Developing Cost Effective Biological Removal Technology for Selenium and Nitrate from Flue Gas Desulfurization (FGD) Wastewater from an Existing Power Generating Facility

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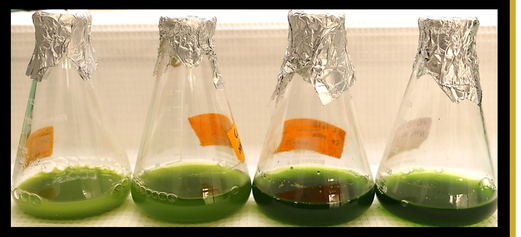


Introduction:

Algae and plants have the natural ability to sequester selenium (Se) and nitrate from Flue Gas Desulfurization (FGD) wastewater to harvestable biomass. Biotechnology has the potential to incorporate this enhanced Se and nitrate sequestration into agricultural systems designed to grow nutrient-fortified crops. The overall goal of our project is to investigate and determine a technically feasible and cost-effective process for designing photosynthetic organisms capable of sequestering Se and nitrates from FGD wastewater. To that end, we will explore a variety of genomics, biochemical, genetic, and molecular approaches to understanding the molecular basis of Se and nitrate sensing, uptake, and sequestration by algae and plants.

The results of our work will contribute to our goal of maximizing the sequestration of Se and nitrates in biomass for FGD wastewater remediation, reduction of power plant use of freshwater resources, and enhanced agricultural production. Development of tools such as transcriptomic and metabolomics data, algae, duckweeds, Arabidopsis T-DNA mutants/transgenic plants will help other scientists working in basic and applied water quality research. Sharing of large-scale sequencing data in this project with the broader scientific community will support research projects beyond water usage.

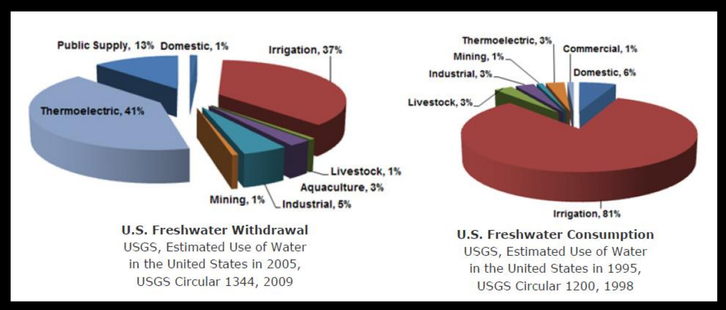
Project Objectives:

(1) Investigate changes in transcripts and metabolism in algae and plants in response to FGD wastewater.

(2) Explore biotechnological strategies to increase sequestration of Se and nitrates in biomass to improve agricultural productivity.

Thermoelectric Power and Freshwater Use:

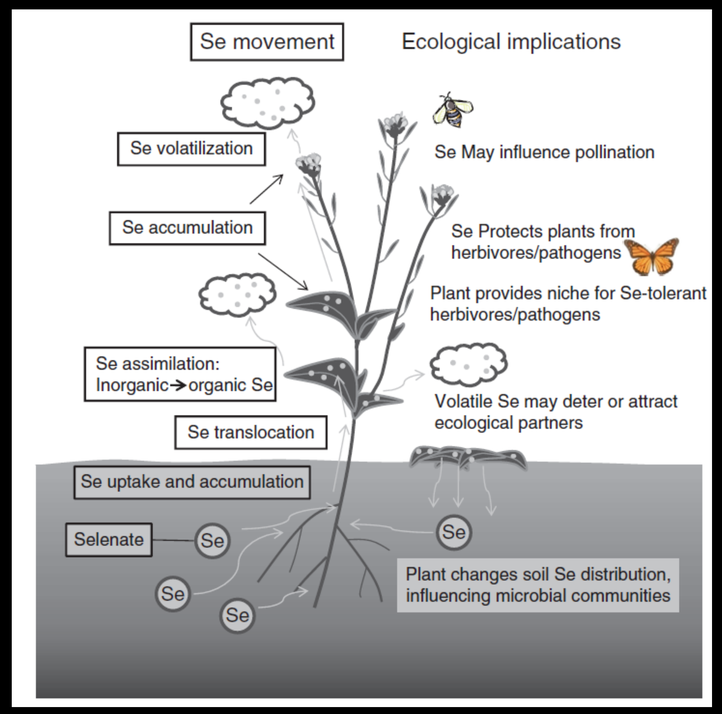
Freshwater consumption is projected to increase further with the implementation of carbon capture technologies



http://www.netl.doe.gov/research/coal/crosscutting/water-management

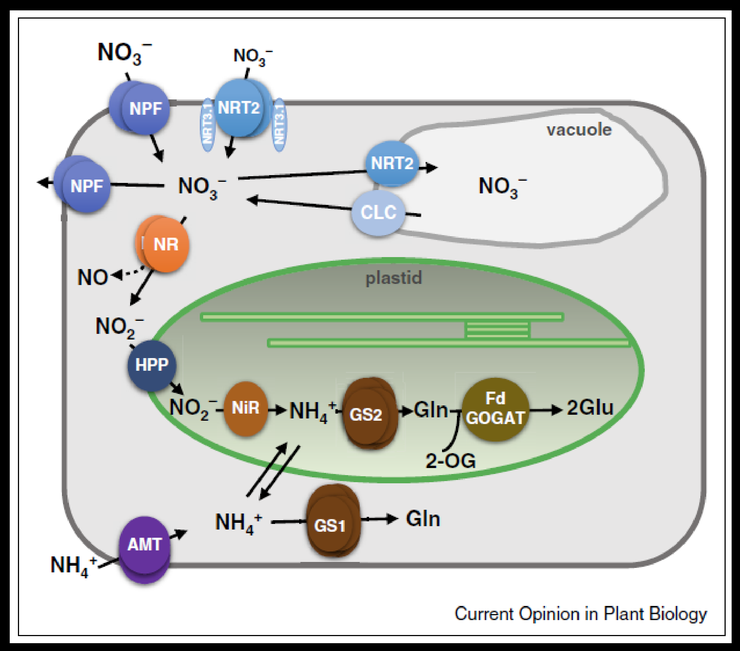
- Flue Gas Desulfurization (FGD) treatment is incorporated in most coal burning power generation plants to remove sulfur dioxide and various oxides of nitrogen by either wet/dry scrubbing.
- Wet scrubber blowdown often contains heavy metals (selenium, chromium, mercury etc.,), and nitrates in harmful concentrations.
- Removing Se and nitrates to ppb level is of particular challenge as conventional methods are generally not effective.
- Over the past two decades, industry has invested substantial resources in Se and nitrate removal technology (biological and chemical), achieving significant progresses.
- However, applications of these emerging technologies are considerably constrained by high cost, process complexity and other limitations.
- Green algae and plants have the natural ability to degrade inorganic Se and nitrates.
- The best methods available for Se and nitrate reduction in FGD wastewater include sequestration in the harvestable biomass.

Overview of the movement and metabolic conversion of Se by plants and their ecological implications



Pilon-Smits and Quinn in R. Hell and R.-R. Mendel (eds.), Cell Biology of Metals and Nutrients, Plant Cell Monographs 17, DOI 10.1007/978-3-642-10613-2_10, # Springer-Verlag Berlin Heidelberg 2010

Transport and enzymatic steps involved in primary nitrogen assimilation



Anne Krapp (2015), Current Opinion in Plant Biology, 25:115-122

Nitrate and ammonium are taken up by the root via specific transporters. Nitrate is reduced in the cytosol to nitrite by nitrate reductase (NR). A side reaction of NR produces nitrogen oxide (NO). Nitrite is then transported into the chloroplast by HPP transporters and reduced to ammonium by nitrite reductase (NiR). Ammonium is then incorporated into glutamate by the GS/GOGAT cycle.

Results/ Accomplishments:

- Initiated collaboration with John Amos power plant through Liberty Hydro and obtained treated and untreated FGD samples.
- Obtained wild type algae, duckweed and Arabidopsis from stock centers and established cultures in the lab.
- Initiated time course experiments on the survivability of algae, duckweed and Arabidopsis in response to FGD wastewater and selenium.
- Continue time course treatment experiments, collection of data on photosynthetic and survivability of photosynthetic organisms on different concentrations of FGD wastewater and selenium.

Objective/Task	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2 Q1	Y2 Q2	Y2 Q3	Y2 Q4	Y3 Q1	Y3 Q2	Y3 Q3	Y3 Q4
Objective 1: Investigate changes in transcripts and metabolism in algae and plants in response to FGD wastewater												
Task 1.1. Characterize the transcriptome signature of photosynthetic organisms exposed to FGD wastewater												
Task 1.2. Perform post-sequence analysis and qRT-PCR analysis												
Task 1.3. Perform functional analysis of candidate genes in model system												
Objective 2. Explore biotechnological strategies to manipulate Se and nitrate metabolism for increased agricultural production												
Task 2.1. Generate transgenic Arabidopsis lines expressing Se/nitrate transporter alone or in combination												
Task 2.2. Perform hydroponic/soil cultivation of algae, Duckweed and transgenic Arabidopsis in FGD wastewater												
Task 2.3. Conduct Se, nitrate, other heavy metals and metabolite analysis												
Task 2.4. Analyze gene expression of transgenic Arabidopsis lines overexpressing transporters												

Milestone Log						
Objective/Task	Fall Y1 (Q1 & Q2)	Spring-Summer Y1 (Q3 & Q4)	Fall Y2 (Q1 & Q2)	Spring-Summer Y2 (Q3 & Q4)	Fall Y3 (Q1 & Q2)	Spring-Summer Y3 (Q3 & Q4)
Project development and agreement with the FPM	X					
Undergraduate Student Recruitment	X		X		X	
Undergraduate training and development of students' Independent Research Projects		X		X		X
Objective 1: Investigate changes in transcripts and metabolism in algae and plants in response to FGD wastewater	X	X	X	X		
Task 1.1. Characterize the transcriptome signature of photosynthetic organisms exposed to FGD wastewater	X	X	X	X		
Task 1.2. Perform post-sequence analysis and qRT-PCR analysis	X	X	X	X		
Task 1.3. Perform functional analysis of candidate genes in model system		X	X	X	X	X
Objective 2. Explore biotechnological strategies to manipulate Se and nitrate metabolism for increased agricultural production	X	X	X	X	X	X
Task 2.1. Generate transgenic Arabidopsis lines expressing Se/nitrate transporter alone or in combination		X	X	X	X	X
Task 2.2. Perform hydroponic/soil cultivation of algae, Duckweed and transgenic Arabidopsis in FGD wastewater			X	X	X	X
Task 2.3. Conduct Se, nitrate, other heavy metals and metabolite analysis			X	X	X	X
Task 2.4. Analyze gene expression of transgenic Arabidopsis lines overexpressing transporters				X	X	X
Students/PI present at the ASPB/GRC on plant lipids conference		X		X		X
Students/PI present at local area schools		X		X		X
Students/PI prepare and submit manuscripts			X		X	X
New grant application preparation and submission			X		X	

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