THE EXCHANGEABILITY AND LEACHABILITY OF METALS FROM SELECT GREEN ROOF GROWTH SUBSTRATES

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Green roofs and water quality

- Runoff from conventional roof surfaces can have unacceptably high concentrations of undesirable pollutants, including heavy metals.
- Studies have indicated that runoff/leachate from green roofs can have lower concentrations.
- Green roof systems can theoretically improve urban water quality via filtration/retention of pollutants.

Green roofs and water quality

- Are green roof substrates sources of pollutants?
- Do the plants in green roof systems enhance the retention of pollutants?
- Are green roofs sinks for deposited pollutants?

Substrate information

Substrate	Size (cm)	Details
Arkalyte	0.6 - 1.6	Proprietary expanded clay
Axis	0.2 - 0.5	Calcined diatomaceous earth
FBA	0.4 - 1.8	Ash from sub-light bituminous coal
Axis+FBA	0.2 - 1.8	Mixture of Axis and FBA
Haydite	0.3 - 2.0	Silicaceous expanded shale
Lassenite	0.5 - 1.5	Amorphous silica
Lava rock	1.3 - 1.9	Natural volcanic stone
Pine bark	variable	Commercial organic amendment

Approach

- Batch studies with select green roof substrates to determine heavy metal content and the exchangeability of those substrates.
- Greenhouse leaching experiment with simulated green roof models with the same substrates.
- Field studies with established green roof models and blocks.

Batch studies

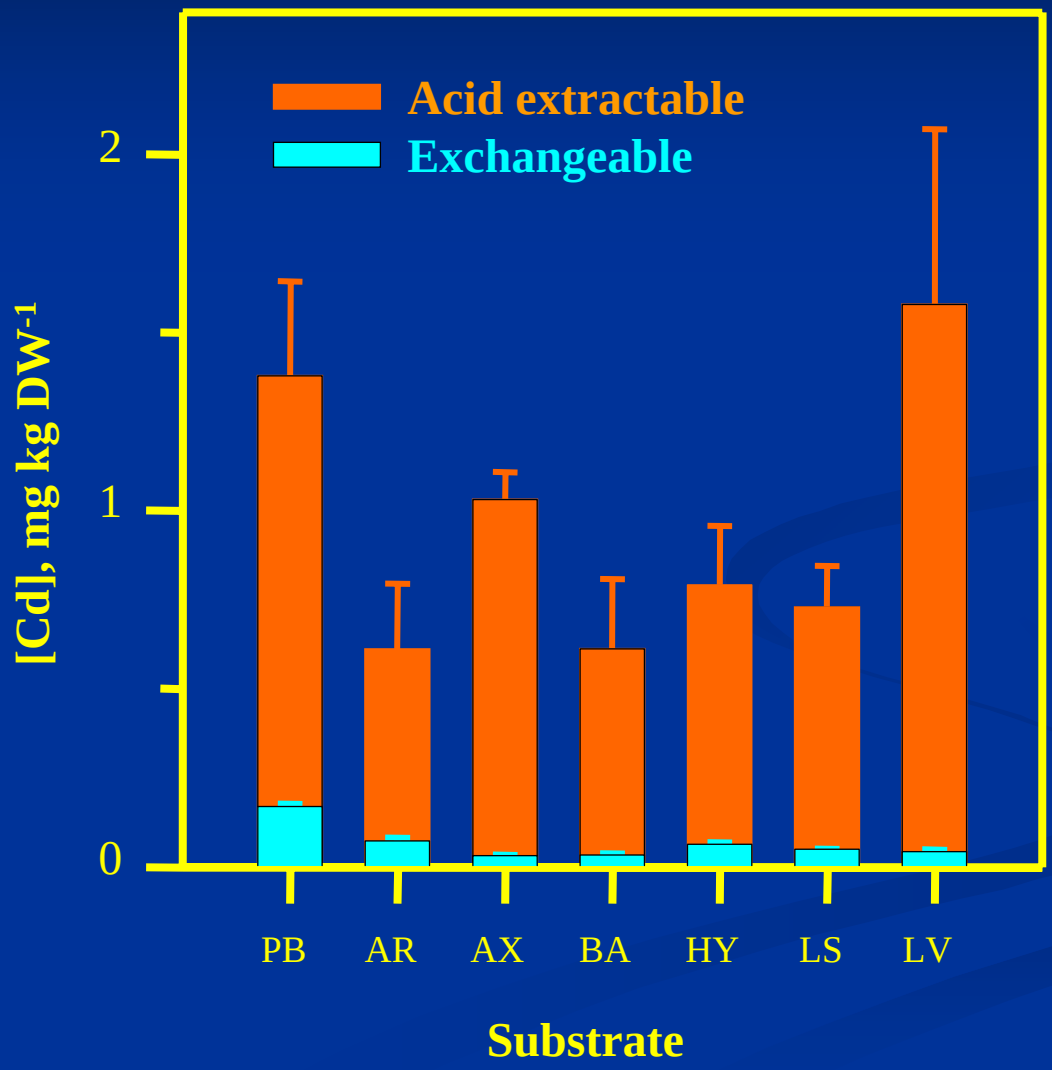
- Total acid-extractable metals determined.
- Ammonium acetate + EDTA extraction to estimate exchangeable metals.
- Target metals: Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn

Leaching experiment

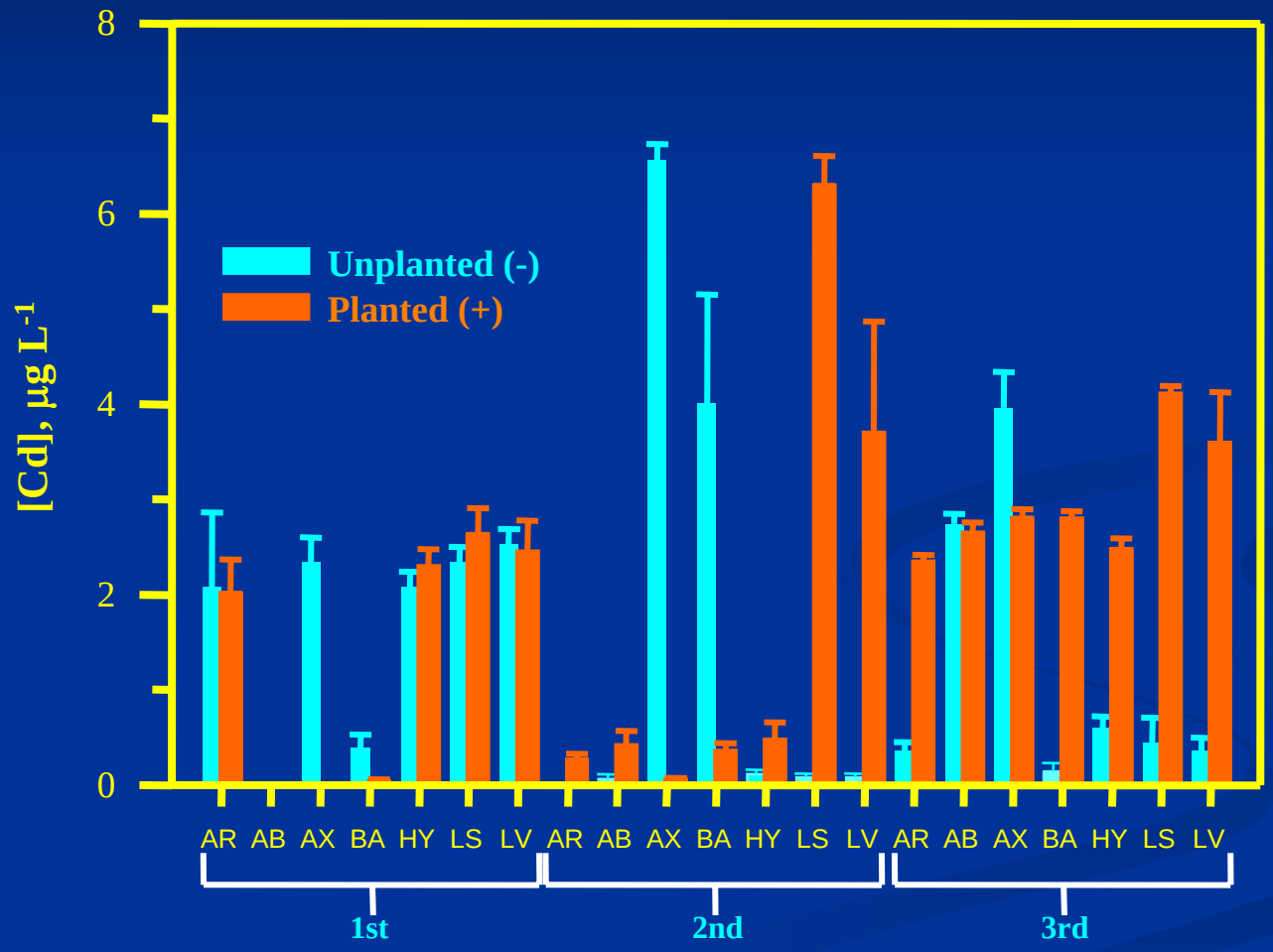
- Eight media (amended with pine bark) at a constant depth, half with *Sedum hybridum*
- Leached with a set volume of water 3 times over 6 months

- Target metals: Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn

Batch extraction results for Cd



Leachate results for Cd

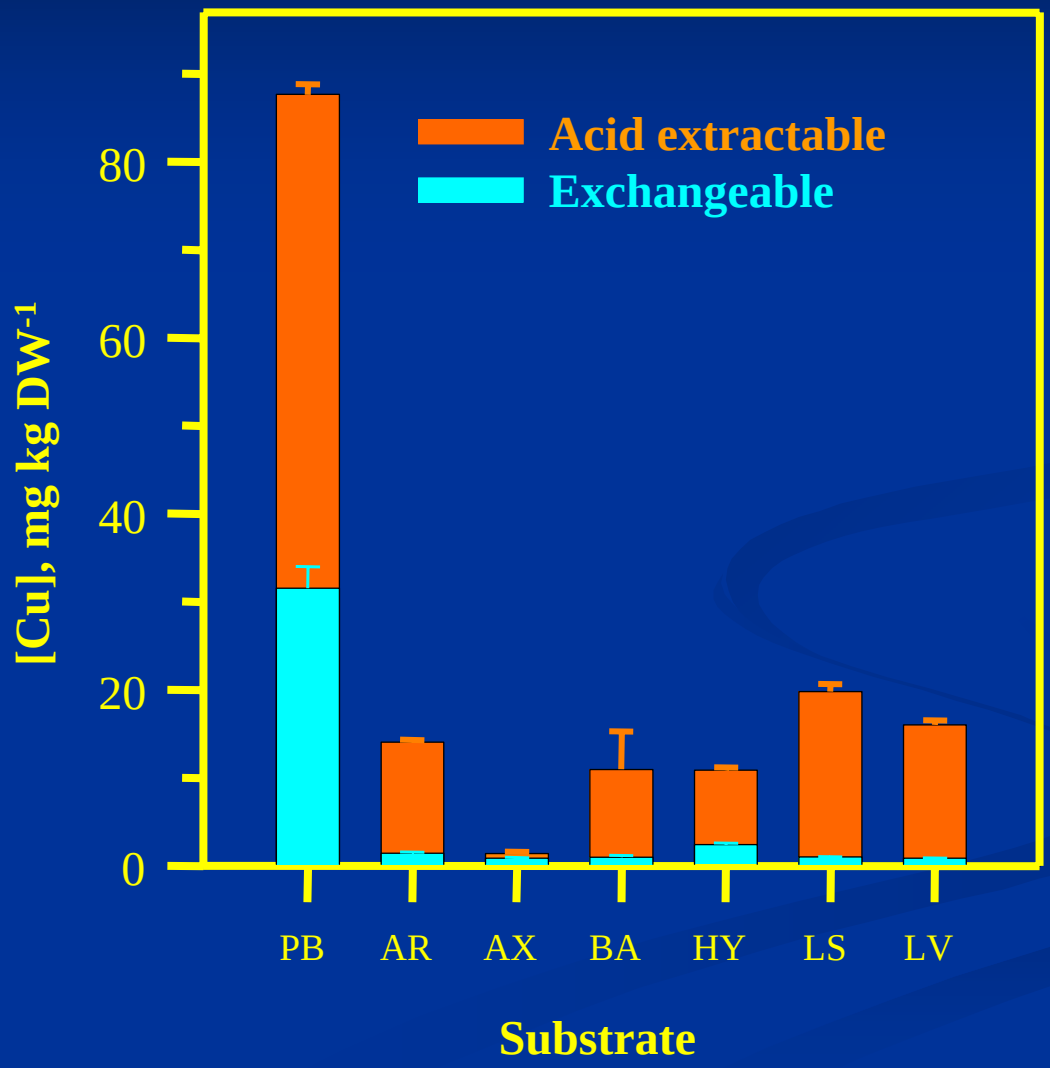


Planting treatment x substrate x leaching event

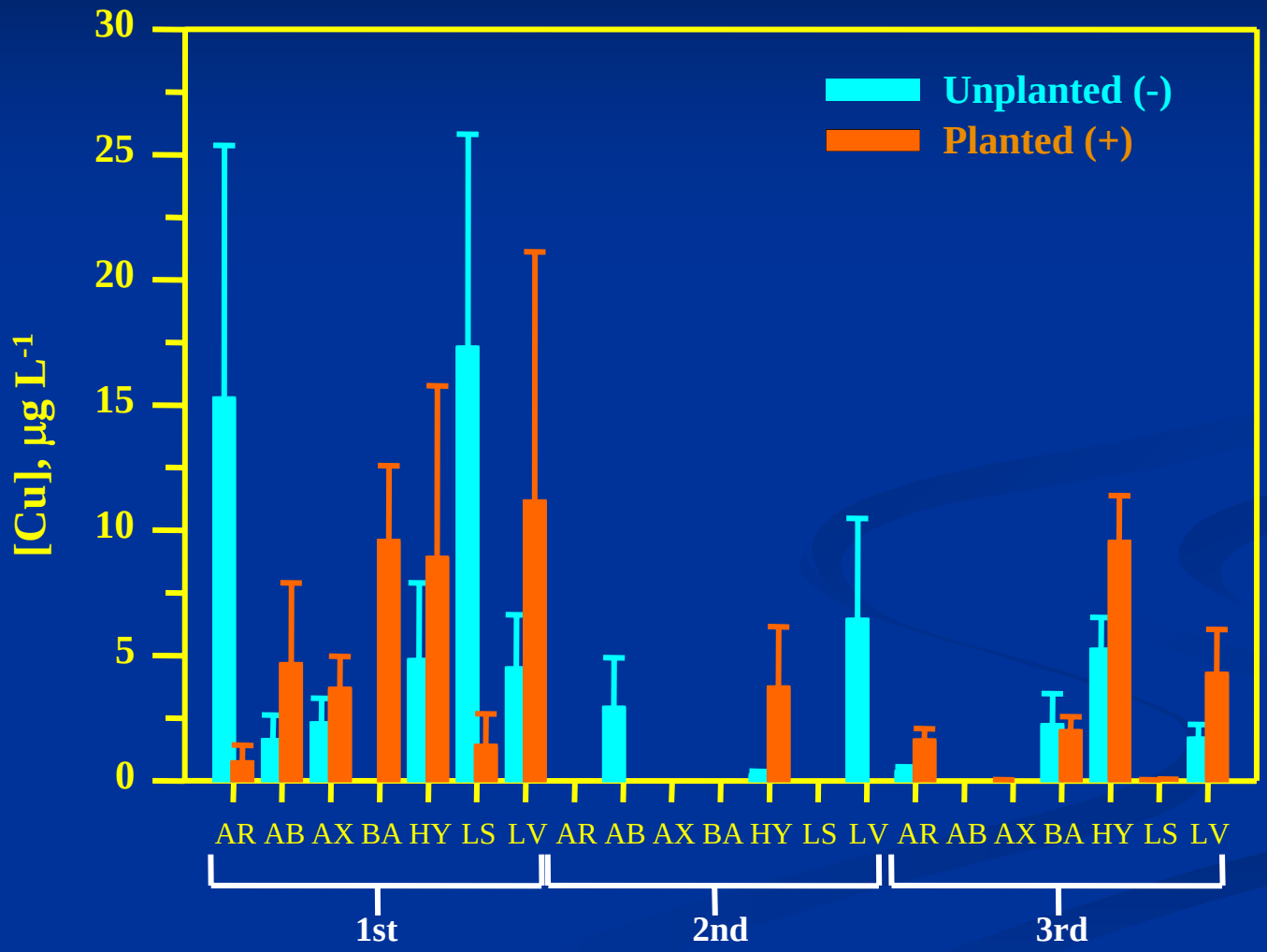
Summary of batch/leachate studies

- Cadmium:
  - Leaching for some substrates showed a “first flush” pattern, but continued leaching for others.
  - Plants enhanced Cd leaching for several substrates.

Batch extraction results for Cu



Leachate results for Cu

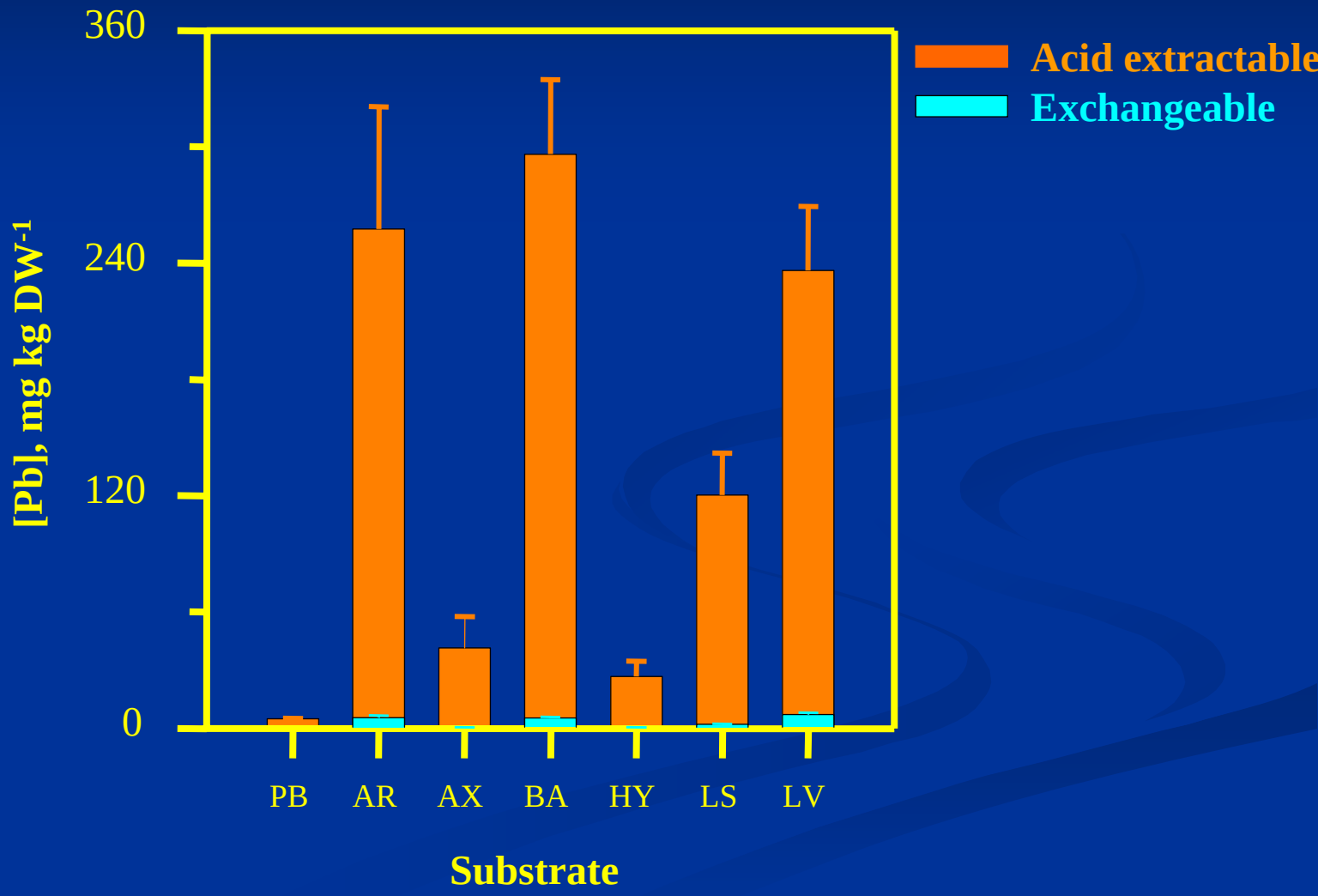


Planting treatment x substrate x leaching event

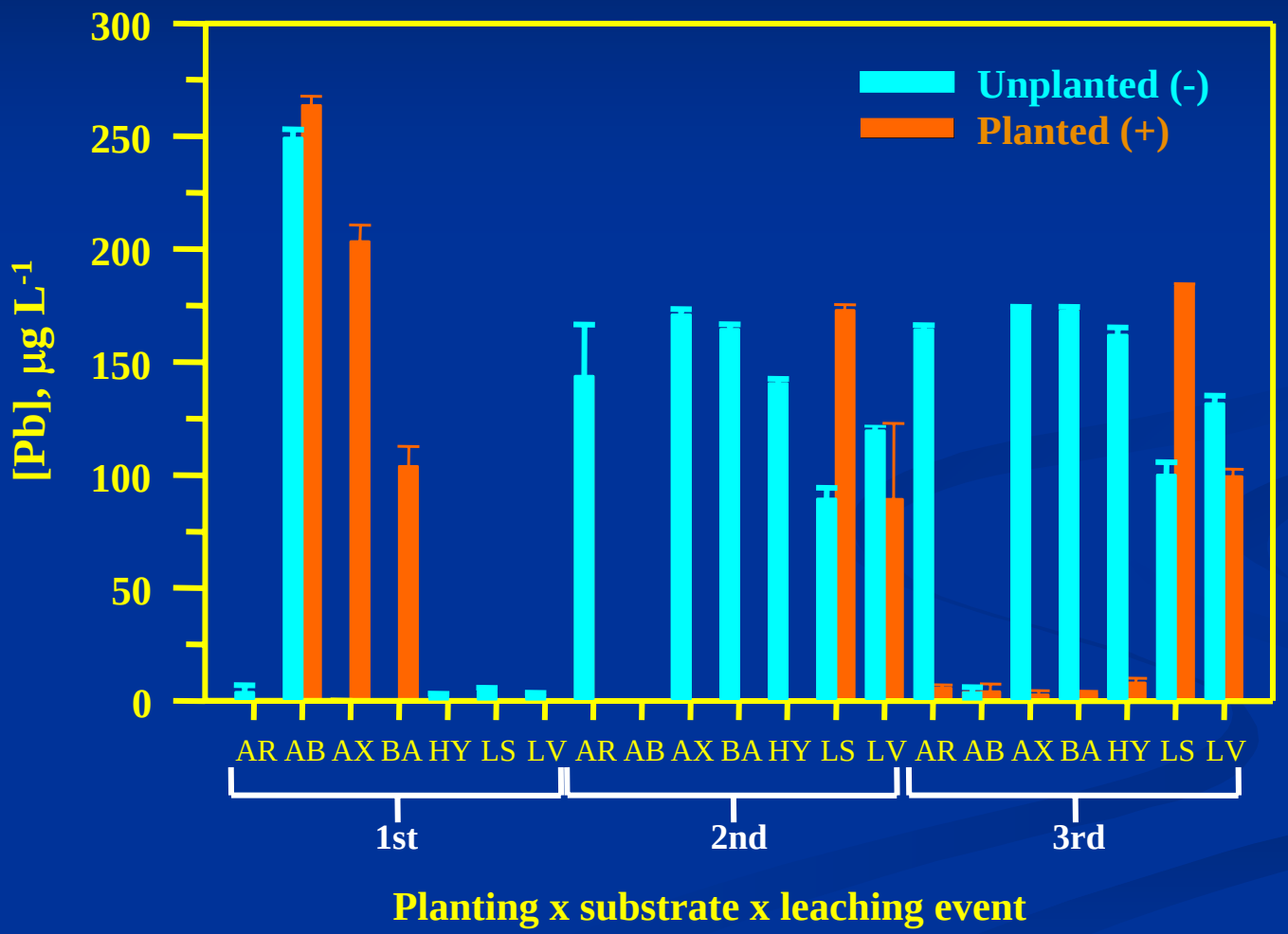
Summary of batch/leachate studies

- Copper:
  - Leaching for most substrates showed a "first flush" pattern, but continued leaching for others.
  - Plants had minimal effect on Cu leaching, except for Haydite and lava rock (increased leaching).
  - Did the copper leached come from the substrates or the pine bark amendment?

Batch extraction results for Pb



Leachate results for Pb



Summary of batch/leachate studies

- Lead:
  - Some substrates had surprisingly high concentrations of Pb, but not apparently exchangeable.
  - However, Pb leaching increased with time.
  - Plants greatly decreased leaching from some substrates but either had no effect or enhanced leaching from other substrates.

Concentration of metals in leachate as compared to U.S. water quality criteria

	Concentration, µg L^{-1}			
	Cd	Cu	Mn*	Pb
U.S. WQC	2	58	50	65
Mean	2.8	2.9	62.9	76.4
Range	<0 - 8.2	<0.1 - 80.9	<0.1 - 1,734	<0.1 - 289.8

* U.S. WQC represents a nuisance criteria

Comparison of leachate concentrations to U.S. water quality criteria

	% of samples exceeding U.S. WQC			
	Cd	Cu	Mn*	Pb
- Plants	30.4	6.0	24.4	60.3
+ Plants	49.1	5.4	16.2	29.3
All pots	39.7	5.7	20.3	45.5

* U.S. WQC represents a nuisance criteria

Summary of batch/leachate studies

- Overall:
  - Batch studies were not indicative of the leaching behavior of substrates.
  - Substrate leaching of metals was highly variable between substrates and between leachings.
  - The influence of the plants varied, decreasing leaching in some cases, promoting in others.
  - Leachate concentrations of Cd and Pb generally exceeded WQC, with plants having opposite effects.

Future questions

- How does source heterogeneity influence the acceptability of these substrates?
- To what extent are the substrates perpetual sources of pollutants as opposed to temporary sources?
- Can substrates be "pre-treated" to reduce the concentration of undesirable elements prior to their deployment in green roof systems?

Future questions

- What physicochemcial and/or biological processes within green roof systems influence metal solubility and therefore water quality?
- How might the pairing of plant species with substrate curtail pollutant leaching?
- Can the substrates act as sinks for pollutants introduced by wet and dry deposition?

Acknowledgments

- Resource providers:
  - Jost Greenhouses
  - Green Roof Blocks
  - EaglePicher Filtration & Minerals, Inc.
  - Western Pozzolan Corp.
  - Lassenite, Buildex, Inc.
  - Ameren UE
- Funding
  - Sigma Xi GIAR to S. Alsup