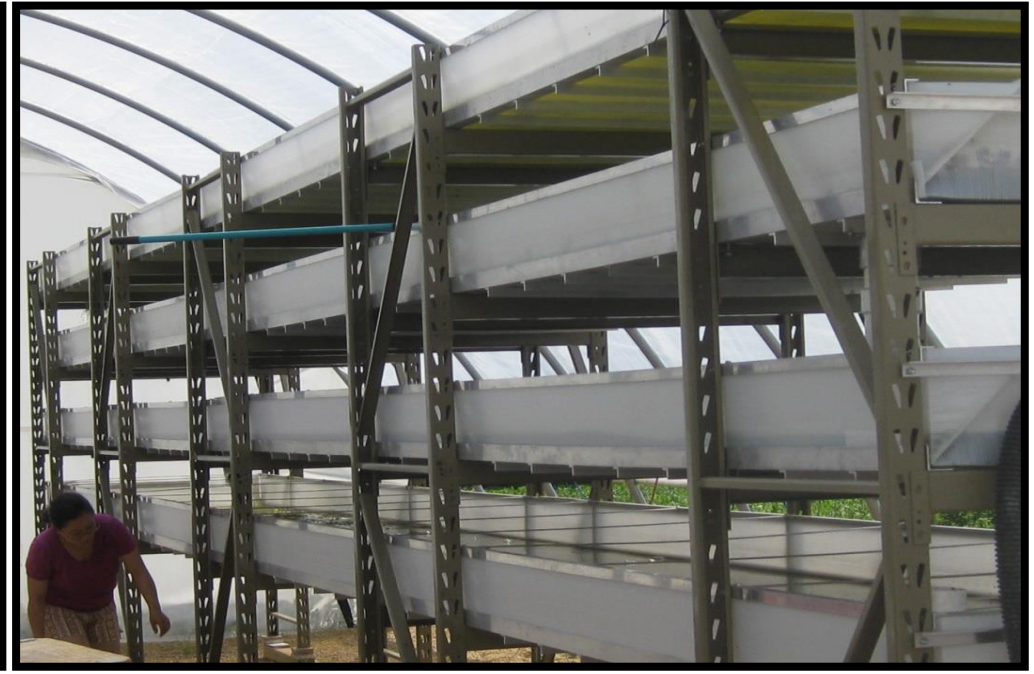
An integrated biological system for animal wastewater treatment through utilization

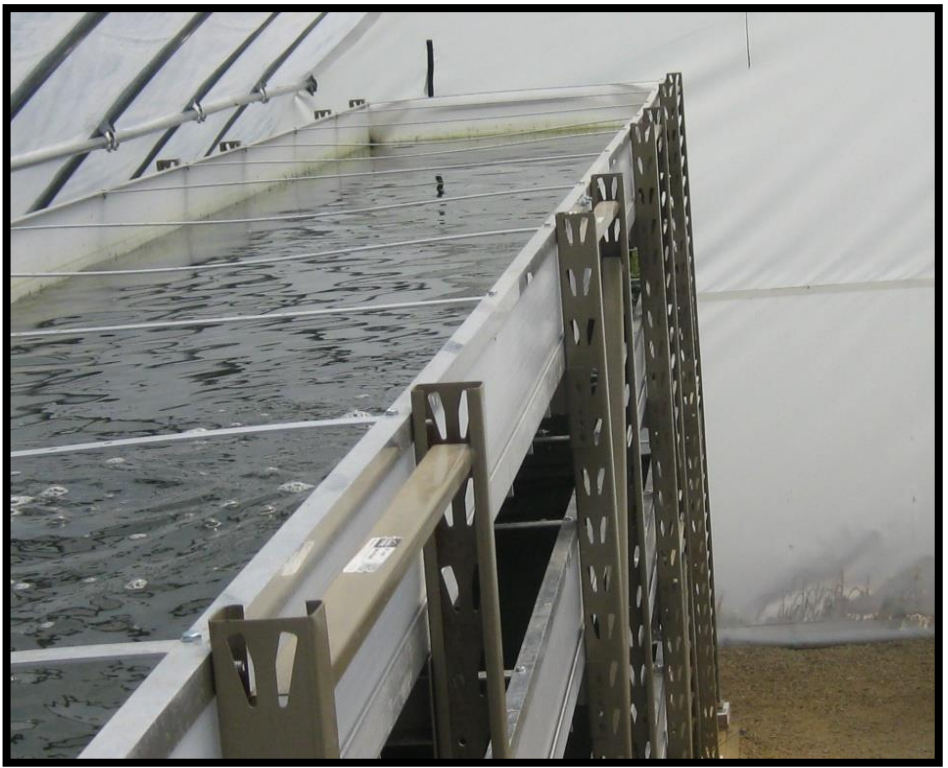


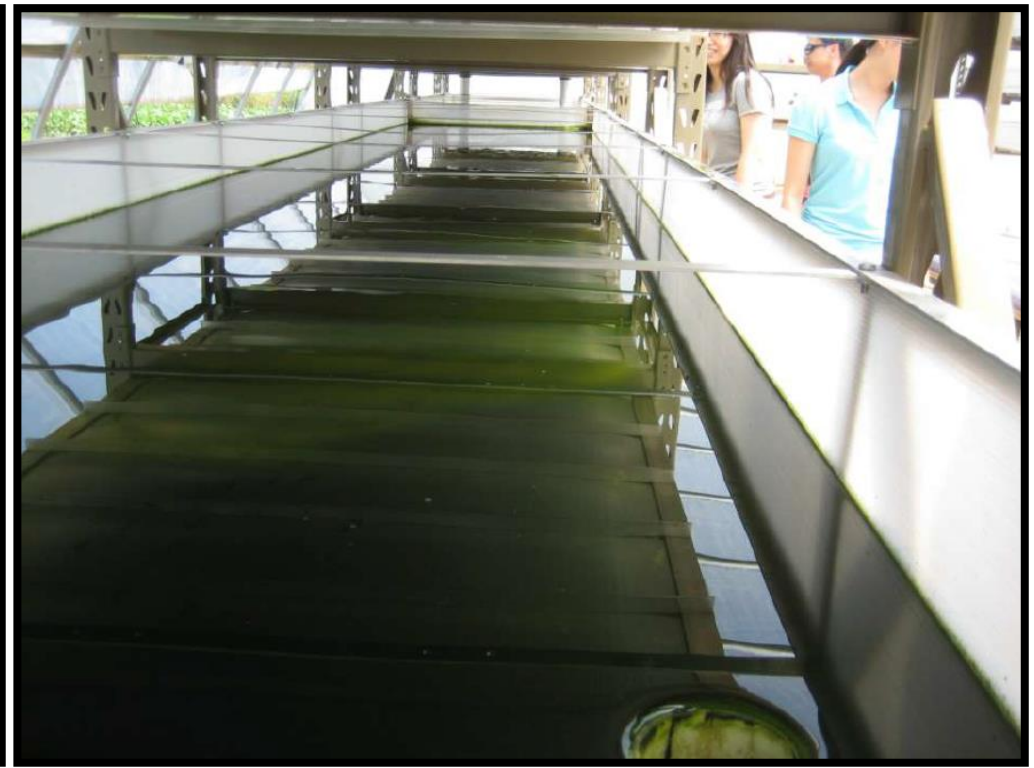
Continuous stirred-tank intermittent vacuum-assisted pretreatment system for the NH3 and H2S removal



Anaerobic Digestion (AD) of Hog Manure Wastewater







Vertical multilayer photobioreactor covered by transparent plastic film to prevent water evaporation

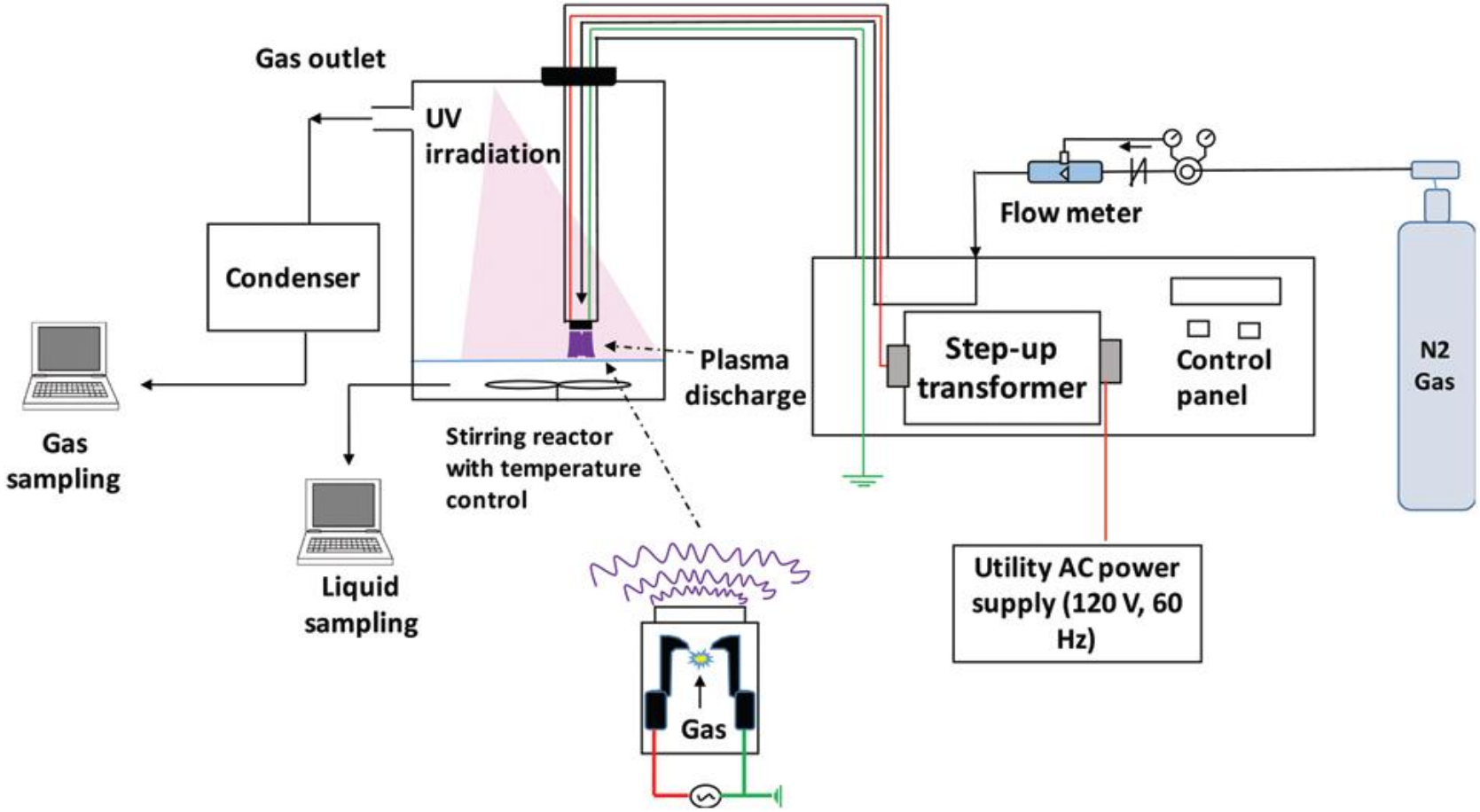
Pioneer Press **front page story on October 23, 2011**

Hydroponic systems


64°

Nelson and Pade System, WI

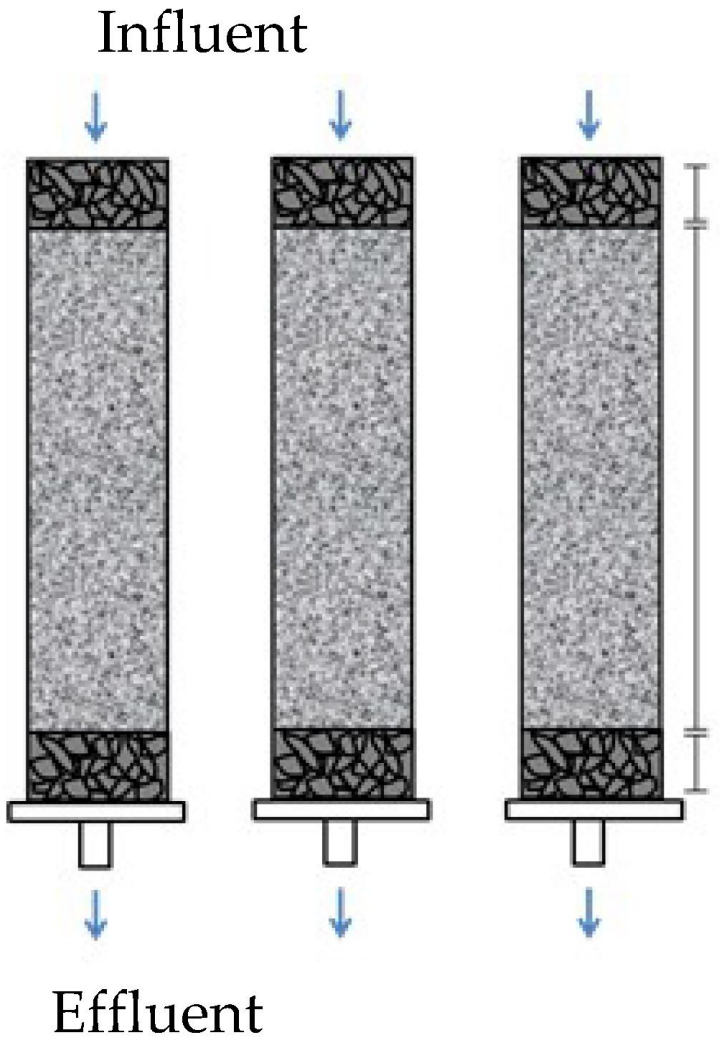
NTP for Nitrate production



- In-situ plasma generation right above the liquid surface in stead of having plasma generated outside of the reactor
- Used glow discharge plasma jet instead of dielectric plasma discharge
- A spray-type plasma jet is used, which greatly increases the reaction area at the plasma-water interface
- Parameter control (temperature, mixing, gas flow rate, etc.)

P. Peng and R. Ruan et al., 2019

Filtration using biochar made from pyrolysis of biomass



Pilot Scale Mobile Fast Microwave-Assisted Pyrolysis System

Examples of in-house developed microwave solid waste treatment and utilization systems

A smart production system with novel intervention technologies for safety and quality assurance and sustainable development

- Cleaning, washing, and disinfecting through ozonation, non-thermal plasma (NTP), and catalytic intense pulsed light (IPL)
- Disinfecting carcasses, processing equipment, and packaged meat products using catalytic IPL
- Air sanitation using NTP and low temperature microwave-based technologies
- Innovative manure pretreatment and AD, algae, hydroponic, and biochar system to treat wastewater through complete utilization
- To improve air quality, reduce air and water pollution, produce renewable energy and products, and generate extra income

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evolutionary energy recovery systems

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Public Disclosure

Dr. Roger Ruan is a Chief Technical Advisor to, and owns equity in, Resynergi, which holds a license to plastic pyrolysis technology. These interests have been reviewed and managed by the University of Minnesota in accordance with its Conflict of Interest policies.

Questions?

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