Reclaimed Water Irrigation: Plant Accumulation of Contaminants of Emerging Concern (CECs)

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Outline

- Problem - CECs in wastewater and biosolids
- Project objectives and setup
- Planned studies:
  - Controlled experiments
  - Field studies
  - Outreach to stakeholders
- Anticipated results and impacts
What are CECs?

“Chemicals and other substances that have no regulatory standard, have been recently “discovered” in natural waters, and potentially cause deleterious effects in aquatic life at environmentally relevant concentrations” — US EPA

- Pharmaceuticals and personal care products (PPCPs)
- Veterinary medicines and antibiotics
- Endocrine-disrupting chemicals (EDCs)
- Plasticizers (e.g., phthalates)
- New persistent organic pollutants (e.g., flame retardants)
- Nanomaterials
- ...

...
What are PPCPs?

“PPCPs refers, in general, to any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock.”

--- US EPA
Routes to Soil Contamination

- Irrigation of reclaimed water
- Biosolids/animal wastes
- Landfills
- Plasticulture
- ...
Treated Wastewater Irrigation
Biosolids Land Application

Material Produced Total

Reuse

Agriculture/Landscape

Biosolids 3.6 × 10^7 metric tons 70% 41%

Treated Wastewater

4.8 × 10^10 m³ 7.4% 55%

Biosolids Land Application
PPCPs in treated wastewater, biosolids and other wastes

Irrigation
land application residues

Plant uptake

PPCP/EDCs in soils

PPCP/EDCs in plant

Potential risk to human or terrestrial organisms
The Challenges of CECs

- Thousands of chemical types!
- Different physicochemical properties
- Mixtures
- Pseudo-persistent contaminants

- Need for a tiered approach in assessment!
Plant Accumulation of CECs from Soil

-代谢在植物中的作用
-从根部到叶片/果实的转移
-根部的吸收
-土壤中吸附及转化 - 可用性
Tiered Approach

- CECs
  - Plant cells
    - Resistant to metabolism
    - Hydroponic
      - Easy uptake
      - Field monitoring
        - Accumulation in edible tissues
          - Exposure prediction
            - Dietary uptake
  - Identify “Priority” CECs
  - Risk assessment
Project Objectives

① Controlled experiments to screen “priority” CECs
   a) Plant cells
   b) Hydroponic

② Effects on terrestrial insects

③ Field studies to understand actual risks

④ Outreach to stakeholders

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Controlled Experiments:
- Plant cells as a rapid screening tool
Screening of 18 CECs in Carrot Cells

10 of 18 PPCPs were relatively stable in carrot cell suspensions
Stability in Cell Suspensions

8 of 18 PPCPs were rapidly transformed!
### Estimated Half-life (h)

<table>
<thead>
<tr>
<th>Recalcitrant compounds</th>
<th>Dissipative Compounds</th>
<th>$t_{1/2}$ (hour)</th>
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<tbody>
<tr>
<td>Acetaminophen</td>
<td>Triclosan</td>
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<td>Caffeine</td>
<td>Naproxen</td>
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<td>Diazepam</td>
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</table>

**Rapidly transformed**
Diclofenac metabolism in *Arabidopsis* Cells
Naproxen Metabolism in Arabidopsis Cells

Parent structure conserved through conjugation!
Controlled Experiments: Hydroponic Cultivation

Goals:
1. Comparative evaluation to identify compounds with high potential of plant accumulation
2. Understand properties influencing plant uptake

- Spiked concentration: 0.5 μg/L, 5 μg/L
- Growth period: 21 d; nutrient solution changed every 3 d
Results - Accumulation of PPCPs in root

0.5 µg/L: 16-19 PPCPs

Fluoxetine: 26-224 ng/g

Triclosan: 0.2-69 ng/g

5 µg/L: 19-20 PPCPs

227-1426 ng/g

3-560 ng/g

Triclocarban: 211-535 ng/g

1437-3119 ng/g
Accumulation of PPCPs in leaf/stem

0.5 µg/L: 12-17 PPCPs

Carbamazepine
Dilantin
Diuron:
2-70 ng/g

Fluoxetine:
7-69 ng/g

5 µg/L: 14-19 PPCPs

23-764 ng/g

122-818 ng/g
Bioconcentration factor of PPCPs in plant tissue

Bioconcentration factor (BCF) = \( \frac{C_{\text{plant tissue}} \ (\mu g/\text{kg})}{C_{\text{nutrient solution}} \ (\mu g/L)} \)

- Lettuce
- Spinach
- Cucumber
- Pepper

0.5 µg/L--Root

Fluoxetine

Triclocarban

0.5 µg/L--leaf
Trends & Patterns

- Understand properties driving uptake or translocation
Effects of PPCPs on Important Insects

- Can PPCPs affect insects at environmentally relevant concentrations?

- Does the effect of PPCPs vary by the feeding ecology of insects?

- Four insect species:
  - Filter feeder (medically important mosquito)
  - Chewing insect (agricultural pest)
  - Phloem feeder (agricultural pest)
  - Detritivore (ecologically and medically important fly)
**Culex quinquefasciatus** (Say)
- Filter feeders
- Aquatic larvae, terrestrial adults
- West Nile Virus, Equine Encephalitis and possibly Zika

**Trichoplusia ni** (Hübner)
- Cabbage looper
- Major pest of cole and solanaceous crops
- Ranges from Canada to Mexico

**Myzus persicae** (Sulzer)
- Green peach aphid
- A top agriculturally important aphid
- Vector for over 100 plant viruses
PPCPs extended mosquito developmental time
PPCPs enhanced mortality by *Bacillus thuringiensis* (*Bt*)
PPCPs changed the Mosquito Microbiome
Two Field Sites

Irvine, Southern CA

Fresno, Central CA
PPCPs in vegetables/fruits

Root:

Leaf:

Fruit:
Stakeholder Outreach

- Regional water districts
- County extension offices
- USDA-ARS in Central Valley, CA
- Address public concerns
- Promote safe reuse of reclaim water
Anticipated Results & Impacts

- New knowledge
  - High risk CECs
  - Properties governing uptake and accumulation
  - Realistic levels and risks

- Impacts:
  - Public perception and awareness
  - Promotion of safe reuse
Funding Support

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