Impact of Heavy Metals on Microalgae Growth and Conversion into Biofuel and Biogas Production: Bioremediation and Flue Gas Integration Potential

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- Utah State University
    - Katerine Napan, Ph. D.
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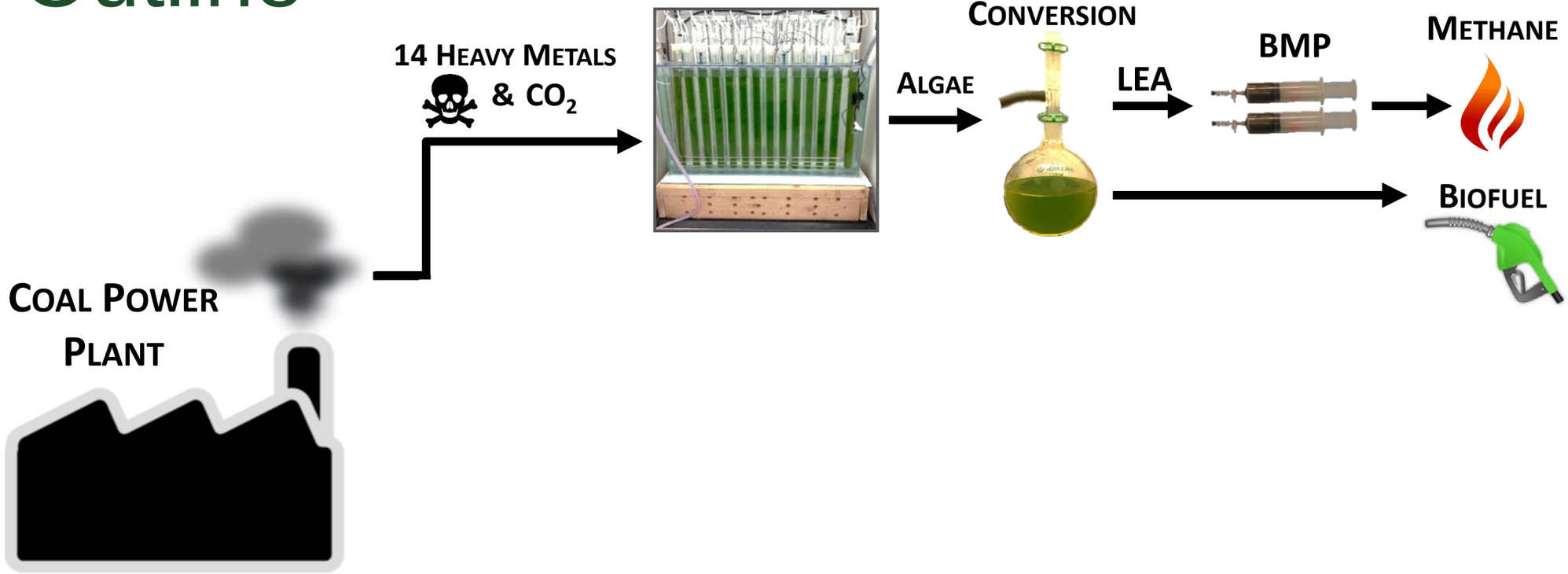
Motivation

Why are waste stream heavy metals important?

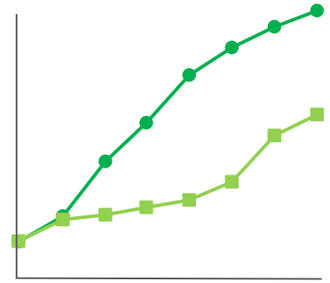
- Unaccounted for in current sustainability models
- Inherent in waste streams
- Possibly detrimental to microalgae productivity
    - Effects of many metals unknown
- Knowing effects necessary for TEA LCA analysis

Outline

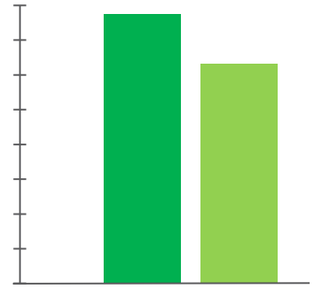
Phase 1



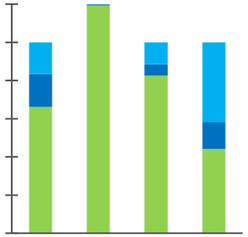
Results



Productivity

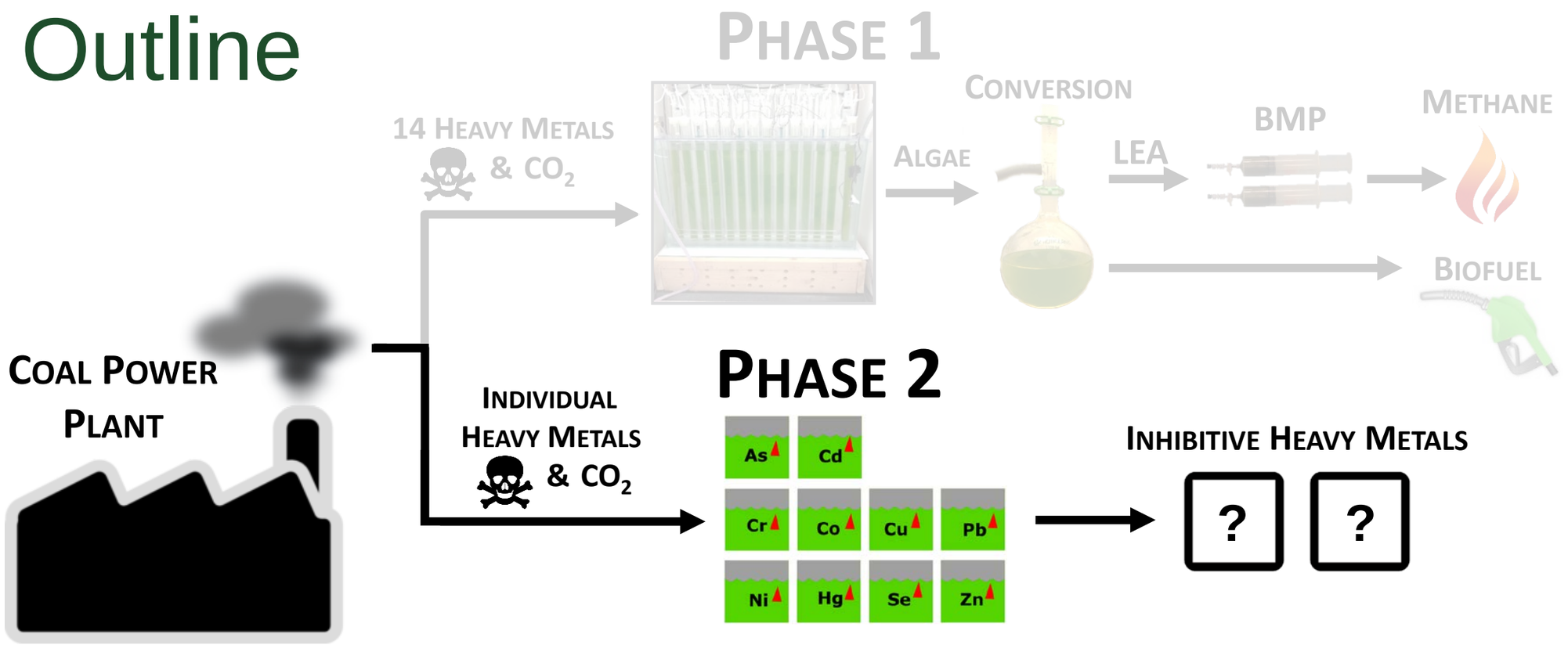


Lipid Yield

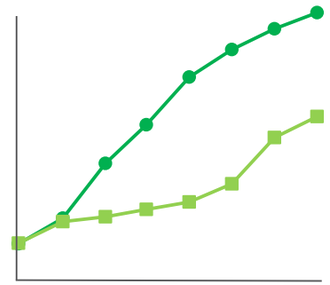


Fate of Metals

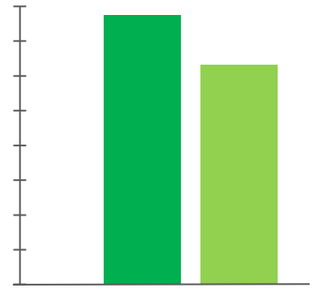
Outline



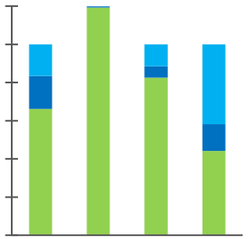
RESULTS



PRODUCTIVITY



LIPID YIELD



FATE OF METALS

Outline

Phase 1

14 Heavy Metals & CO_2

Algae

Conversion

LEA

BMP

Methane

Biofuel

Phase 2

Individual Heavy Metals & CO_2

Inhibitive Heavy Metals

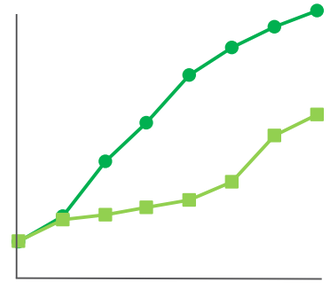
Phase 3

Heavy Metals & CO_2

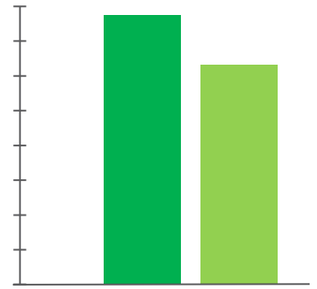
Algae

Coal Power Plant

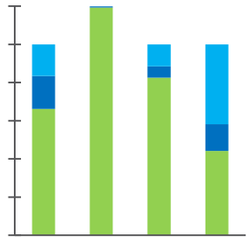
Results



Productivity

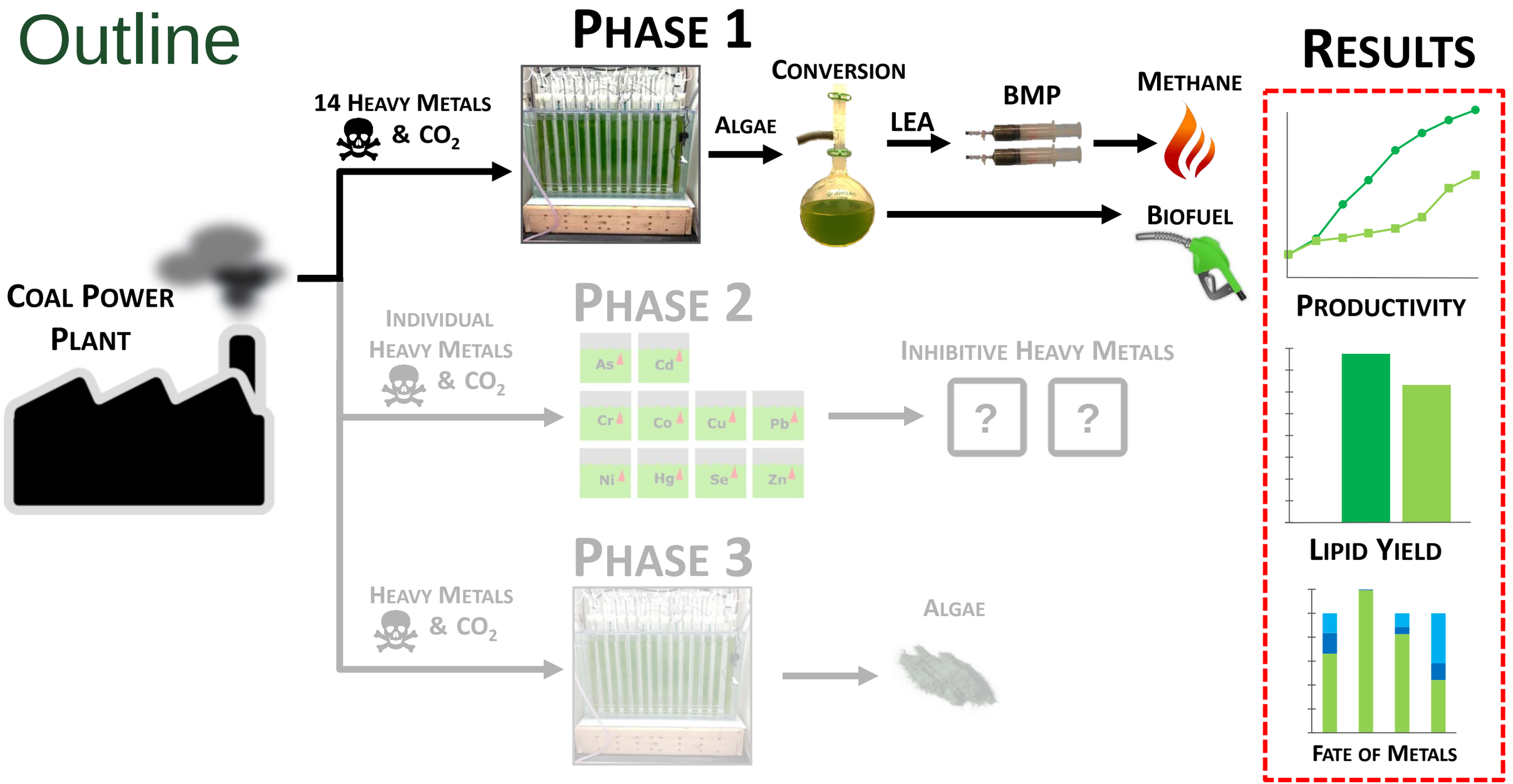


Lipid Yield



Fate of Metals

Outline


PHASE 1
14 HEAVY METALS & CO_2
ALGAE
CONVERSION
LEA
BMP
METHANE
BIOFUEL
COAL POWER PLANT
PHASE 2
INDIVIDUAL HEAVY METALS & CO_2
As
Cd
Cr
Co
Cu
Pb
Ni
Hg
Se
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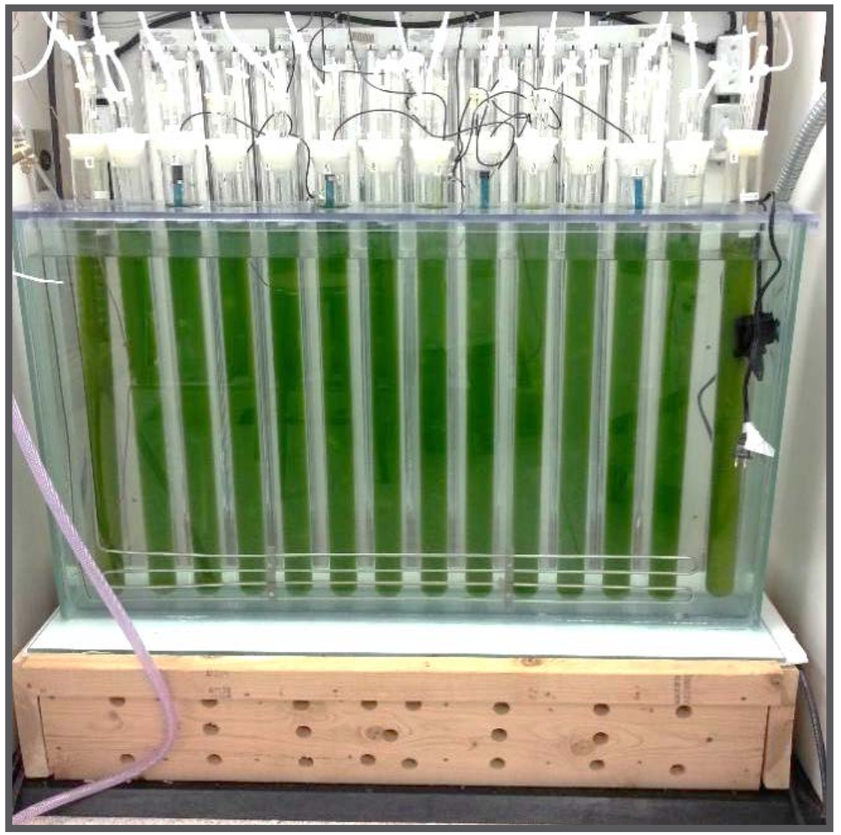
INHIBITIVE HEAVY METALS
?
?
PHASE 3
HEAVY METALS & CO_2
ALGAE
RESULTS
PRODUCTIVITY
LIPID YIELD
FATE OF METALS

Growth Setup

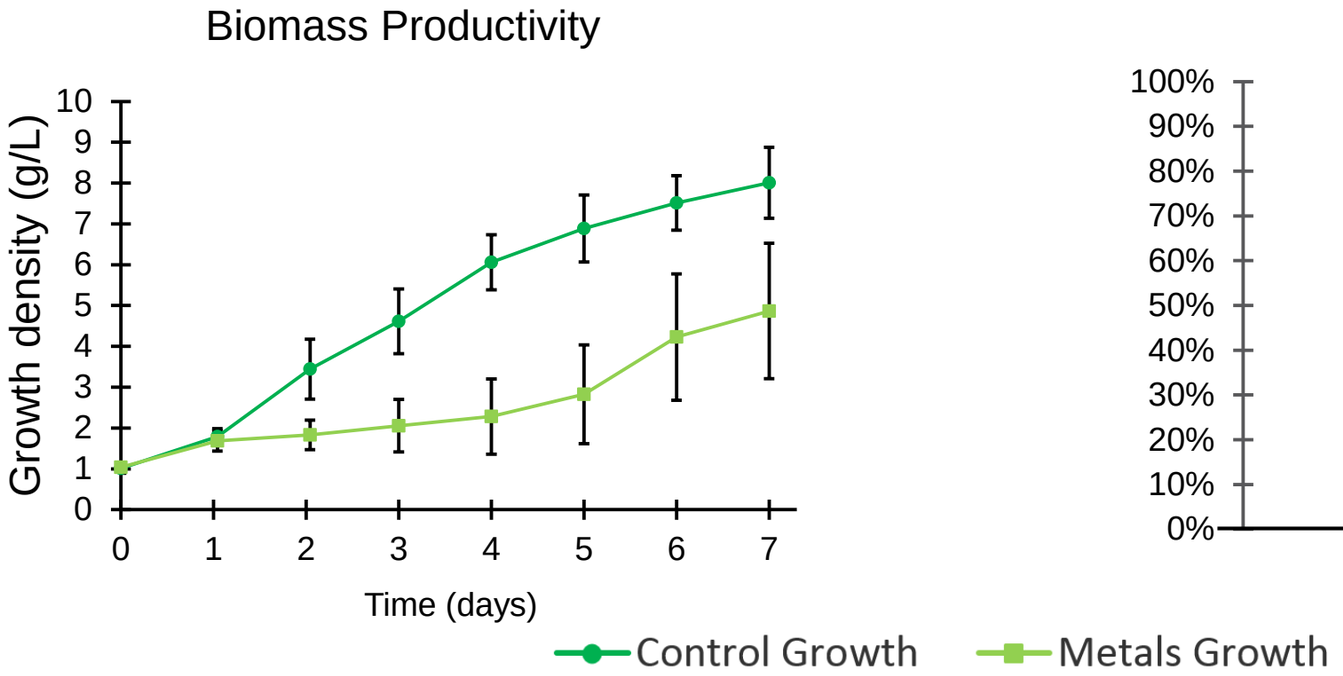
14 Heavy metals used

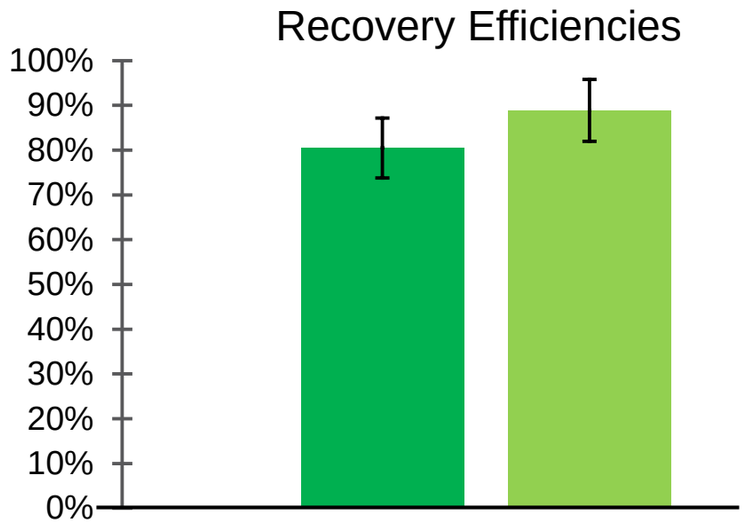
1X		
Element	Fly Ash (mg metal·kg-1)	PBR (mg metal * L^{-1})
As	391.0	0.078
Cd	76.0	0.015
Co	79.0	0.016
Cr	651.0	0.130
Cu	655.0	0.131
Hg	49.5	0.010
Mn	745	0.149
Ni	1270.0	0.250
Pb	273.0	0.054
Sb	203.0	0.041
Se	49.5	0.010
Sn	18.8	0.004
V	565.0	0.113
Zn	2200.0	0.440

Nannochloropsis salina



Microalgae Productivity and Conversion Results





- Impact of metals on production:
  - Growth: 45.5% decrease
  - Lipid Yield: 18.6% decrease

Productivity: 56% decrease in total lipid production

- Impact of metals on extraction:
  - Control: 80% ± 7%
  - Metals : 89% ± 7%

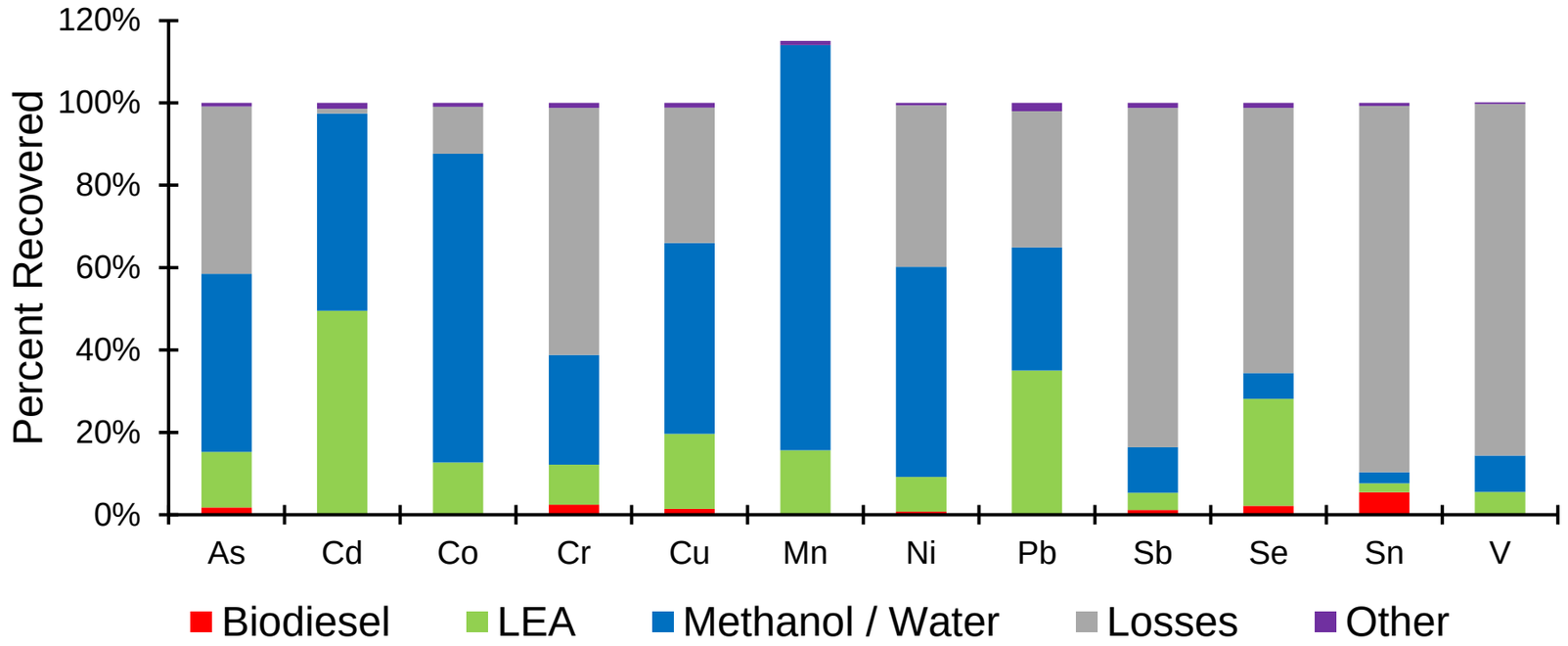
Conversion: 9% increase in recovery efficiency

Combined impact (productivity & recovery): *51%* decrease in lipid production

ICPMS: Fate of Metals

ICPMS analyses of the biofuel, and all by-products

Majority of heavy metals found in LEA and Methanol / Water by-products.
Minimal Biofuel Contamination



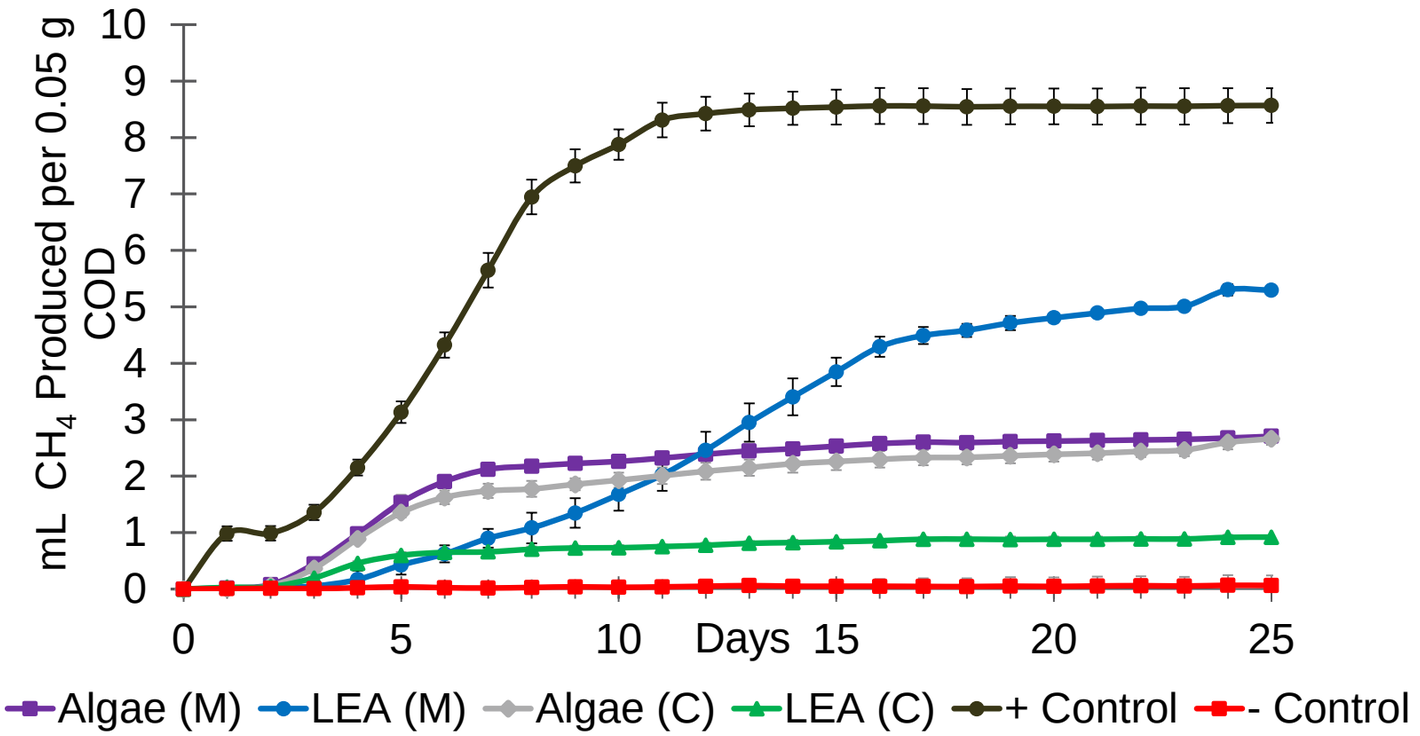
* The metal Zn was removed due to contamination

** The metal Hg conc. was below ICPMS detection limit

BMP Results

% Methane	
Algae (Metals)	36.28
LEA (Metals)	49.45
Algae (Control)	37.47
LEA (Control)	36.87 *
+ Control	46.94
- Control	36.87 *

* Estimation of conc. Volume produced was below GC detection limit.



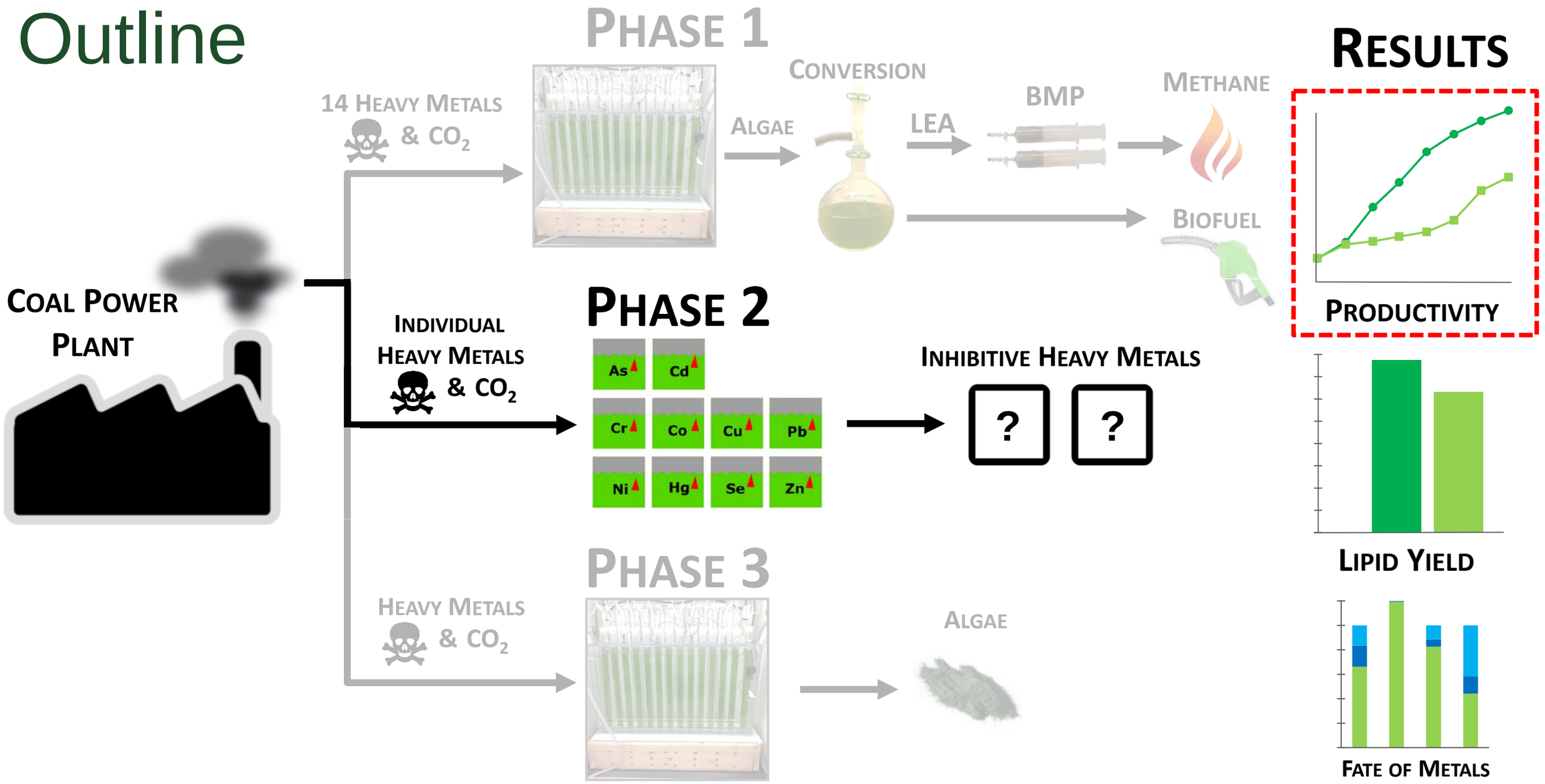
Methane Concentration increased by 12%

Methane Production is 65% of optimum

Weaknesses of Phase 1

- Which heavy metal(s) inhibit growth is unknown
- Chemostat addition of heavy metals would be more representative of actual growth system than batch addition of heavy metals.

Outline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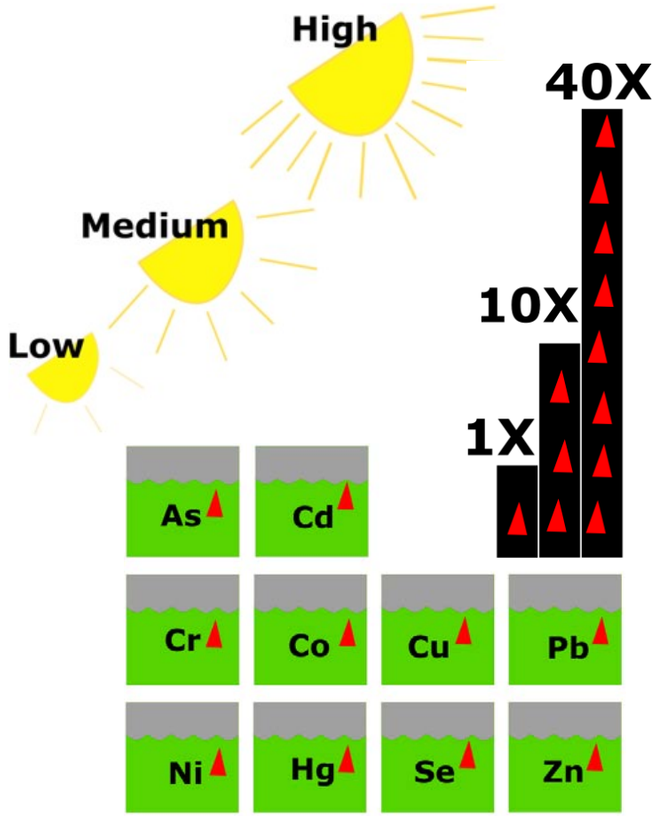
Experimental Design



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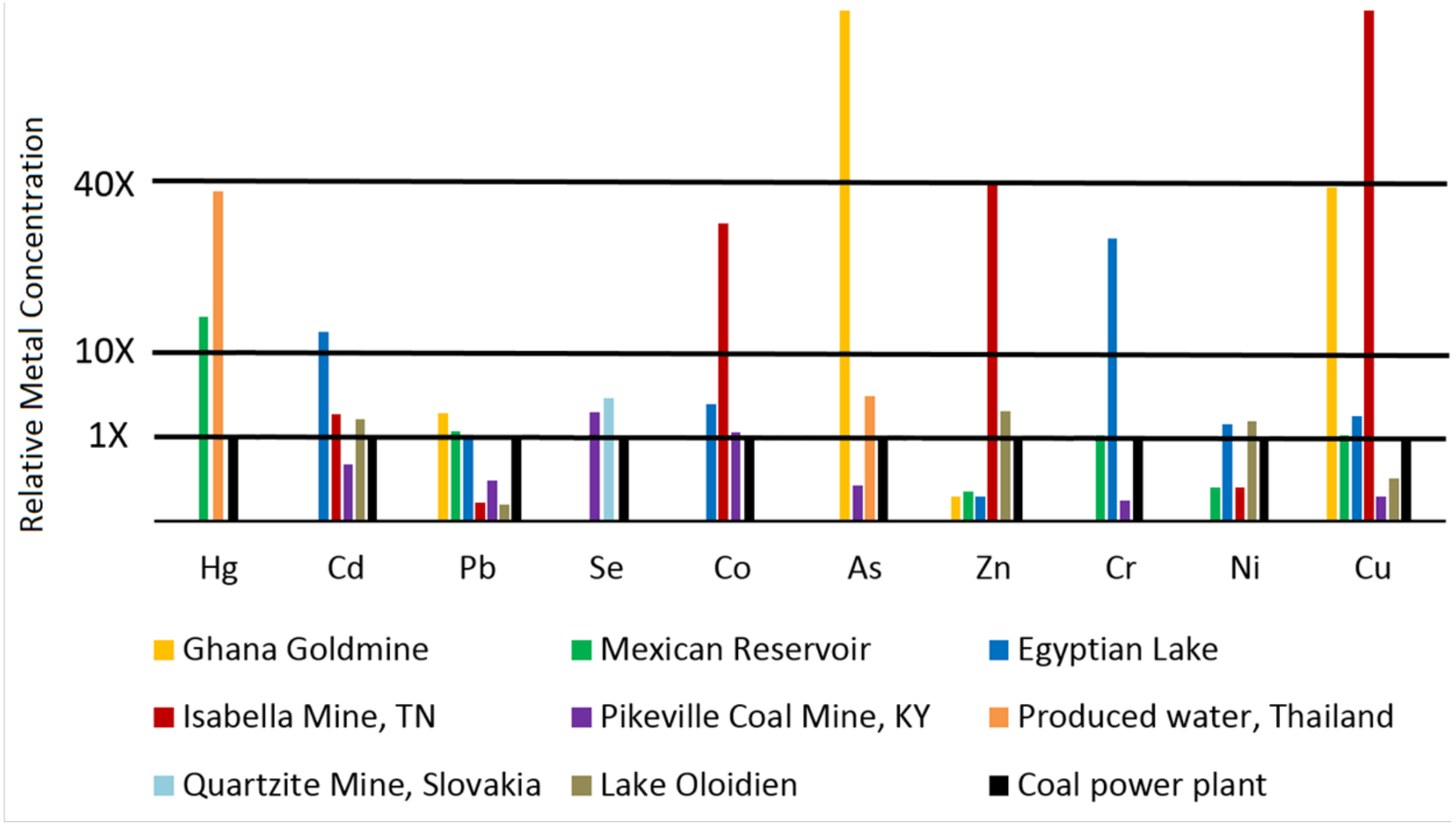
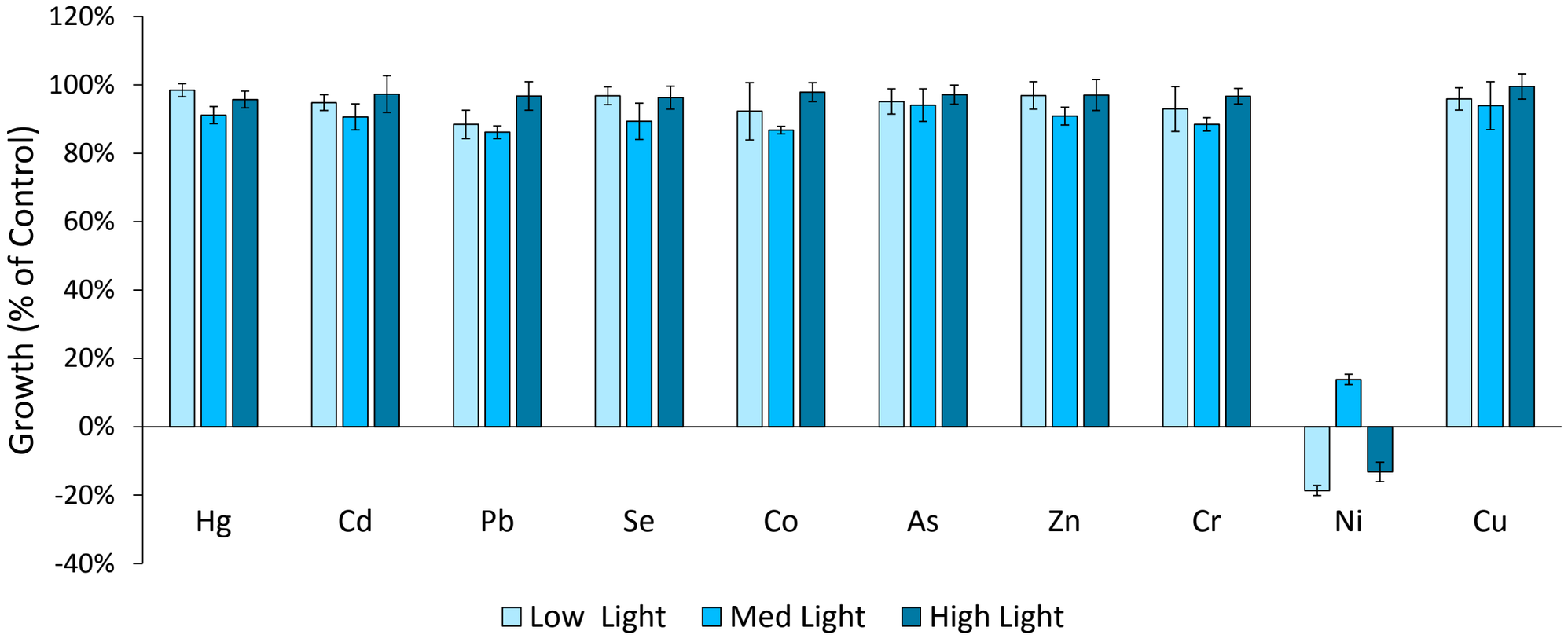
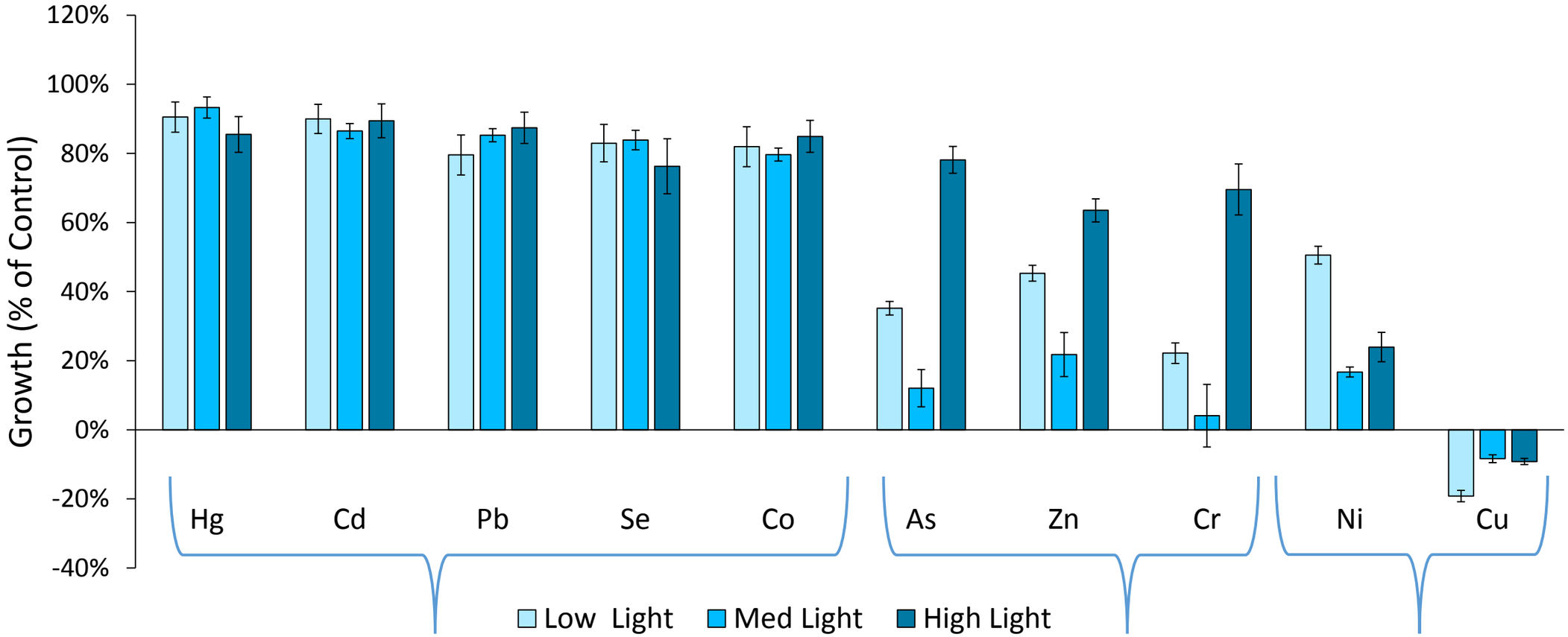


Effects on Growth- 1X Concentration



Nickel inhibits growth

Effects on Growth- 40X Concentration

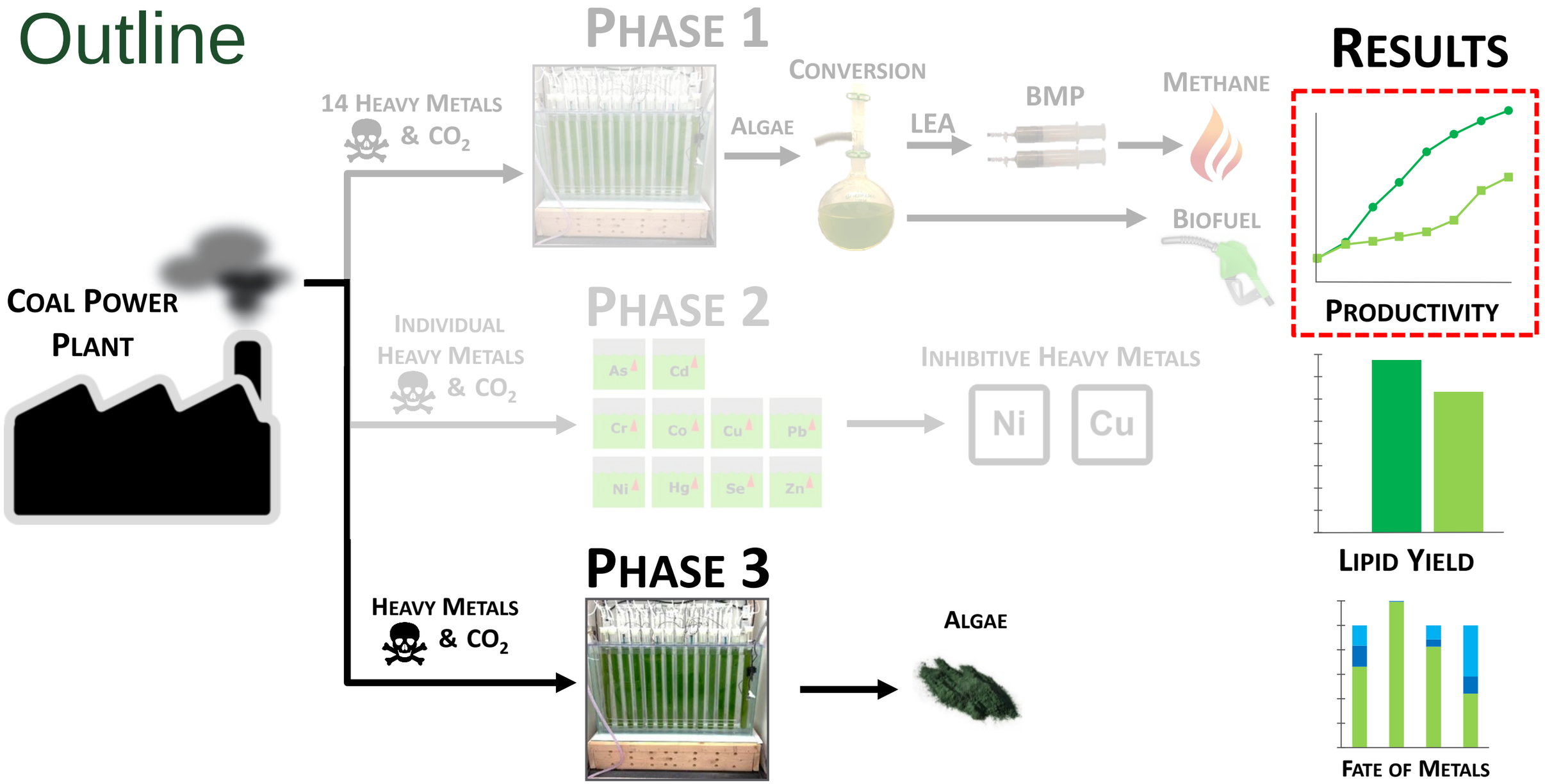


Slight decrease in growth

High light overcomes inhibitory effects

Copper kills the algae while Ni inhibits growth

Outline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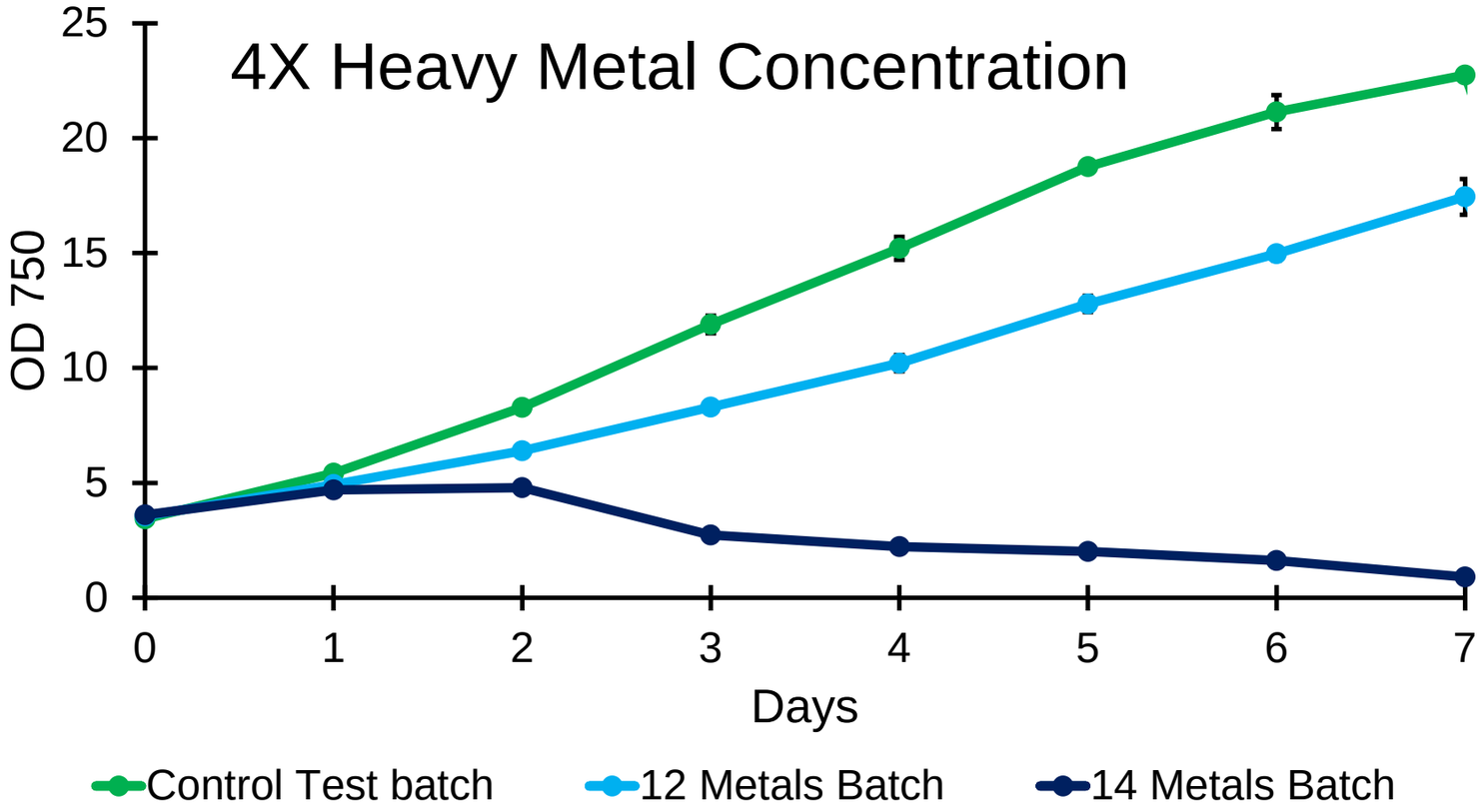
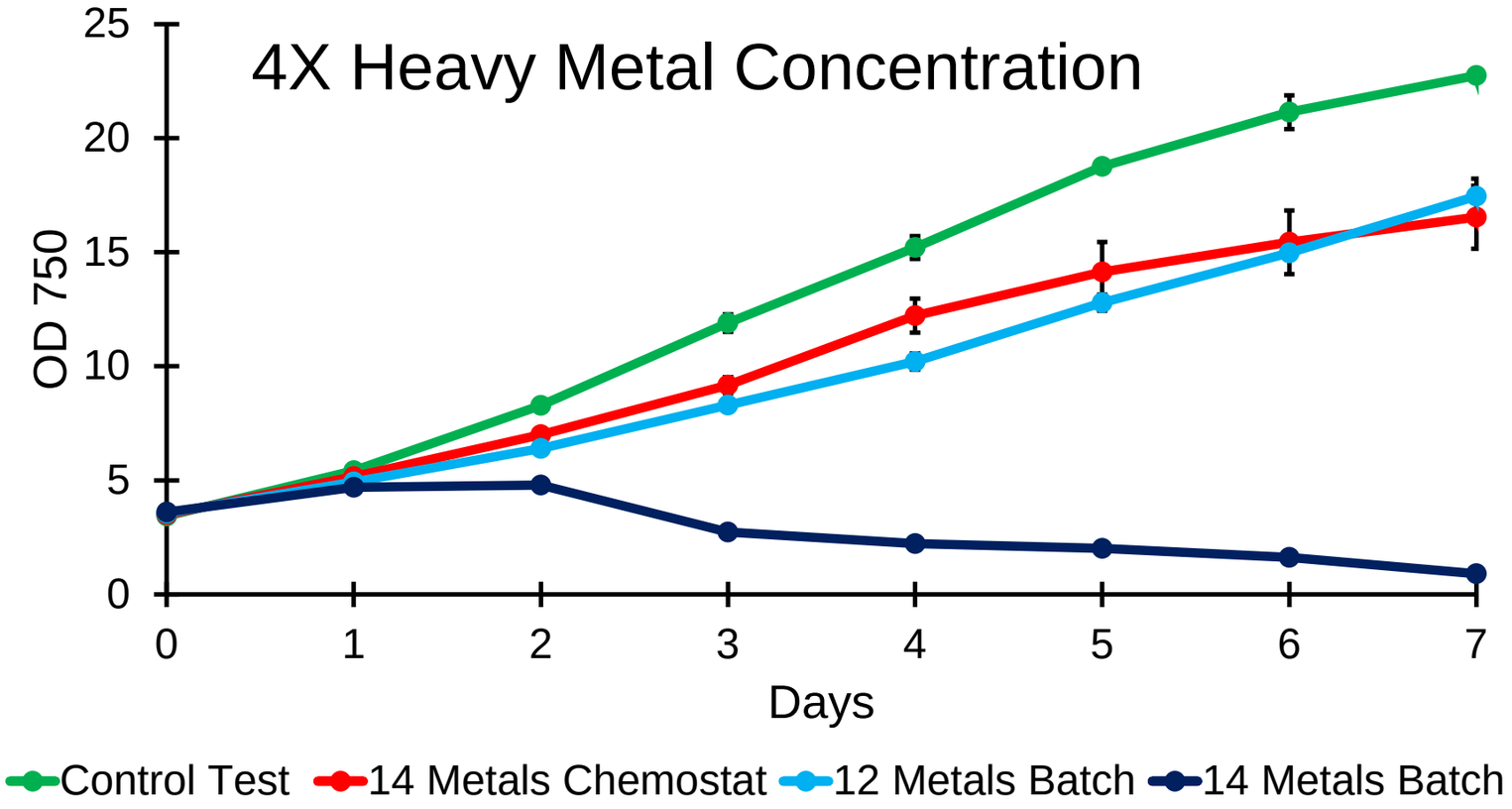
12 Heavy Metals and Chemostat



12 Heavy Metal: 23.31% decrease

12 Heavy Metals and Chemostat



12 Heavy Metal: 23.31% decrease

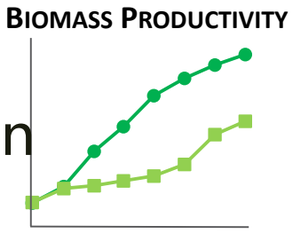
Chemostat 14 Heavy Metal: 27.33% decrease

Future Work

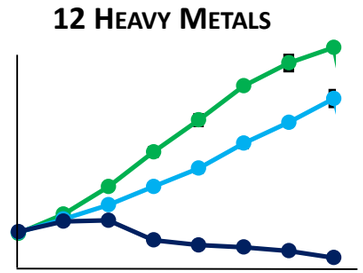
- Further investigation of chemostat approach at various heavy metal concentrations.
- Model relationship between chemostat and batch cases.
- Model media reuse by combining batch and chemostat approaches.

Conclusions

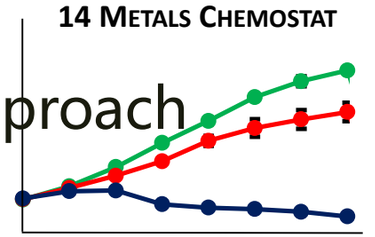
- Metals Negatively Impact Biofuel Production



- Reduction of Ni and Cu increases microalgae growth



- Microalgae shows greater resistance to chemostat approach



- Chemostat approach should be utilized for TEA and LCAs.

Thank You

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