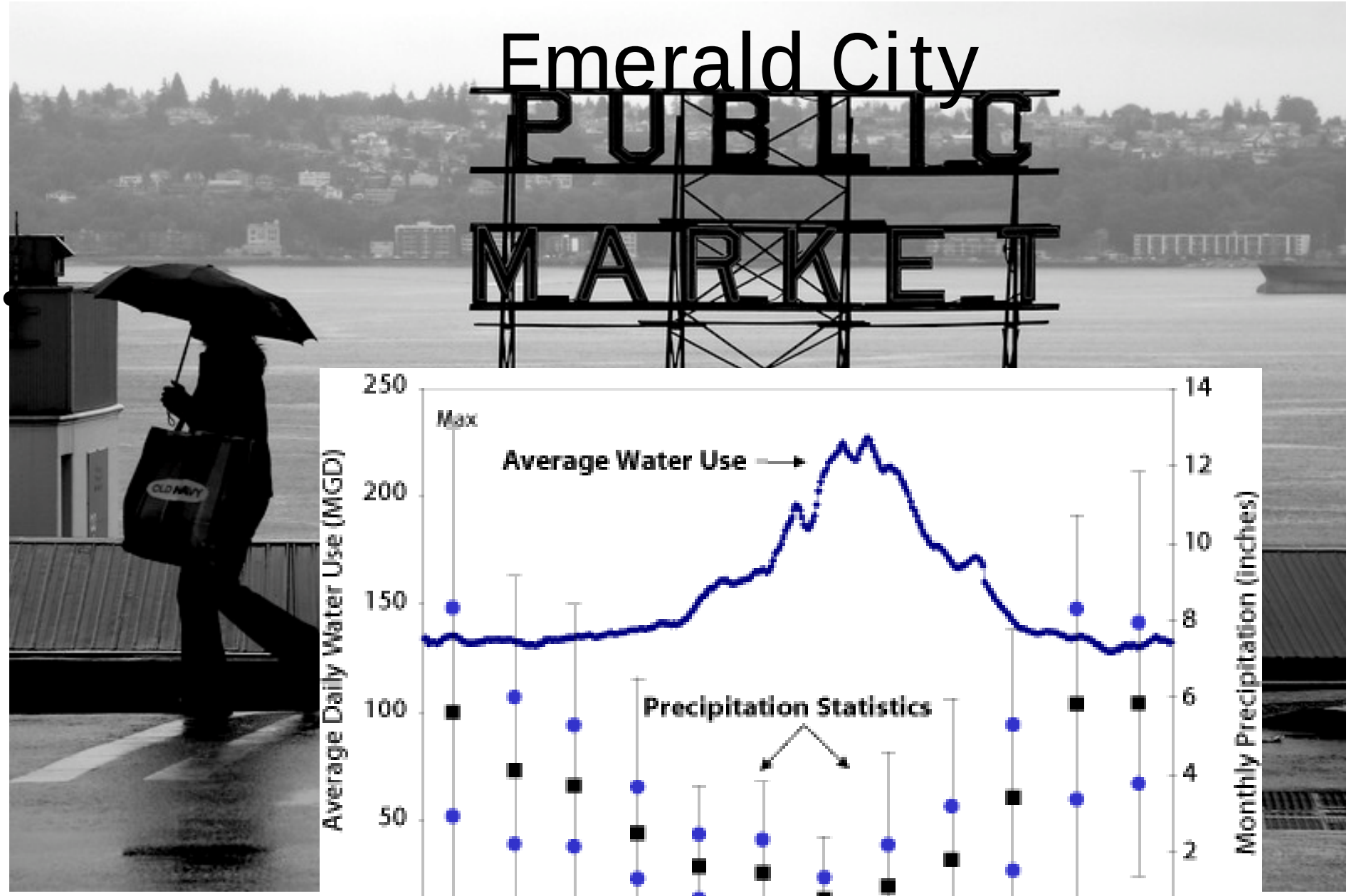
Developing a Reclaimed Water Program in King County

Sally Brown, Dana Devin-Clarke, Hannah Kinmonth-Schultz, and Soo-Hyung Kim

University of Washington

Emerald City



Then there is the question of wildlife impacts of conventional discharges

- Excess nutrients-
  - Aquatic systems can cause eutrophication
  - Soil system are a resource
- Endocrine disrupting compounds
  - Evidence of harm in aquatic systems
  - No evidence of harm in soil systems

Time for a Reclaimed water program

- **Prove safety**
  - **For public perception**
    - **Metals**
    - **Pathogens**
    - **Microconstituents**
- **Demonstrate benefits**
  - **For farmer/golf course superintendent…**
    - **Reduced nutrient requirements**
    - **Positive effects for plants**
    - **No harm to soil/produce turf quality**

Two studies:

Turf grass

- Geared to potentially largest market for reclaimed water: landscaping and golf courses

Edible crops and flowers

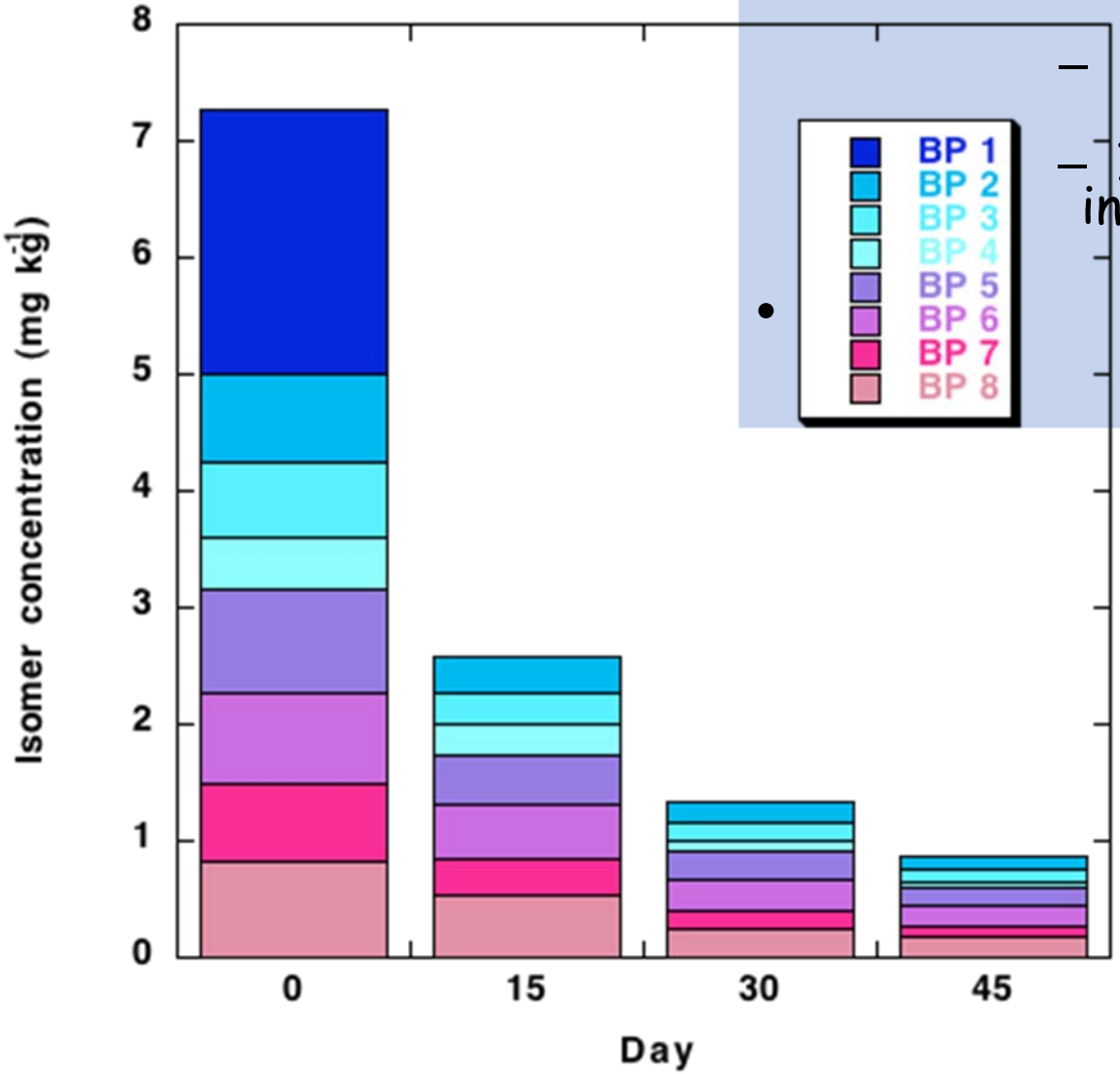
- Local agriculture- improve economics and sustainability
- Highest area for public concern

For each:

- **Safety of practice**
  - Contaminants of concern
  - Pathogens
  - Metals
  - Soil properties
- **Benefits of use**
  - Fertilizer value
  - Growth response

Background

- King County sponsored previous research on nonylphenol
  - Brown et al., 2009
  - Present at high concentrations in biosolids
  - Known endocrine disrupting potential
  - It degrades quickly with no indication of accumulation of metabolites



Extraction and Analysis of Estrogens and Triclosan Introduced into a Soil System through Reclaimed Water and Biosolids

By
Dana Devin-Clarke and Sally E
University of Washingto

Turf grass-
Growth response + microconstitutents

- **Turf collected from area course**
  - **5 cm depth squares**
- **Potted over sand**

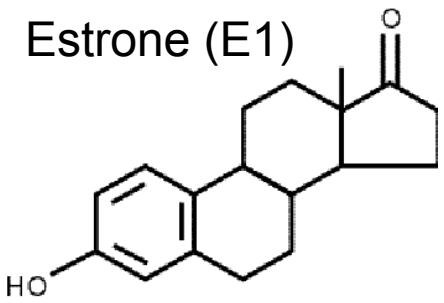
Treatments- water source x fertilization

- **Control (Tap water + 100%Fert)**
- **Reclaimed water (RW) only**
  - **2.75 l per pot**
- **Biosolids (Tap water only)**
  - **7.5 Mg ha**

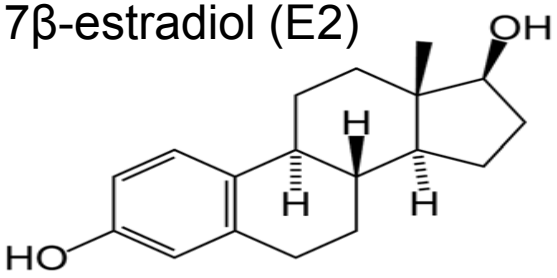
- **Monitored from 07/05/07 - 12/18/07**

Contaminants of concern selected for study

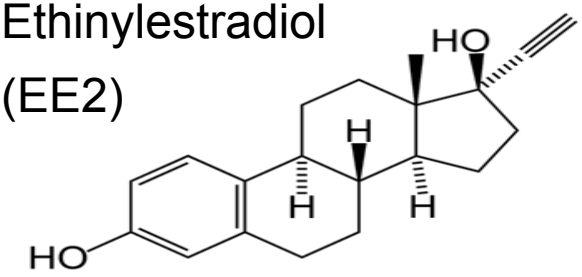
Estrone (E1)



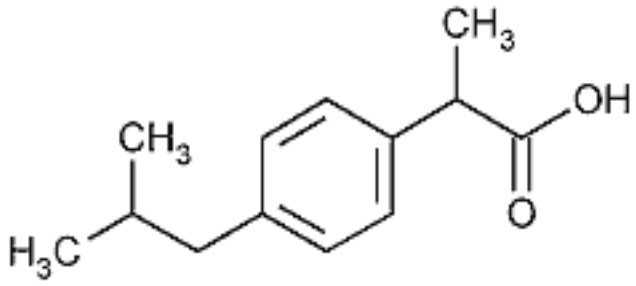
17β-estradiol (E2)



Ethinylestradiol (EE2)

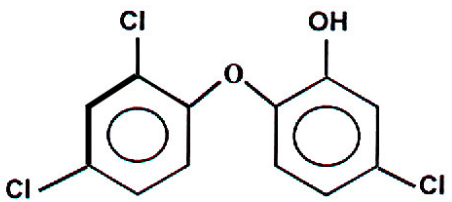


Ibuprofen



Triclos

Triclosan



Contaminants from 3 groups Easily recognized by public That we could analyze for

- Pharmaceutical
  - Ibuprofen
- EDC
  - Estrogens
- Anti-microbial
  - Triclosan

We analyzed:

- Reclaimed water and biosolids
- Leachate
  - Every 2 weeks
  - Not all water was collected at each watering
- Soils (end of study)
  - Soils split into 3 depths
- Plants (end of study)
  - Single harvest, above ground plant tissue

Estrogens in the Reclaimed Water

Concentration of estrogens in reclaimed water (RW): added 6 liters from 7/5 – 12/11

Collections	E1 (µg/L)	Recovery %	E2 (µg/L)	Recovery %	EE2 (µg/L)	Recovery %
1	0.267	103	0.035	105	0.046	120
2	0.003	75	< MDL	79	0.035	66
3	0.038	70	0.032	72	0.0044	86
4	0.018	82	0.012	91	*	*
5	0.014	95	0.014	98	< MDL	101
Avg +/- St. error	**0.068 +/- 0.049**		**0.019 +/- 0.0065**		**0.021 +/- 0.011**	

- MDL = samples less than 0.0012 µg/L (E1) and 0.002 µg/L for E2 and EE2 were listed < MDL;
- EE2 response changes over time, with a decrease in sample concentration after a month of storage

Estrogens in the biosolids

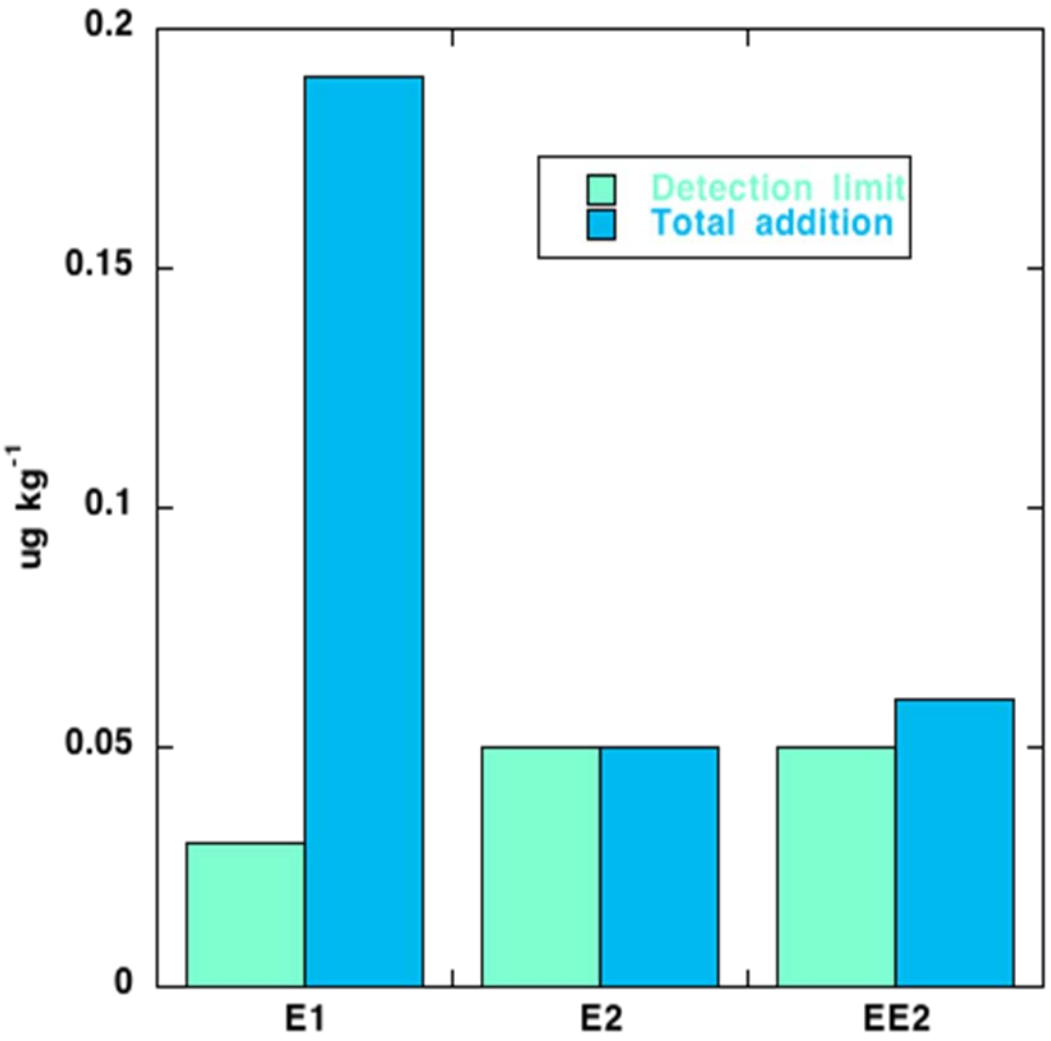
Compound	Biosolid 1	Biosolid 2	Average
E1	153.2	150.4	151.8
E2	10.8	10.4	10.6
EE2	4.6	5	4.8

Results-Estrogens in the leachate (n=10)

Treatment	E1 (µg l)	Avg. Recovery +/- st. error	E2 (µg l)	Avg. Recovery +/- st. error	EE2 (µg/l)	Avg. Recovery +/- st. error
Control	< MDL	102+/-0.4	< MDL	111+/-1.5	< MDL	101+/-1.0
RW	< MDL	106+/-0.6	< MDL	151+/-4	< MDL	100+/-1.0
Biosolids	< MDL	101 +/- 0.5	< MDL	102 +/- 0.6	< MDL	95+/-0.6

on-column value of 0.3 ng/mL for E1 (or final

Estrogens in the soil samples



• The detection limits in the soil system for E1 was 0.03µg/kg and 0.05 µg/kg for E2 and EE2.

The amount of E1, E2 and EE2 added the pots by the reclaimed water totaled about 0.187, 0.052, and 0.058 µg.

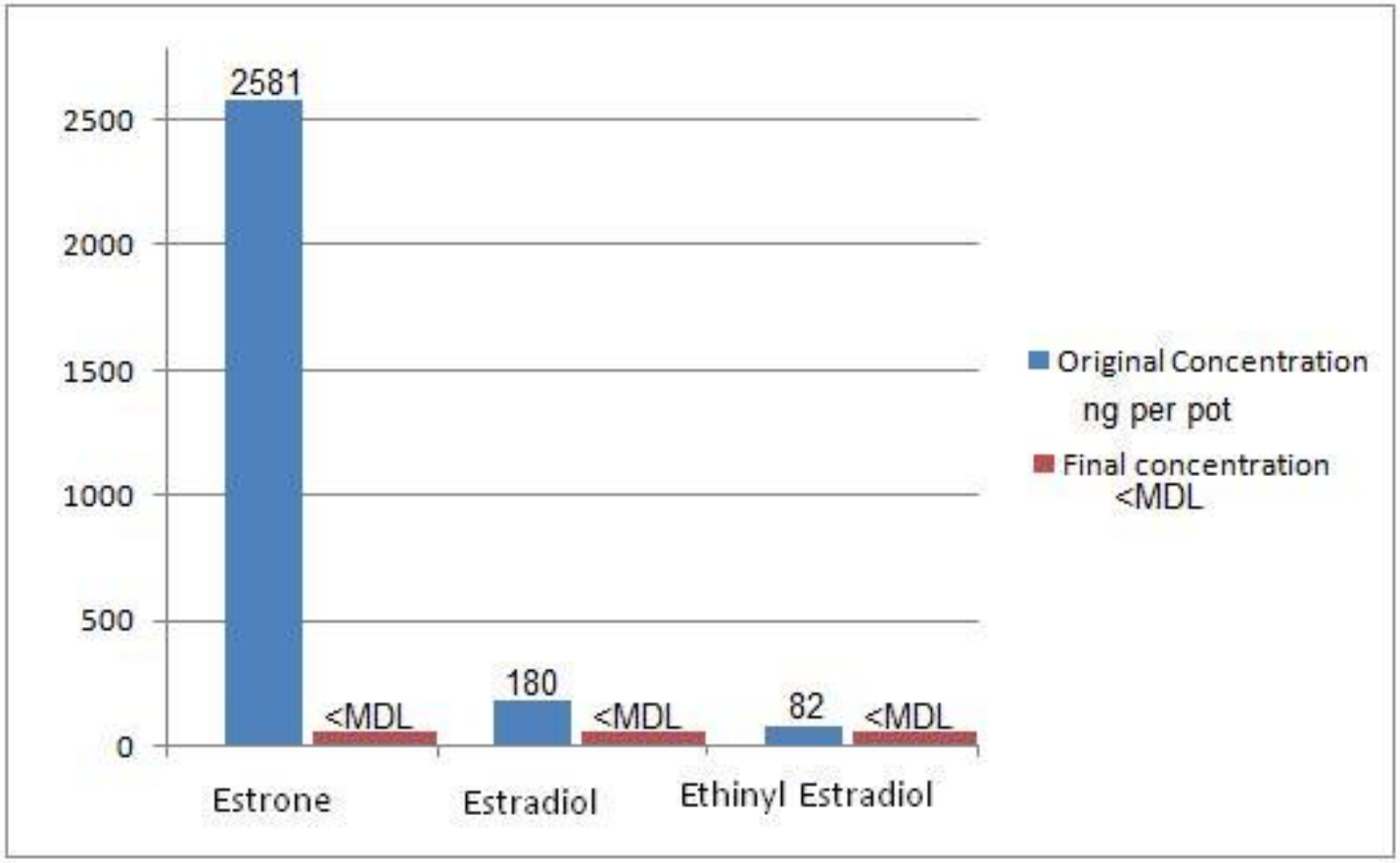
When soil weight is taken into account, the total loading rate was below the method detection limit.

Soils were analyzed and no estrogen was detected

Estrogen degradation after solids application

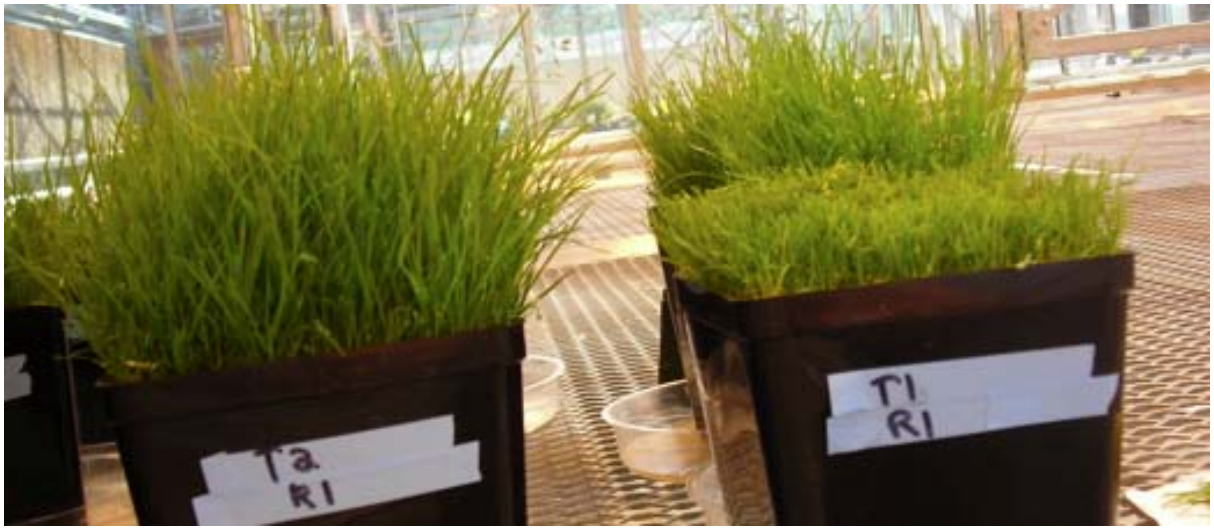
Addition with solids was sufficient to detect change over time

If you date biosolids, act quickly before the estrogen is all gone



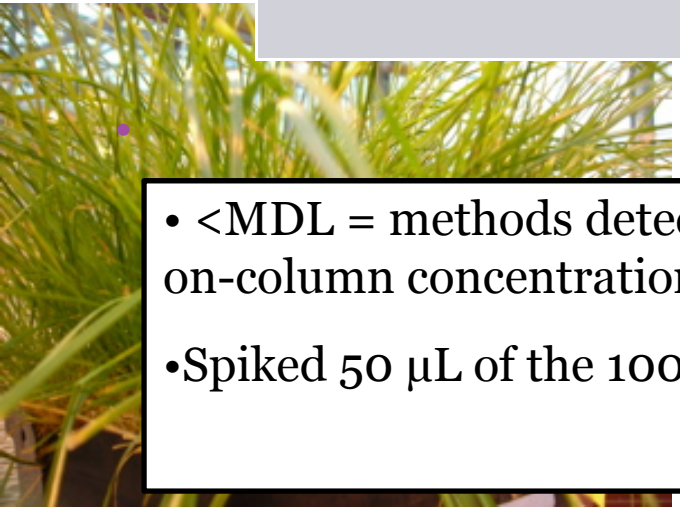
Estrogens in the Plant Samples

Treatment	E1 (µg kg)	Avg. Recovery +/- st. error	E2 (µg kg)	Avg. Recovery +/- st. error	EE2 (µg kg)	Avg. Recovery +/- st. error
Control	< MDL	102+/-0.4	< MDL	111+/-1.5	< MDL	101+/-1.0
RW	< MDL	106+/-0.6	< MDL	151+/-4	< MDL	100+/-1.0
Biosolids	< MDL	101 +/- 0.5	< MDL	102 +/- 0.6	< MDL	95+/-0.6



Triclosan in reclaimed water

Compound	RW source
Triclosan (µg/L)	**1.23 +/- 0.5**
C13-Triclosan (µg/L)	6.08 +/- 0.22
Recovery (%)	119 +/- 4



- <MDL = methods detection limit is <0.025 (µg/L) sample concentration or on-column concentrations of 0.25 (µg/mL)
- Spiked 50 µL of the 100 µg/L C_{13}-Triclosan into each sample

Results: Triclosan in Biosolids

3 samples of 0.5 g of air dried biosolids were mixed with sand and hydromatrix
Cells were spiked with 50 µL of C13-Triclosan

Dental hygiene is higher priority for biosolids than for reclaimed water

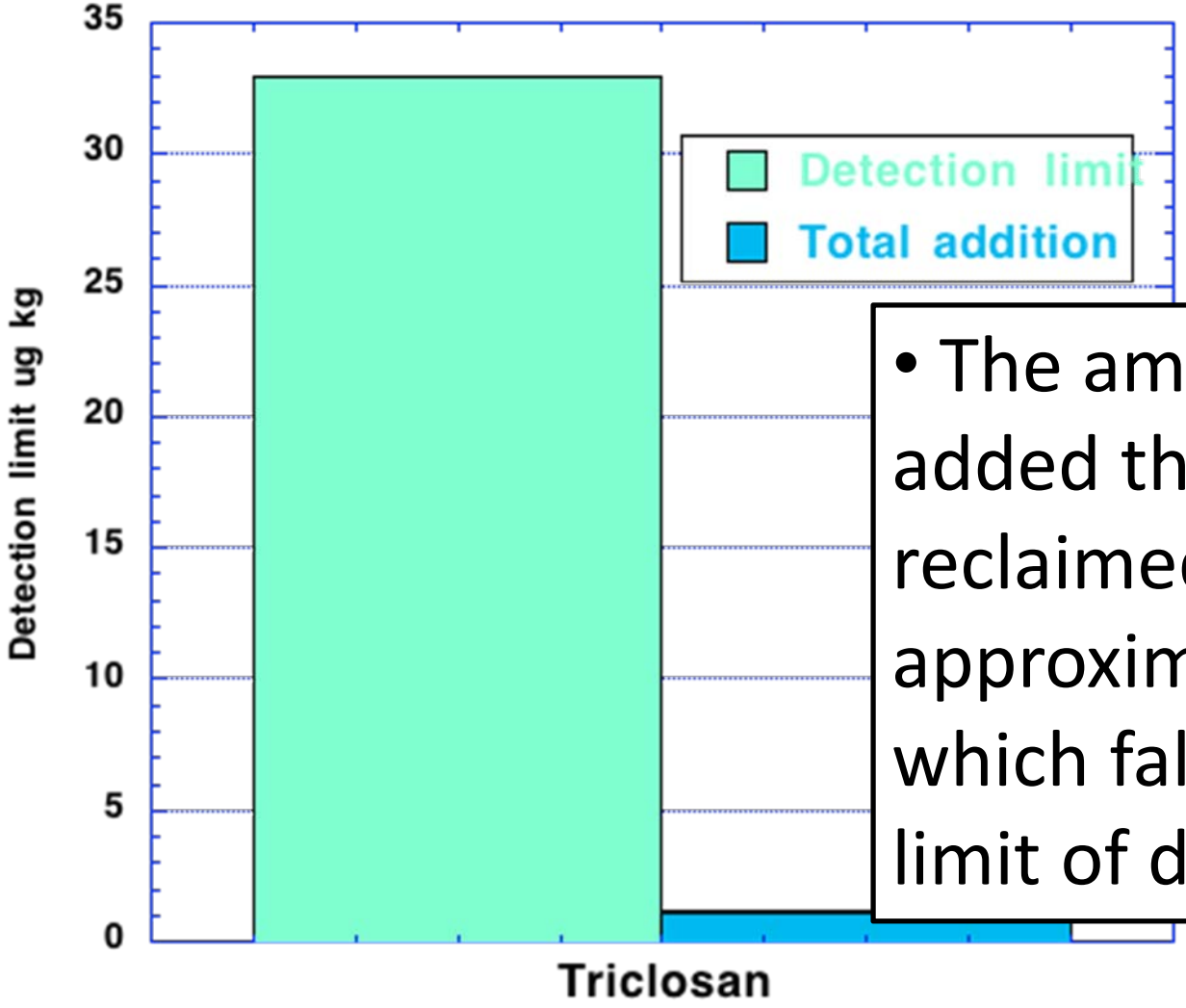
Compound	B 1	B 2	B 3
Triclosan (µg kg)	37200	32920	34800
Recovery (%)	117	104	111

Triclosan in leachate

Compound	RW source	Control	RW	RW- 50% Fert	RW – 100% Fert
Triclosan (µg/L)	**1.23 +/- 0.5**	< MDL	< MDL	< MDL	< MDL
C_{13}-Triclosan (µg/L)	6.08 +/- 0.22	4.52 +/- 0.87	6.06 +/- 0.59	6.62 +/- 0.62	6.51 +/- 0.36
Recovery (%)	119 +/- 4	102	109	120	123

- <MDL = methods detection limit is <0.025 (µg/L) sample concentration or on-column concentrations of 0.25 (µg/mL)
  - Spiked 50 µL of the 100 µg/L C_{13}-Triclosan into each sample

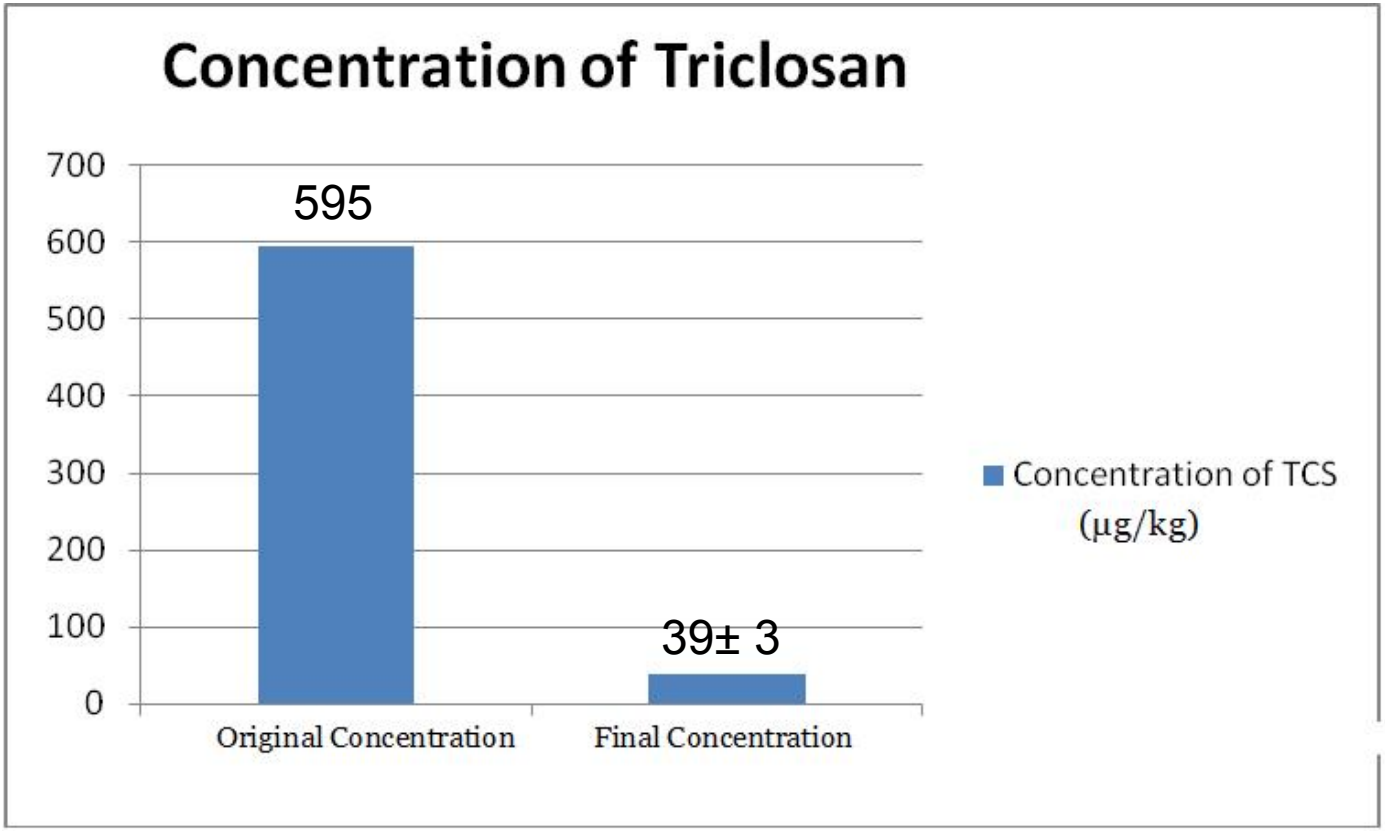
Triclosan in the soil samples



- The amount of TCS added the pots by the reclaimed water totaled approximately 1.23 µg/L, which falls well below the limit of detection

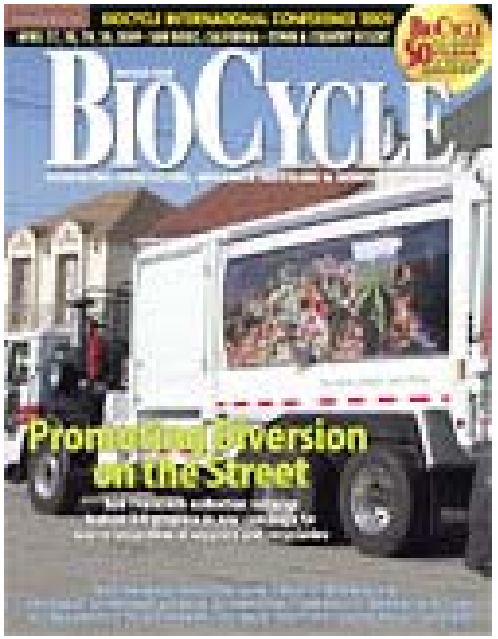
Triclosan degradation after biosolids application

(initial concentration calculated based on soil weight and biosolids addition)

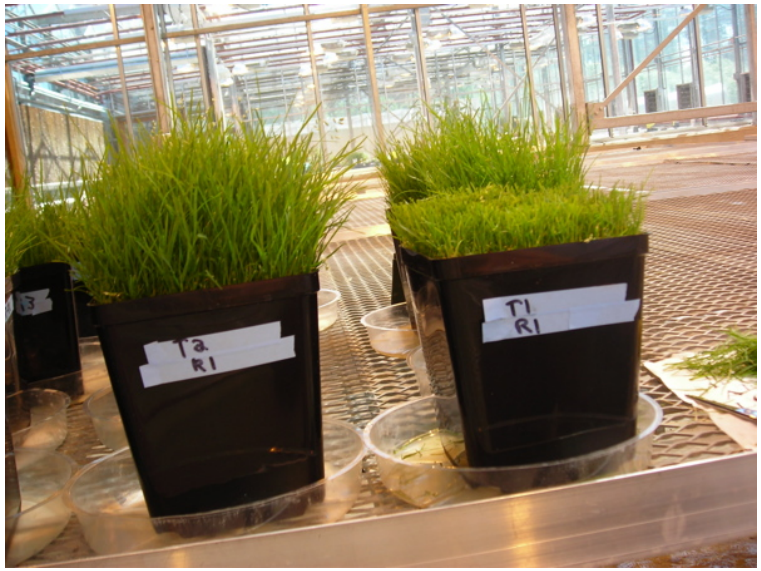


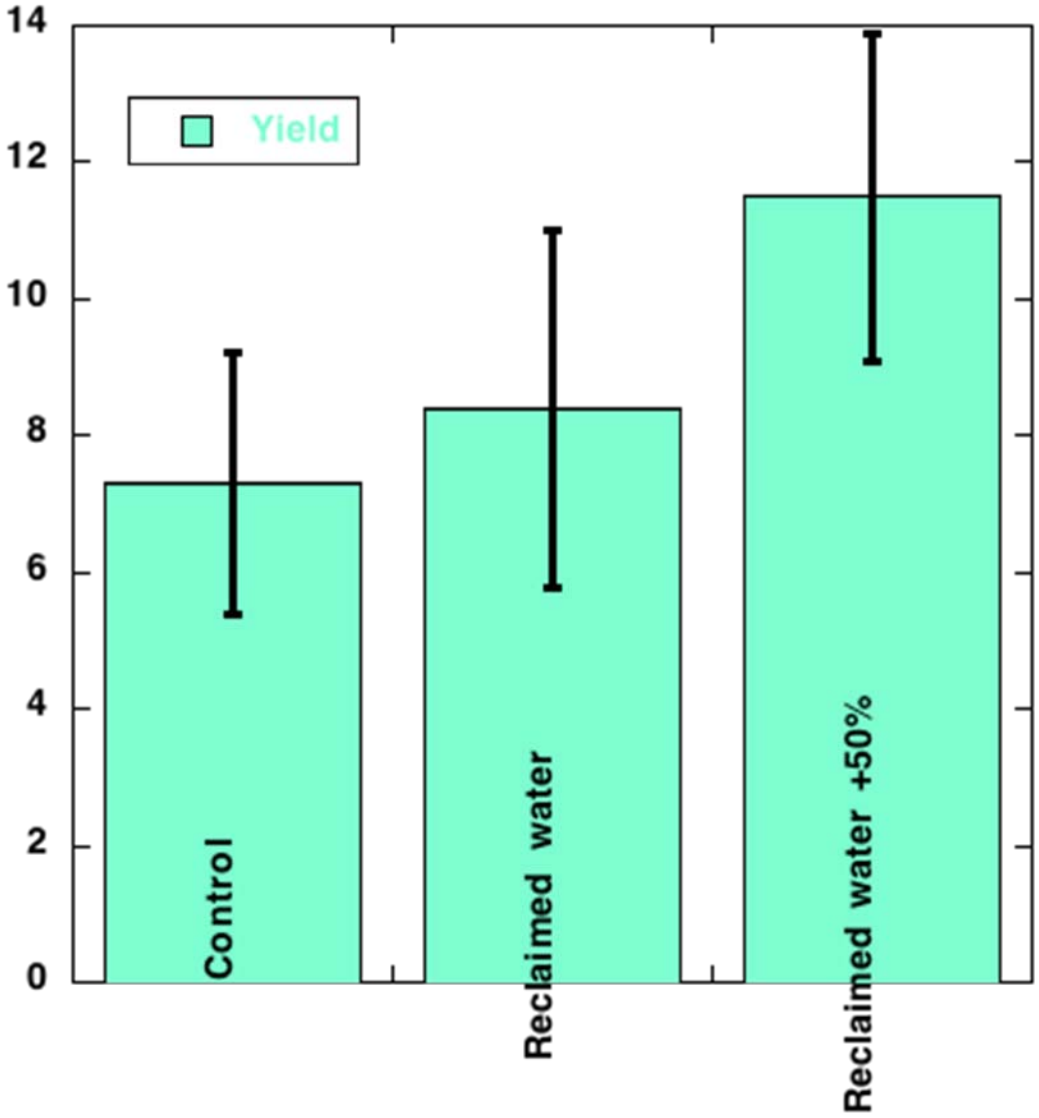
Conclusions:

- Not designed as a complete fate and degradation study, more to get a picture
- Reclaimed water is not a significant source of estrogen or triclosan to a soil system
- When applied at high concentrations with biosolids, the compounds readily degraded over time
- For the end harvest, estrogen and triclosan were below detection limits in grass



Perhaps the real take home message…..



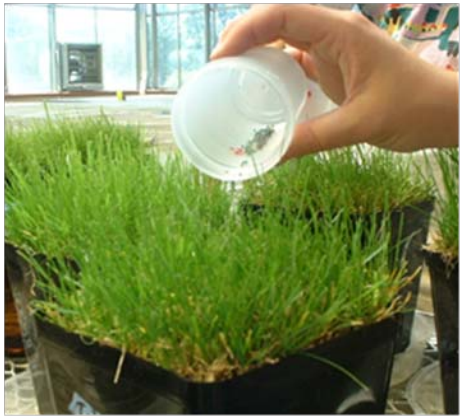


Soils- product quality

Treatment	Soil pH	Soil EC
Control	4.85	0.2
Reclaimed water	5.5	0.3
Reclaimed water + 50% fertilizer	5.3	0.2
Reclaimed water + 100% fertilizer	5.3	0.4

Reclaimed Water Nutrient Addition

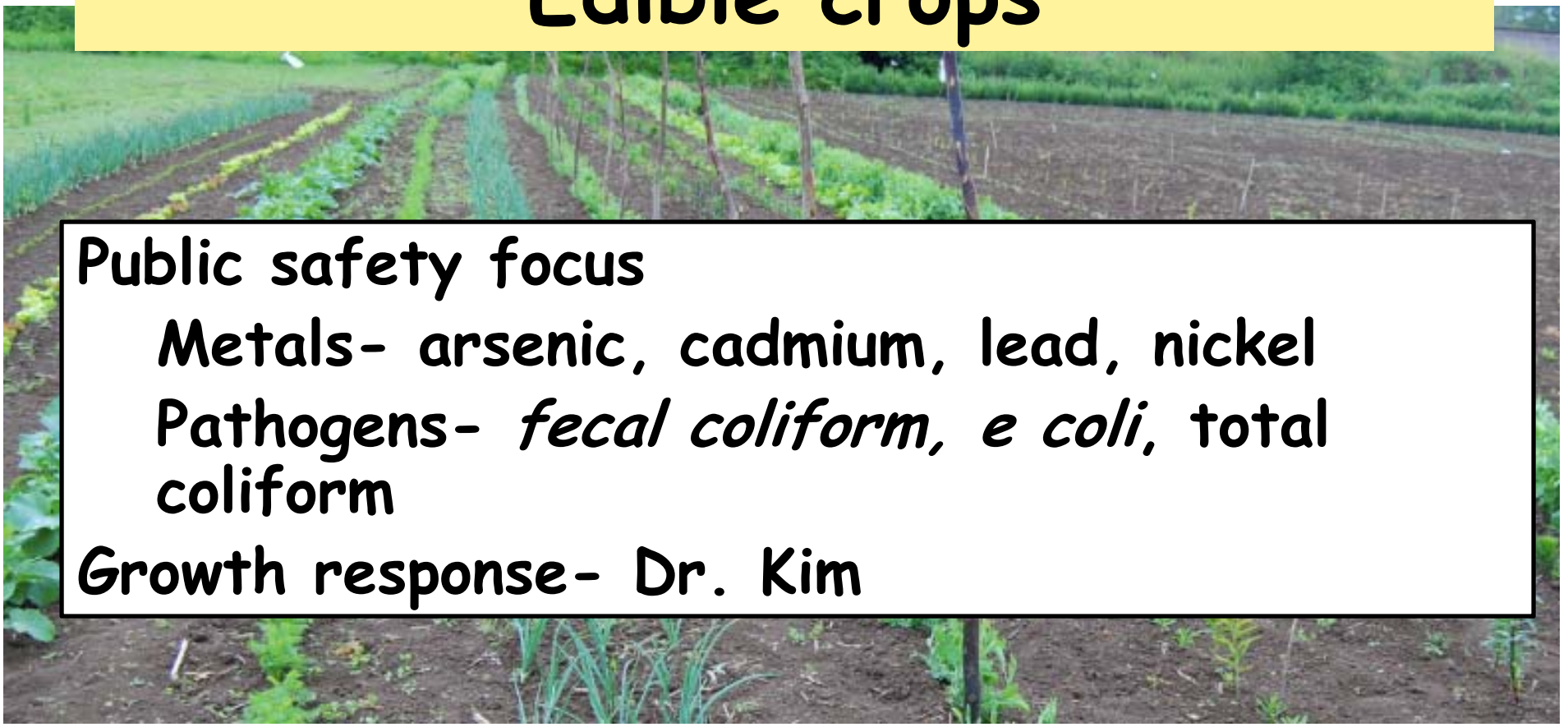
Nutrient	Pounds per inch per acre	Pounds per inch per 1000 sq ft
Total N	15.8 ± 2.3	0.36
Total P	0.5 ± 0.1	0.01
Total K	3.6 ± 0.2	0.08



Conclusions:

- For customer
  - High nutrient value
  - Beneficial for soils
- For public
  - No movement or plant uptake of microconstituents

Edible crops



Public safety focus

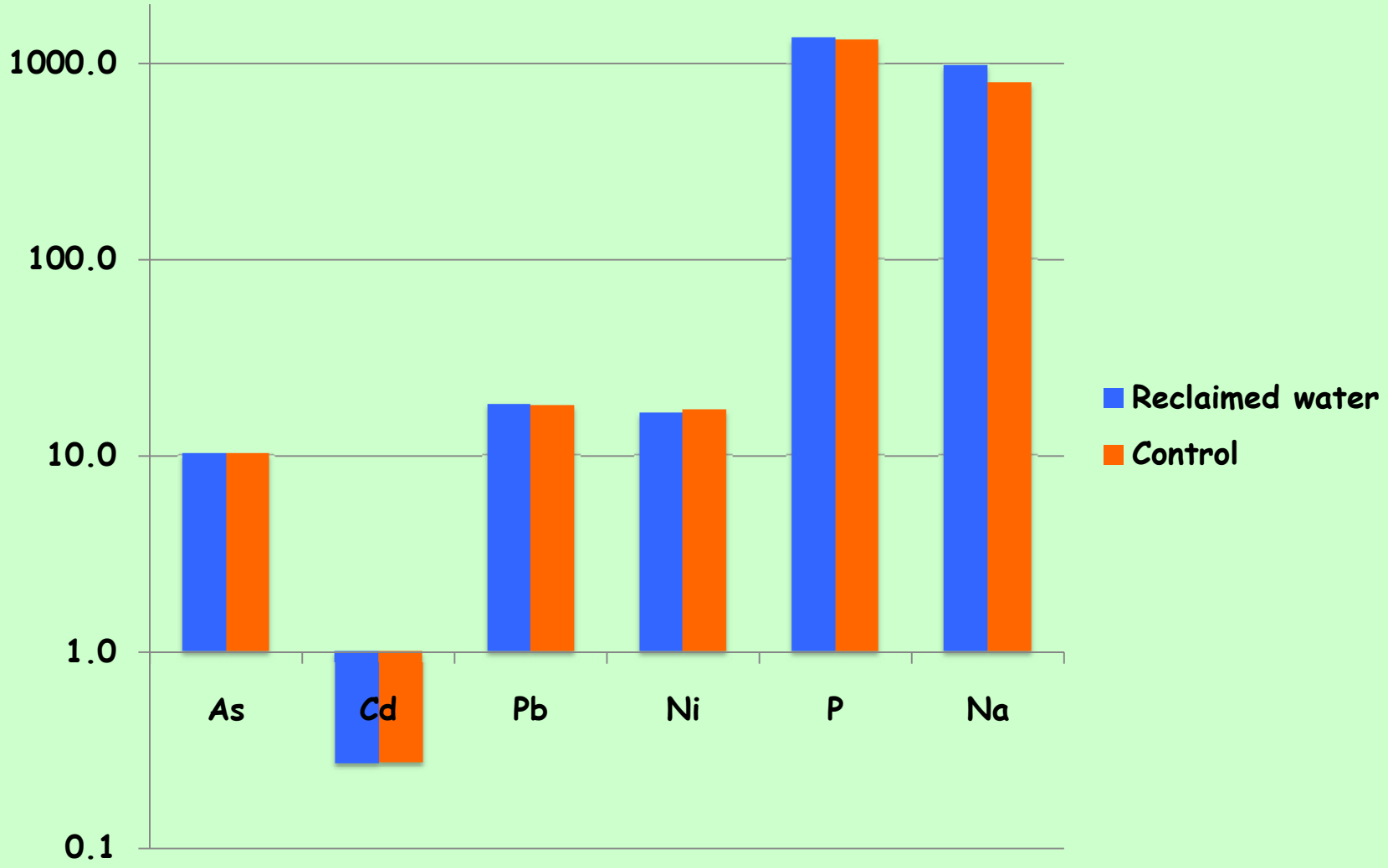
- Metals- arsenic, cadmium, lead, nickel
- Pathogens- *fecal coliform, e coli*, total coliform

Growth response- Dr. Kim

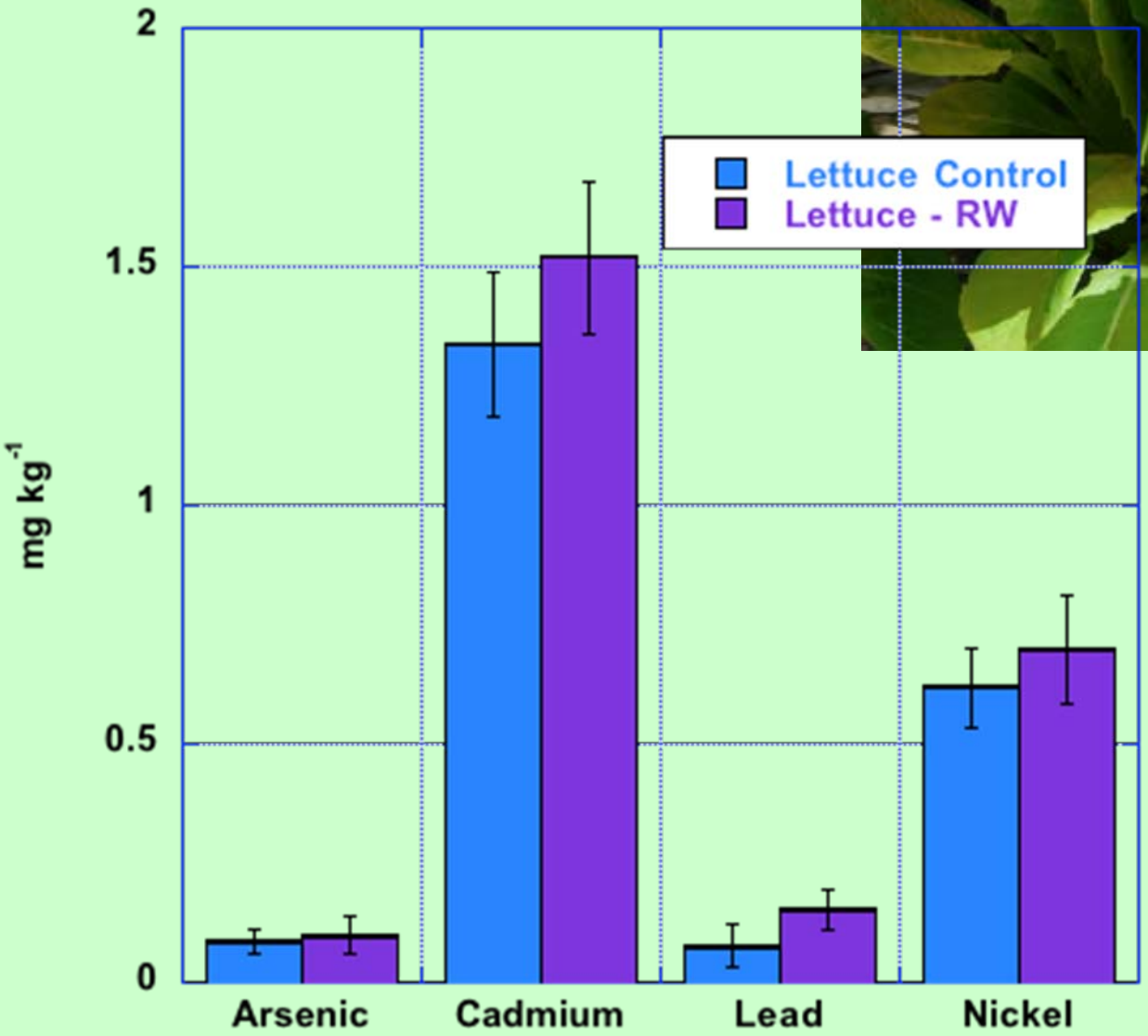
Replicated greenhouse study

- Soils collected from truck farm
- Lettuce- known metal accumulator, eaten raw
- Strawberries- eaten raw
- Carrots- direct contact with soil, can also be eaten raw

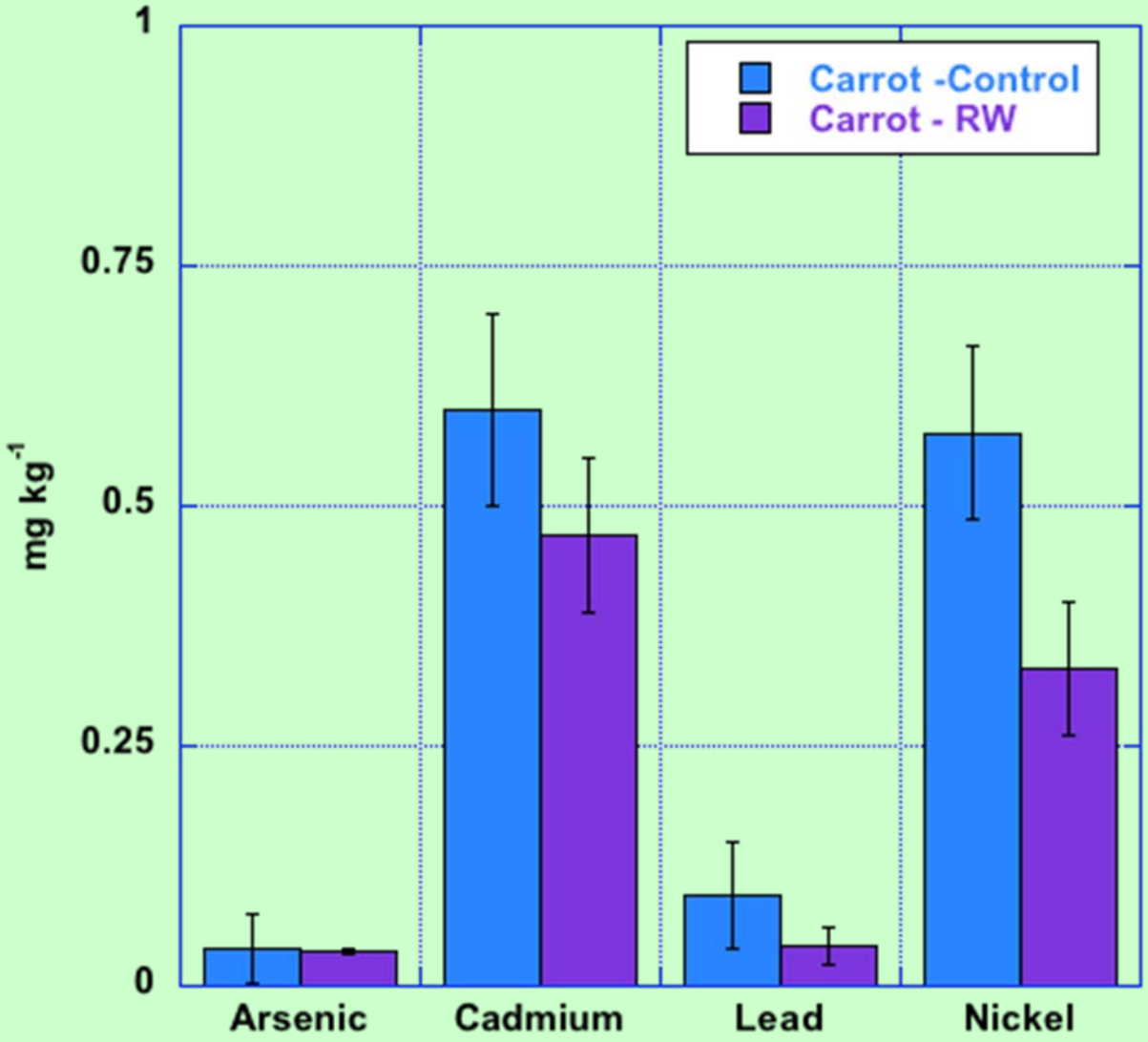
Soil metals- exactly the same



Plant metals- scientifically the same



Plant metals- scientifically the same



Pathogens?

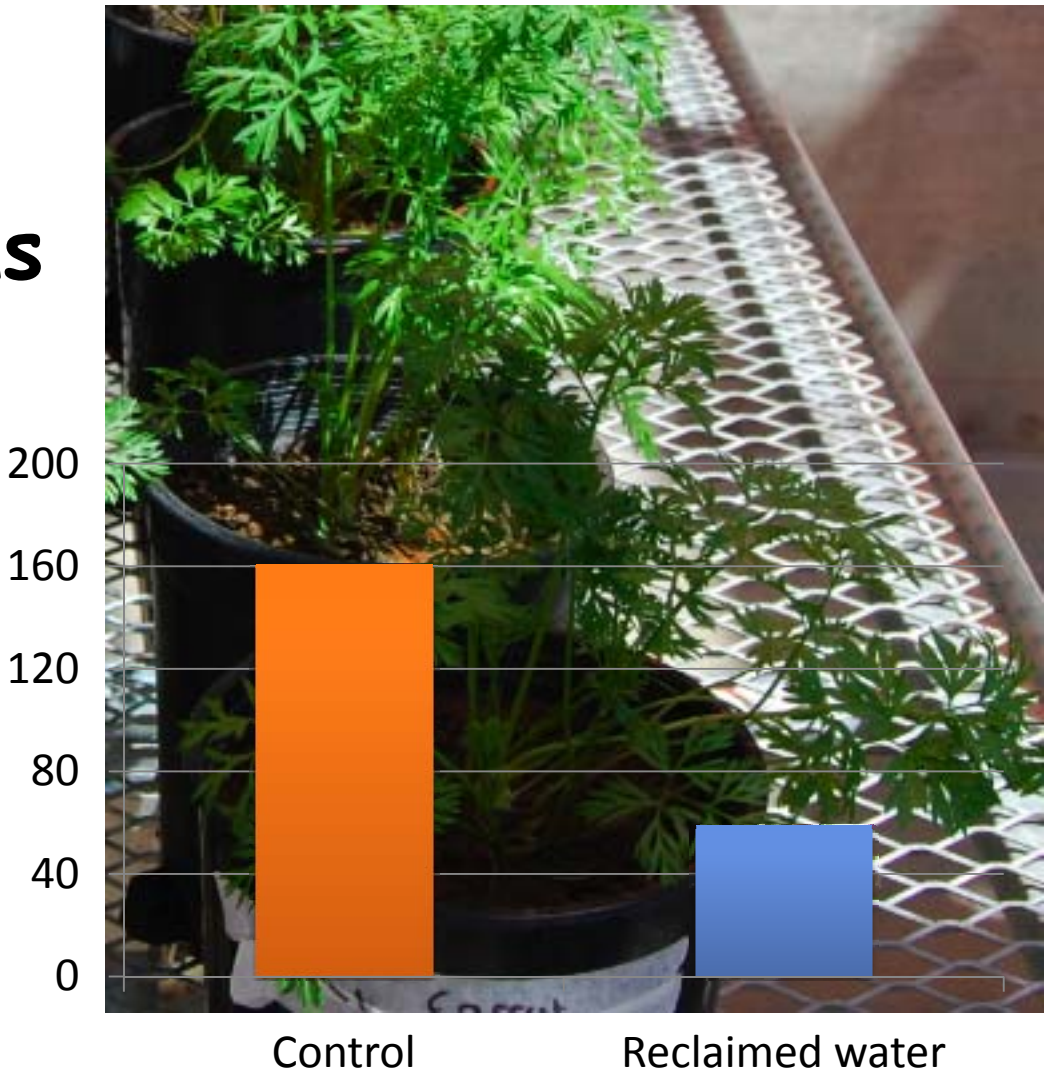
- Strawberries- **fecal, total and e coli** below most probable number for all reclaimed water and control samples
- Eat them raw- washing makes them soft

Pathogens?

- Lettuce- for both washed and unwashed, **fecal and e coli** below most probable number for all reclaimed water and control samples
- Total coliform- only detected in control samples

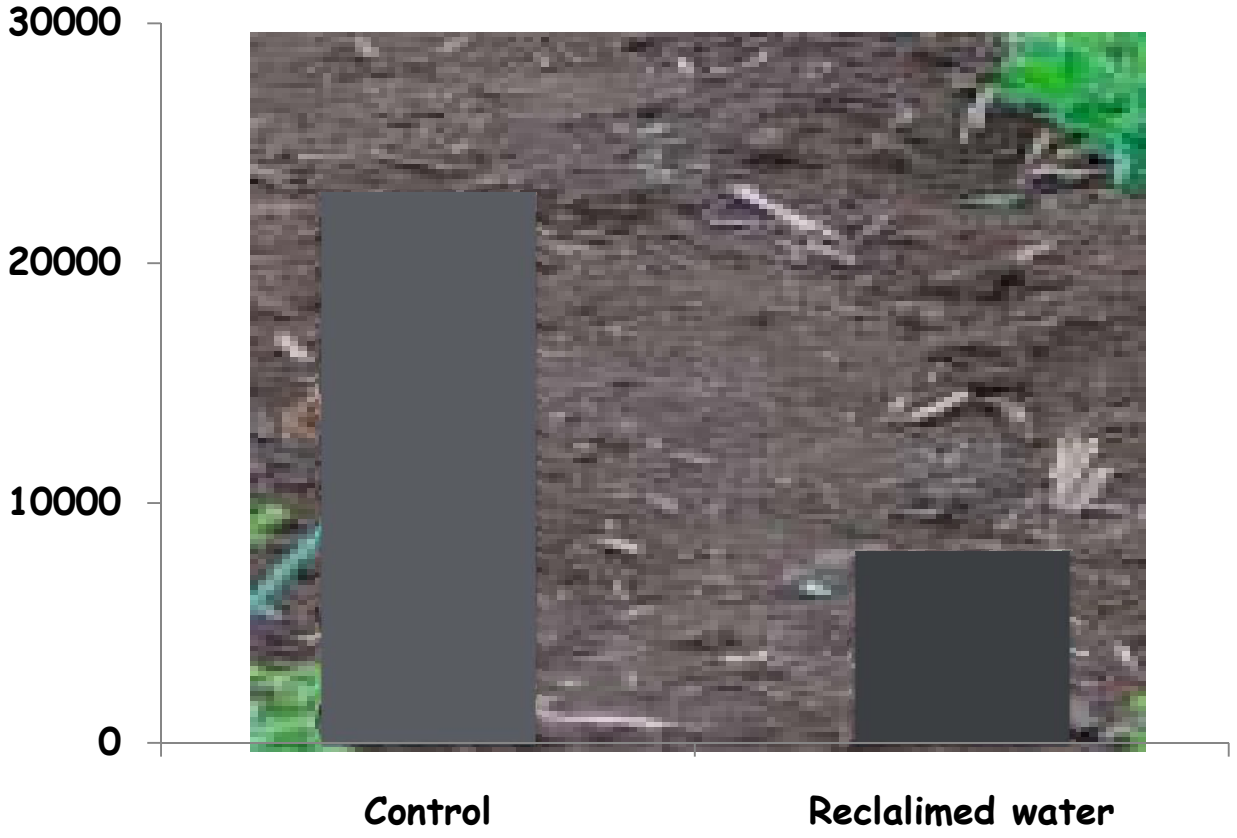
Pathogens- carrots

- No **e. coli or fecal coliforms**
- Total **coliform** in both treatments



Pathogens- soils

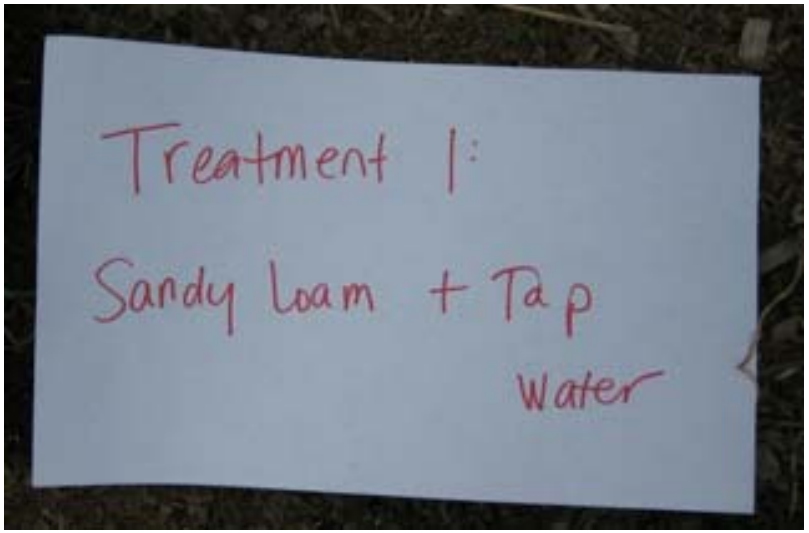
- No evidence of fecal contamination in any soil- however **total coliforms** present in all soils

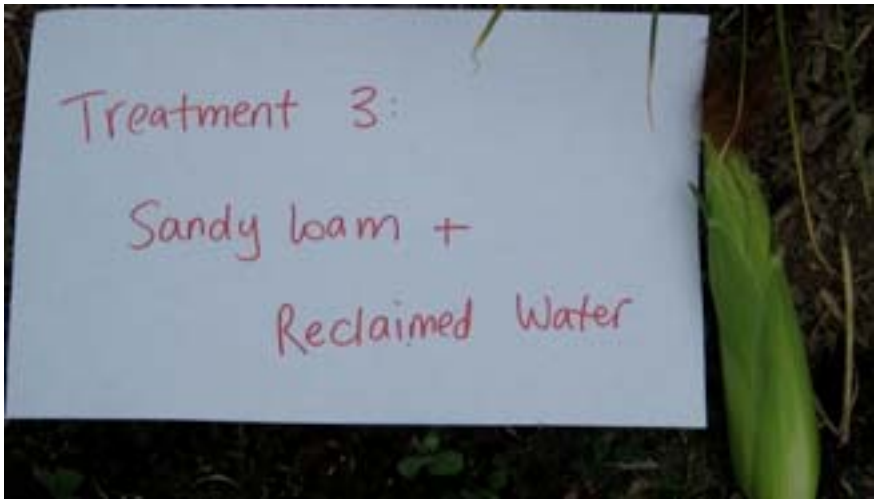


Edible crops- outdoor

- Kristen McIvor- PhD student, master gardener, Seattle Tilth
- Attempt to replicate greenhouse study
- GroCo- Biosolids compost included as part of experimental design

Yield- pictures tell the story

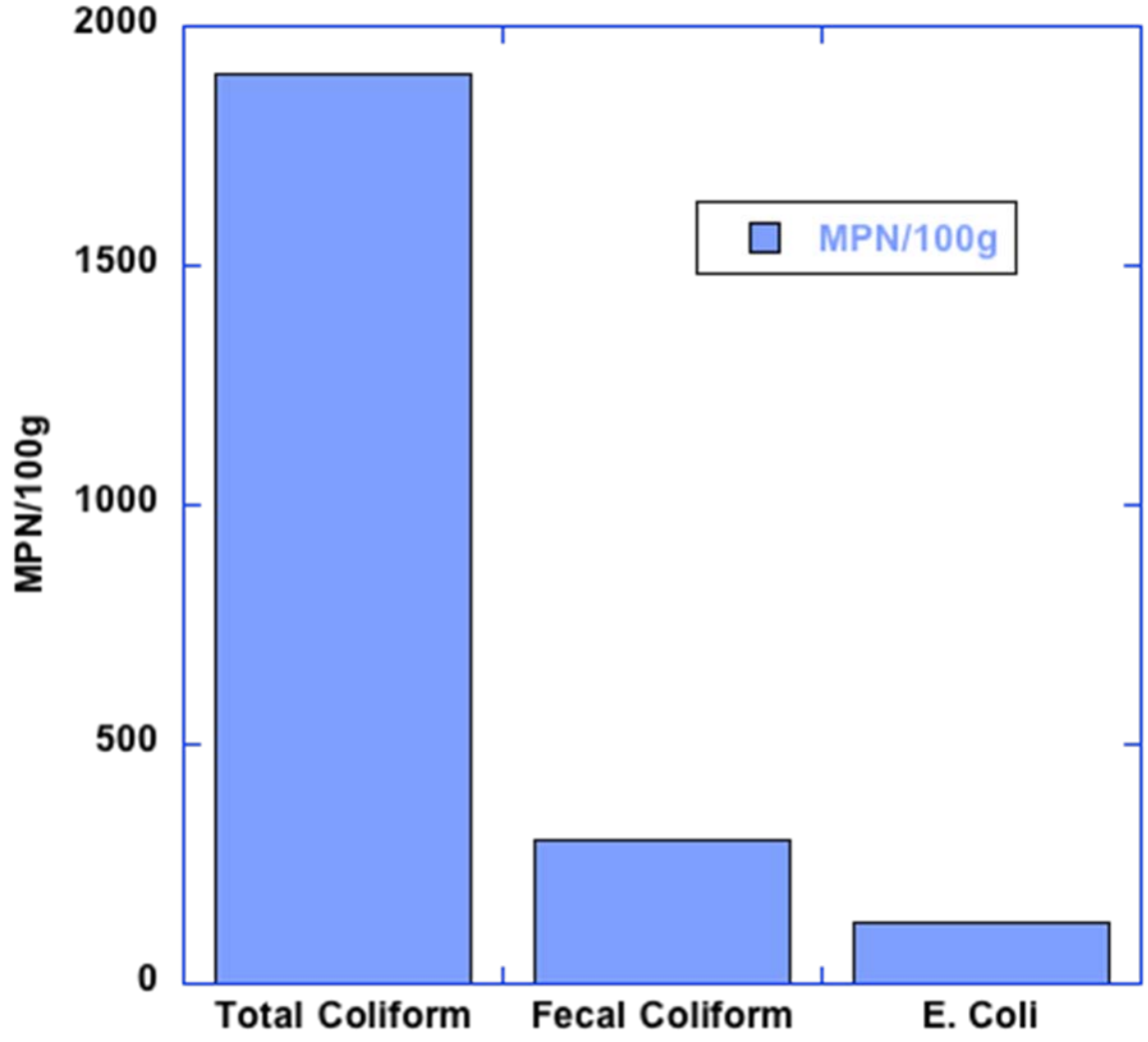




Pathogens- E Coli
(data tells part of the story)

	Control	RW	GroCo	GRO RW
Lettuce	<MDL	<MDL	<MDL	<MDL
Potato	<MDL	<MDL	<MDL	<MDL
Strawberry	<MDL	<MDL	<MDL	<MDL
Soil	20	<MDL	20	20

The Commercial topsoil-



Thank you

Contact: slb@u.washington.edu