Evaluating Plant Uptake Pathways of Chemical Contaminants in State Models for Risk Assessments of Contaminated Urban Gardening Sites

EPA

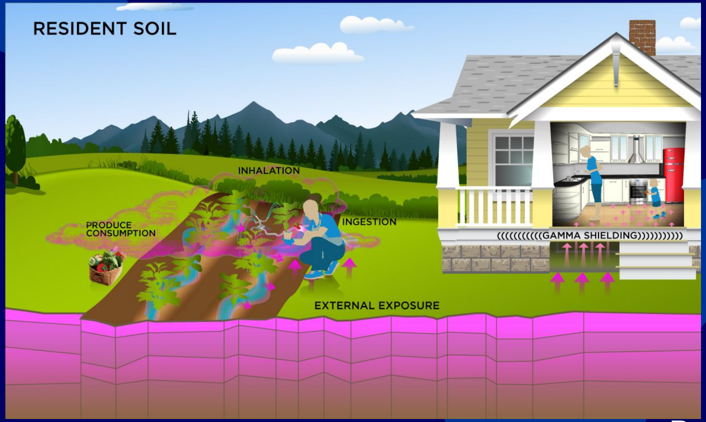
Sponsors of the Virtual Student Federal Service Internships

- Stuart Walker, Lisa Raterink and Michele Burgess, U.S. Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation (OSRTI),Assessment and Remediation Division (ARD)
  Science Policy Branch (SPB)

- Jon Richards, U.S. Environmental Protection Agency, Superfund Division Restoration & Site Evaluation Branch, Region 4

Purpose

- Provide chemical screening levels for evaluating contaminated sites to protect:
  - » Humans consuming home grown food
    - — Edible vegetables, fruit & herbs
  - » Uptake of chemicals in plants
  - » Soil conditions that influence uptake

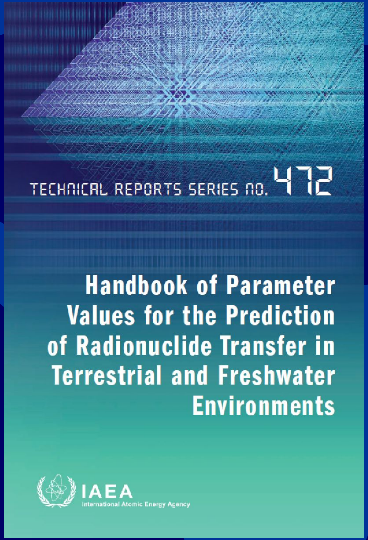


Radiological PRG and DCC – Farmer and Resident Produce Categories

- 25 specific subcategories of produce. 23 are used in default mode.
  - Apples, Asparagus, Beets, Berries, Broccoli, Cabbage, Carrots, Cereal Grains, Citrus Fruits, Corn, Cucumbers, Lettuce, Lima Beans, Okra, Onions, Peaches, Pears, Peas, Peppers, Potatoes, Pumpkin, Rice, Snap Beans, Strawberries, Tomatoes
- Mass loading factors (MLFs) for each produce subcategory (25 MLFs)
- Child and Adult ingestion rates for all 25 categories
  - Both for fresh weight (if site has sensitive populations) and more typical ingestion rate with cooking and preparation loss

PRG and DCC – Farmer and Resident Produce Categories, cont.

- Users are able to select:
  - » Three climate zones (temperate, subtropical, tropical).
  - » Seven soil types (default, sand, loam, clay, organic, coral sand, other)
- If climate/soil specific transfer factors for that element/produce category are available from IAEA, then the correct factor will be selected
  - » User can enter site-specific transfer factor



EPA-US-69 Report

Evaluating Plant Uptake Pathways of Chemical Contaminants in State Models for Risk Assessments of Contaminated Sites

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Project Description – 1st Year Report

“Comparison of Risk Assessment Parameters for Homegrown Produce in Various Models” by EPA intern Amanda Balogh

- https://semspub.epa.gov/work/HQ/100002896.pdf

Objective:

- Evaluate the homegrown produce portion of several government issued international models for assessing the risks from chemicals at contaminated sites.
- The report focused on three models with information on how to conduct site-specific chemical risk assessments that include the human consumption of homegrown produce:
  - the Contaminated Land Exposure Assessment (CLEA) model from the United Kingdom’s Environment Agency
  - the S-Risk model from Belgium
  - the CSOIL model from the Netherlands

Project Description – 2nd Year Report

"Evaluating Plant Uptake Pathways of Chemical Contaminants in State Models for Risk Assessments of Contaminated Sites"

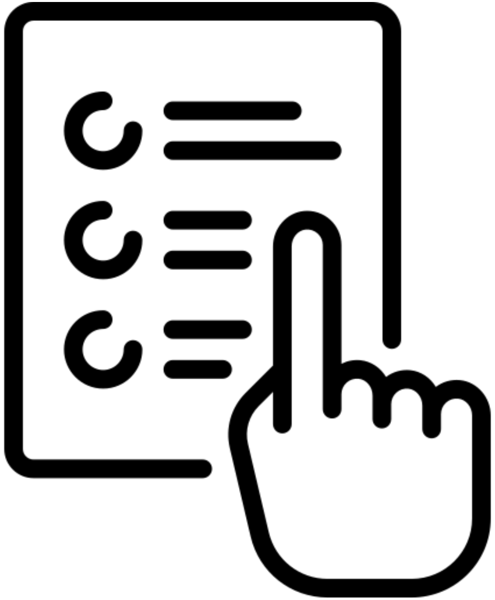
Objective:

- Evaluate current state models and parameters used in assessing the plant uptake pathways of chemical contaminants found in urban agriculture (UA) scenarios.
- Identify food exposure risks associated with contaminated urban sites.

Purpose:

- EPA receives numerous requests from communities near Superfund sites regarding the safety of eating vegetables, fruits and herbs grown in those soils.
- Guidance to assist health assessors and EPA risk assessors in answering those frequently asked questions.
- It is critical that better information regarding soil bioavailability and plant uptake be incorporated into Superfund human health risk assessment.

Poll Time!



Common Anthropogenic Sources of Contaminants of Emerging Concern (CEC)[1]

Source	Contaminant Type	
	Trace Elements	*Persistent Organic Pollutants (POPS)*
Paint (before 1978)	Pb	
High traffic areas	Pb, Zn	PAHs
Treated lumber	As, Cr, Cu	
Burning wastes		PAHs, Dioxins
Contaminated manure	Cu, Zn	
Coal production	Mo, S, Se	PAHs, Dioxins
Sewage sludge	Cd, Cu, Zn, Pb	
Petroleum refining/spills	Pb	PAHs, MAHs
Pesticides	Pb, As, Hg	OC Compounds
Commercial/industrial site use	Pb, As, Ba, Cd, Cr, Hg, Zn	PAHs, MAHs, PBDEs, PCBs, PFAS

Lead (Pb); Zinc (Zn); Arsenic (As); Chromium (Cr); Copper (Cu); Molybdenum (Mo); Sulfur (S); Selenium (Se); Cadmium (Cd); Mercury (Hg); Barium (Ba); Organochlorine (OC); Polybrominated diphenyl ethers (PBDEs); Polychlorinated biphenyls (PCBs); Per- and polyfluoroalkyl substances (PFAS)

Trace Elements

- Heavy metals and metalloids are among the most investigated soil contaminants.

Table 2.1. Classification of essential and nonessential heavy metals/metalloids[2]

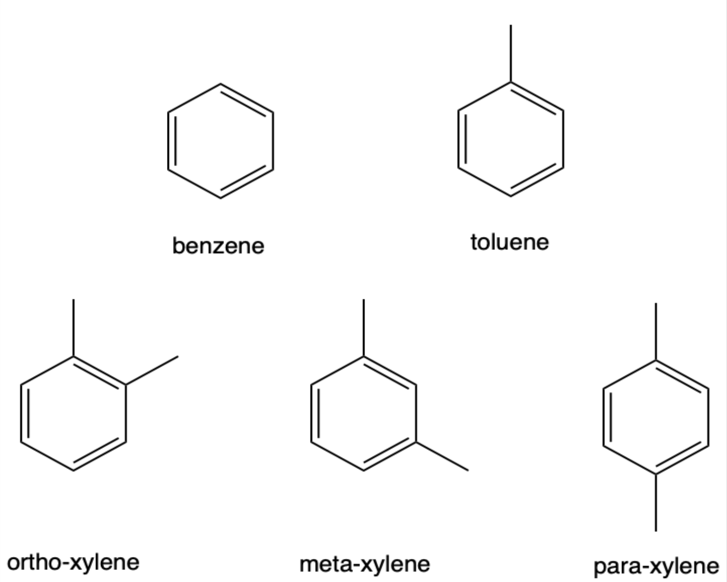
Essential	Nonessential
Zinc (Zn)	Cadmium (Cd)
Nickel (Ni)	Lead (Pb)
Copper (Cu)	Mercury (Hg)
Molybdenum (Mo)	Chromium (Cr)
Selenium (Se)	Arsenic (As)
	Barium (Ba)

- *Essential metals/metalloids:* function as protein cofactors in various biological processes and are considered non-toxic when present in trace amounts.
- *Nonessential metals/metalloids:* have no biological function and are considered toxic in trace amounts. Nonessential metals pose a threat to human health because of their ability to hijack the essential metal transport mechanisms of cells.

Petroleum Products: includes (i) monoaromatic hydrocarbons (MAHs) and (ii) polyaromatic hydrocarbons (PAHs).[3]

(i) monoaromatic hydrocarbons (MAHs)

BTEX Compounds



(ii) polyaromatic hydrocarbons (PAHs)

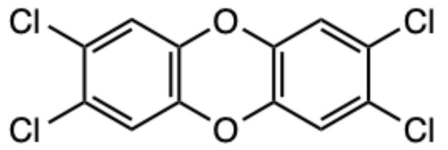
Table 2.2. 16 Designated High Priority PAH Pollutants

16 Priority PAHs	
Naphthalene (NAP)	Benzo[a]anthracene (B[a]A)
Acenaphthylene (ACY)	Chrysene (CHRY)
Acenaphthene (ACE)	Benzo[b]fluoranthene (B[b]F)
Aluorene (FLU)	Benzo[k]fluoranthene (B[k]F)
Phenanthrene (PHEN)	Benzo[a]pyrene (B[a]P)
Anthracene (ANTH)	Benzo[g,h,i]perylene (B[ghi]P)
Fluoranthene (FLTH)	Indeno[1,2,3-c,d]pyrene (IND)
Pyrene (PYR)	Dibenz[a,h]anthracene (D[ah]A)

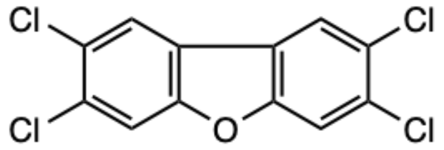
Dioxins

- Polychlorinated dibenzodioxins (PCDDs)
- Polychlorinated dibenzofurans (PCDFs)

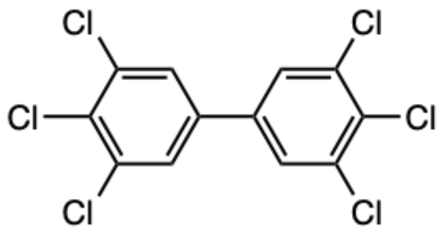
Note: Only PCDDs and PCDFs with the chlorine atoms at positions 2, 3, 7, and 8 on the benzene ring are toxic.[4]



2,3,7,8-tetrachlorodibenzo-p-dioxin



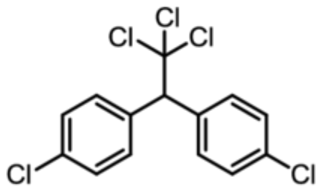
2,3,7,8-tetrachlorodibenzofuran



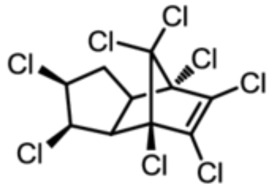
3, 3’, 4, 4’, 5, 5’-hexachlorobiphenyl

Organochlorine Pesticides (OCPs)

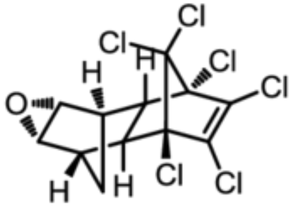
- Used from the 1940s to the 1960s
- Chlordane, dichlorodiphenyltrichloroethane (DDT), aldrin, dieldrin[5]
- Most have been banned



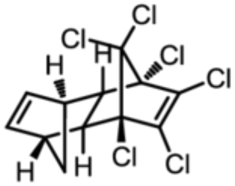
P,P'-DDT



chlordane



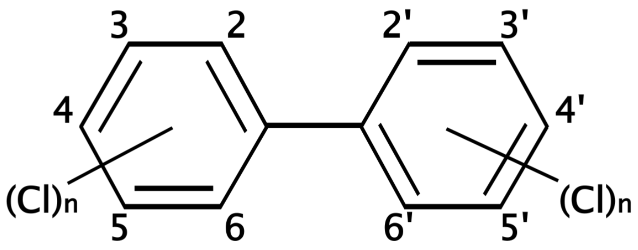
dieldrin



aldrin

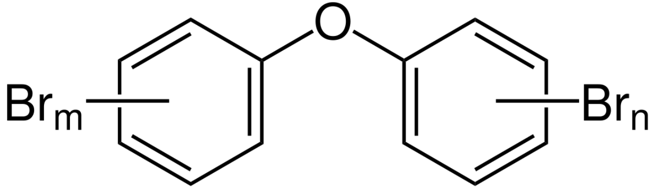
Polychlorinated Biphenyls (PCBs)[6]

- Synthetic chlorinated hydrocarbons
- Used in electrical equipments, paints/plastics/rubbers
- Effects on nervous, reproductive, endocrine and immune systems



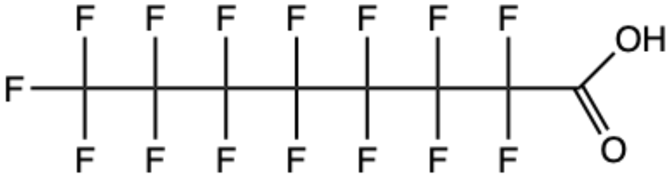
Polybrominated Diphenyl Ethers (PBDEs)[6]

- Synthetic brominated hydrocarbons
- Used in products to prevent from catching fire
- Effects on thyroid, liver and brain development

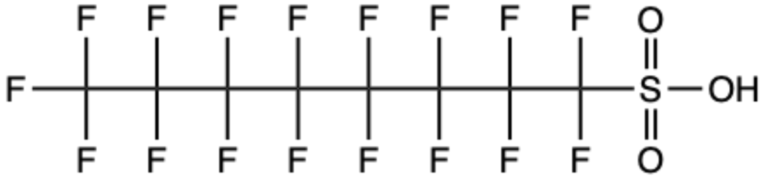


Per- and polyfluoroalkyl Substances (PFAS)[7]

- Large class of synthetic fluorinated compounds
- PBT characteristics
- Developmental, immunological and carcinogenic effects
- Legacy industrial use in stain-, grease- and water-repellent products



perfluorooctanoic acid (PFOA)



perfluorooctane sulfonic acid (PFOS)

Are there any CECs that we did not mention here that you believe would be useful to add to future research?

Type your answers in the Q&A chat!

State-Specific CECs: What We Know

Region 1	Connecticut, Maine, Massachusetts
Region 2	New Jersey
Region 3	Maryland
Region 4	Florida, Kentucky, North Carolina, South Carolina, Tennessee
Region 5	Minnesota
Region 6	n/a
Region 7	n/a
Region 8	n/a
Region 9	n/a
Region 10	n/a

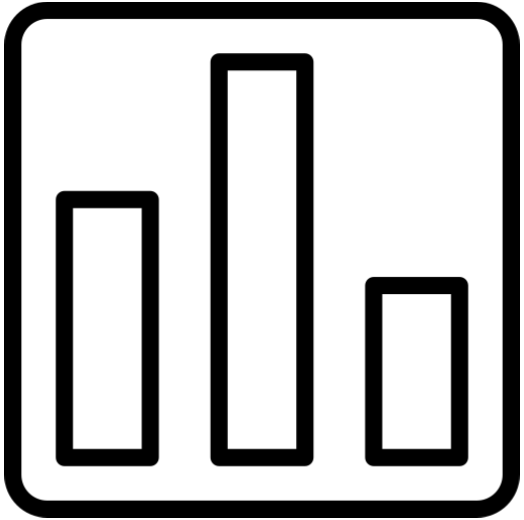
State-Specific CECs: Regions Lacking Information

Region 1	New Hampshire, Rhode Island, Vermont
Region 2	New York
Region 3	Delaware, Pennsylvania, Virginia, West Virginia, Washington, DC
Region 4	Alabama, Georgia, Mississippi
Region 5	Illinois, Indiana, Michigan, Ohio, Wisconsin
Region 6	Arkansas, Louisiana, New Mexico, Oklahoma, Texas
Region 7	Iowa, Kansas, Missouri, Nebraska
Region 8	Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming
Region 9	Arizona, California, Hawaii, Nevada
Region 10	Alaska, Idaho, Oregon, Washington

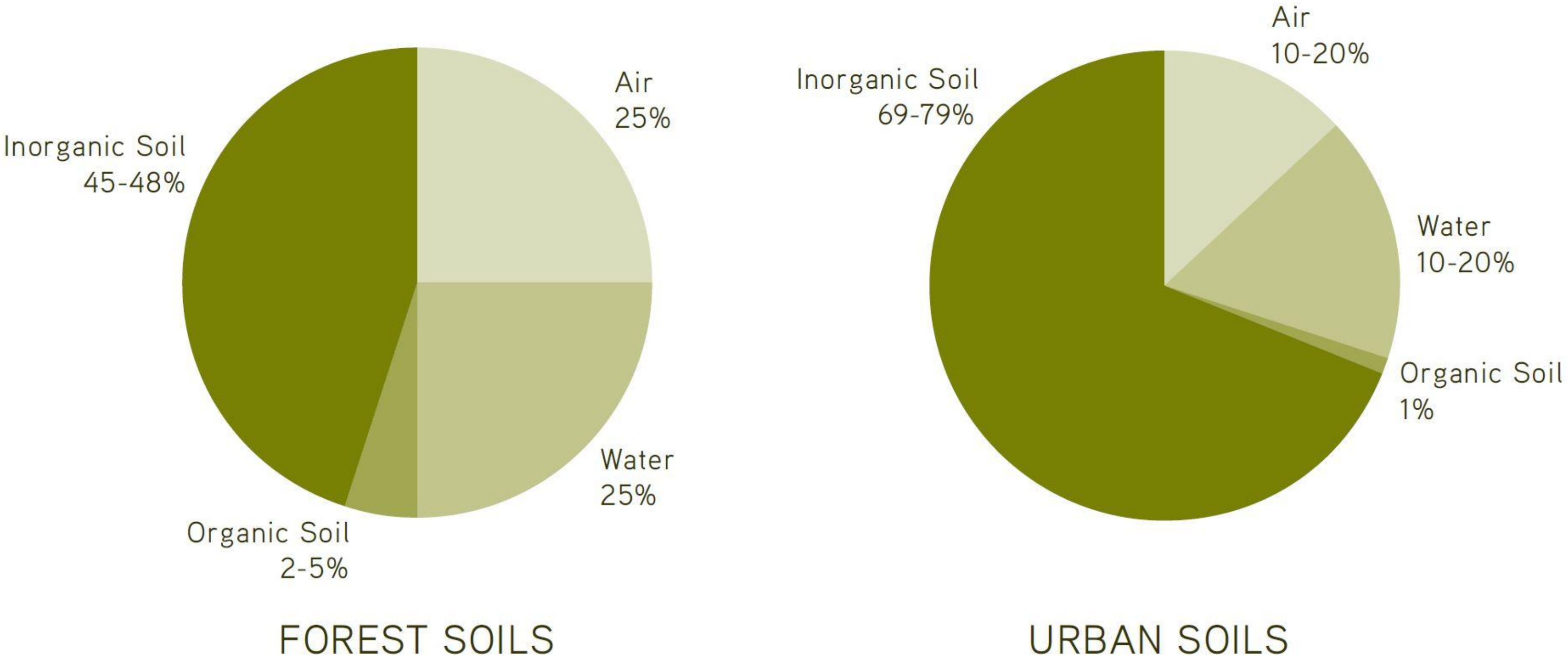
Are you aware of any articles or information about CECs at urban agricultural sites in the states and regions listed here?

Type your answers in the Q&A chat!

Poll Time!



Urban vs Rural Soil Systems



Environmental Factors

Table 4.1. Environmental Factors Affecting Evapotranspiration (K_c) by Plants[8]

+	-
High temperature	Low temperature
High wind speed	Low wind speed
Low air humidity	High air humidity
Hot/Dry agricultural areas	Cold/Contintental agricultural areas
Adequate soil moisture	Drought conditions

Plant Physiology

Table 4.2. Plant Physiology Factors Affecting Bioconcentration Factor (BCF) of Plants [8]

+	-
Plant genotype (genus & species) i.e. leafy vegetables	Crops with small root systems i.e. succulent plants
Summer growing season	Rainy growing season
Healthy plants	Stressed plants
High plant Kc values	Low plant Kc values
High net irrigation requirments	Low net irrigation requirements
Low lipid content in roots	High lipid content in roots

Soil Characteristics

Table 4.3. Soil Properties Affecting CEC Uptake by Plants[8]

+	-
Low levels of SOM	High levels of SOM
Sandy soils	Clay or loamy soils
Acidic pH (pH < pKa of CEC)	Basic pH (pH > pKa of CEC)
Aerated soils (aerobic conditions)	Waterlogged soils (anaerobic conditions)

Mechanism of contaminant uptake by plants[9]

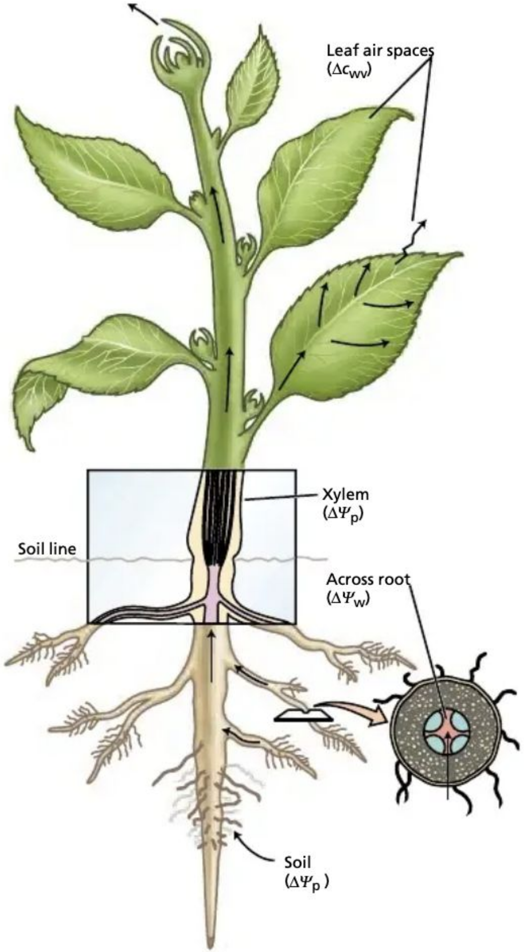
Contaminant uptake by plants generally follow two main uptake pathways:

(i) Extracellular transport

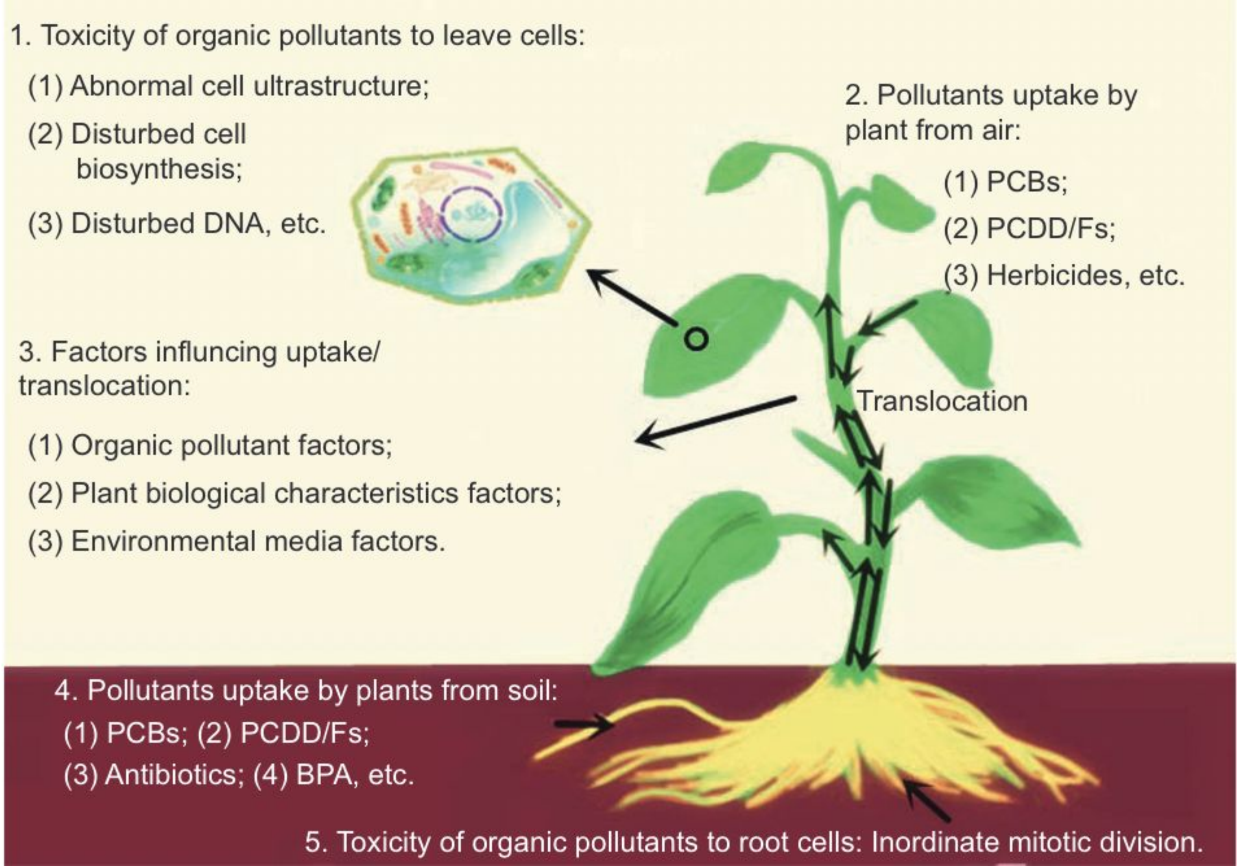
- Depends on nature of elements only
- Physiological conditions have no effect on uptake rate

(ii) Intracellular transport

- Depends on:
  - Pollutant factors
  - Plant biological characteristics
  - Environmental media factors



Mechanism of contaminant translocation by plants[9]



Quantifying Uptake of CECs Across Plant Species[8]

- Fruit vegetables growing under control greenhouse conditions (i.e. cucumber, green beans, tomatoes) have higher potential to uptake and accumulate CECs in their edible parts compared to plants cultivated in open fields.
  - Due to:
    - longer growing and irrigation period
    - higher NIR values
    - water requirements met solely with irrigation–no precipitation events occur in protected agriculture.
- Fruit vegetable crops uptake and accumulate CECs based on their reported BCF and NIR values

cucumber > okra > tomatoes > green beans > eggplants > pepper > melons > marrows > watermelons > artichokes > peas

Quantifying Uptake of CECs Across Plant Species[8]

Highest potential for CEC uptake by plants	Celery, spinach, lettuce, cabbage, carrots, radish, late-season potatoes, spring potatoes, mid-season potatoes, cucumber, green beans, okra, marrows, tomatoes, watermelons
Lowest potential for CEC uptake by plants	Melons, pepper, eggplant, maize, alfalfa, peanuts, haricot beans, wheat, barley, bananas, walnut, citrus, avocado, fruit trees, pistachio, table olives, almonds, table grapes

Research Gaps

1. **State specific CECs**
2. Screening Standards for Urban AG Sites
3. **State specific plant uptake models**
4. What role do non-EPA agencies with authority to protect food supply, agricultural resources, and public health have in developing baseline standards for food production?
5. **Variability in plant uptake and exposure risk of CECs within plant species**

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Please contact us with any questions or information you think may help phase 3 of our project!

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