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ADVANCED TRANSPORTATION ENGINEERING SYSTEMS

Environmental Impacts of Reclaimed Asphalt Pavement

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In this presentation…

- ❑ Why RAP?
- ❑ Goals & Objectives
- ❑ Research Approach
- ❑ Study Results
- ❑ Conclusions & Recommendations
- ❑ Questions

Study's Motivation

Problem Statement

- Stockpiles of reclaimed asphalt pavement in New Jersey are growing in size
- The NJ EPA prohibits the use of RAP in *unbound applications* that stem from environmental concerns
- Does RAP introduce toxic pollutants to the environment?

EIRAP Study Objectives

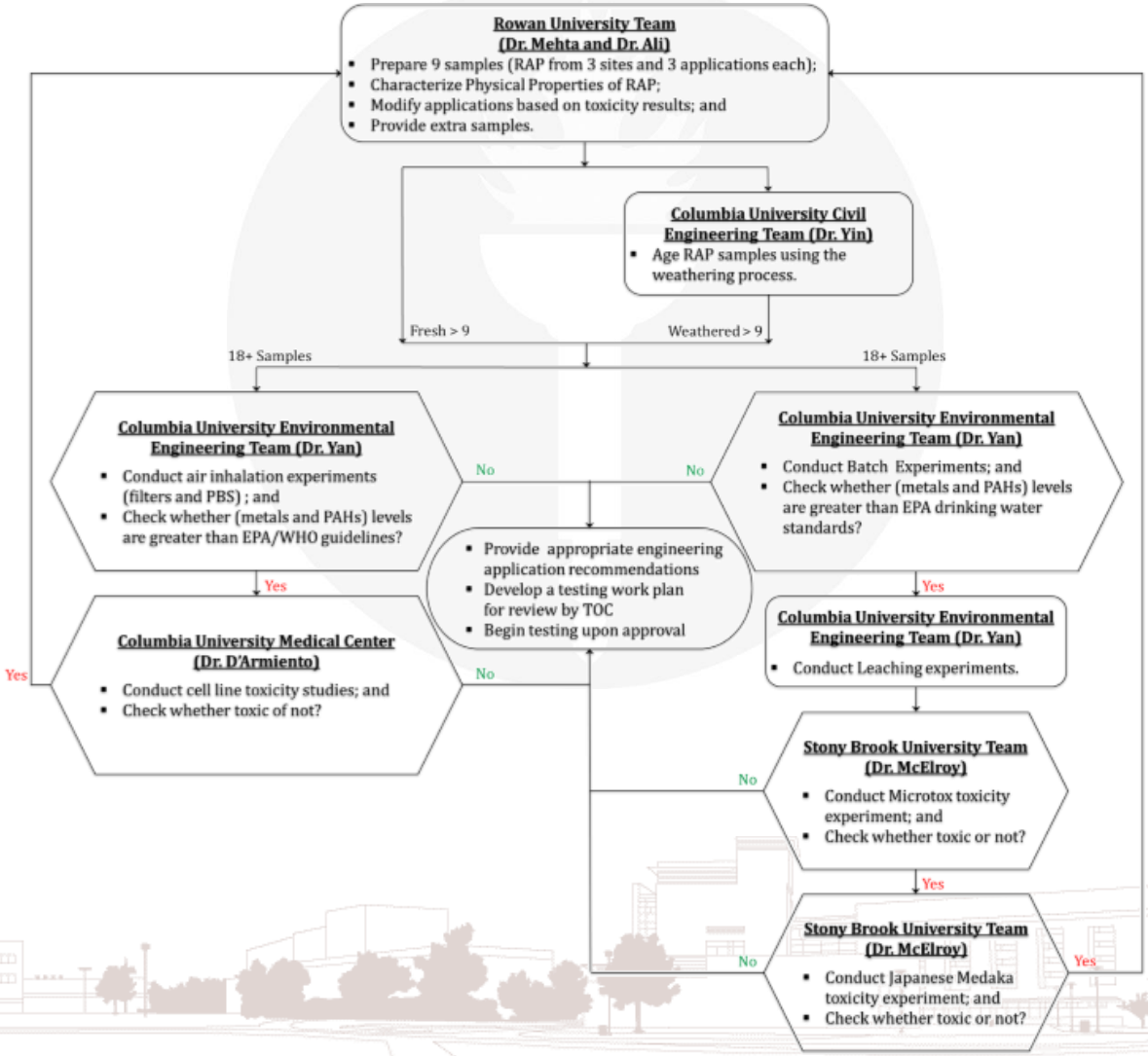
- To better understand the *environmental impacts of RAP* and to provide appropriate recommendations of *viable unbound RAP applications* other than usage in producing surface course mixes for asphalt pavements.

Significance

- Conclusively state if RAP has leaching characteristics that are detrimental to the environment.
- Comparing weathered test samples to a reference sample and non-weathered samples is unique to this study.
- Distinctive use of biological tests offer further insight into toxicity of RAP.

Research Approach

Research Approach



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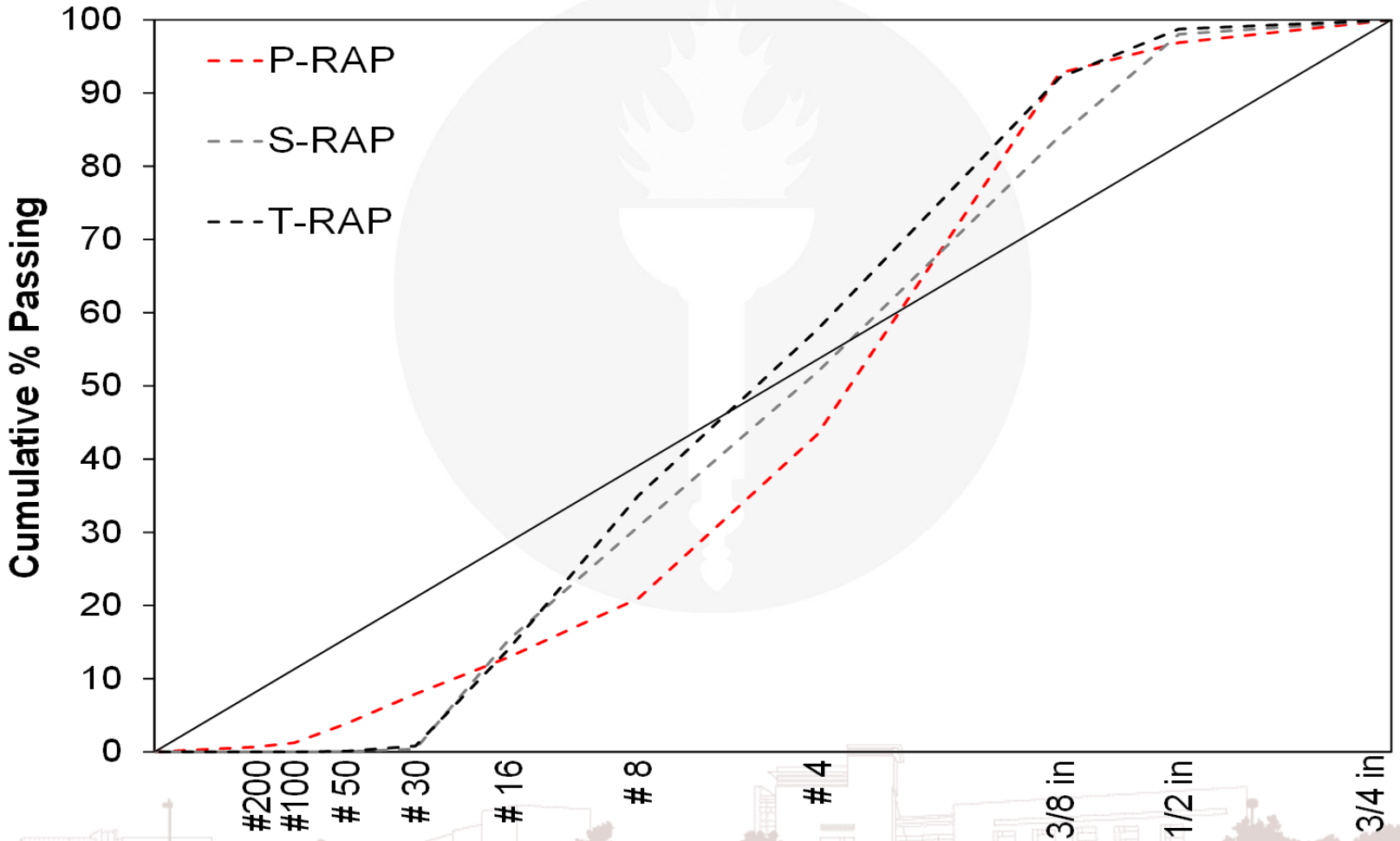
RAP Materials

RAP Materials

- RAP samples for this study were collected from three plants in NJ:
  - Southern NJ
  - Central NJ
  - Northern NJ
  - A fresh asphalt mix was also collected to serve as baseline for comparisons.

RAP Materials



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RAP Weathering

NEAUPG Annual Fall Meeting – October 18-19, 2017

RAP Weathering Procedures

- Both loose RAP materials and extracted RAP binder were aged as a part of this study using a QUV Machine (Q-Lab UV Tester).
- Two Procedures employed:
  - Continuous UV aging procedure
  - UV/Moisture/condensation aging procedure

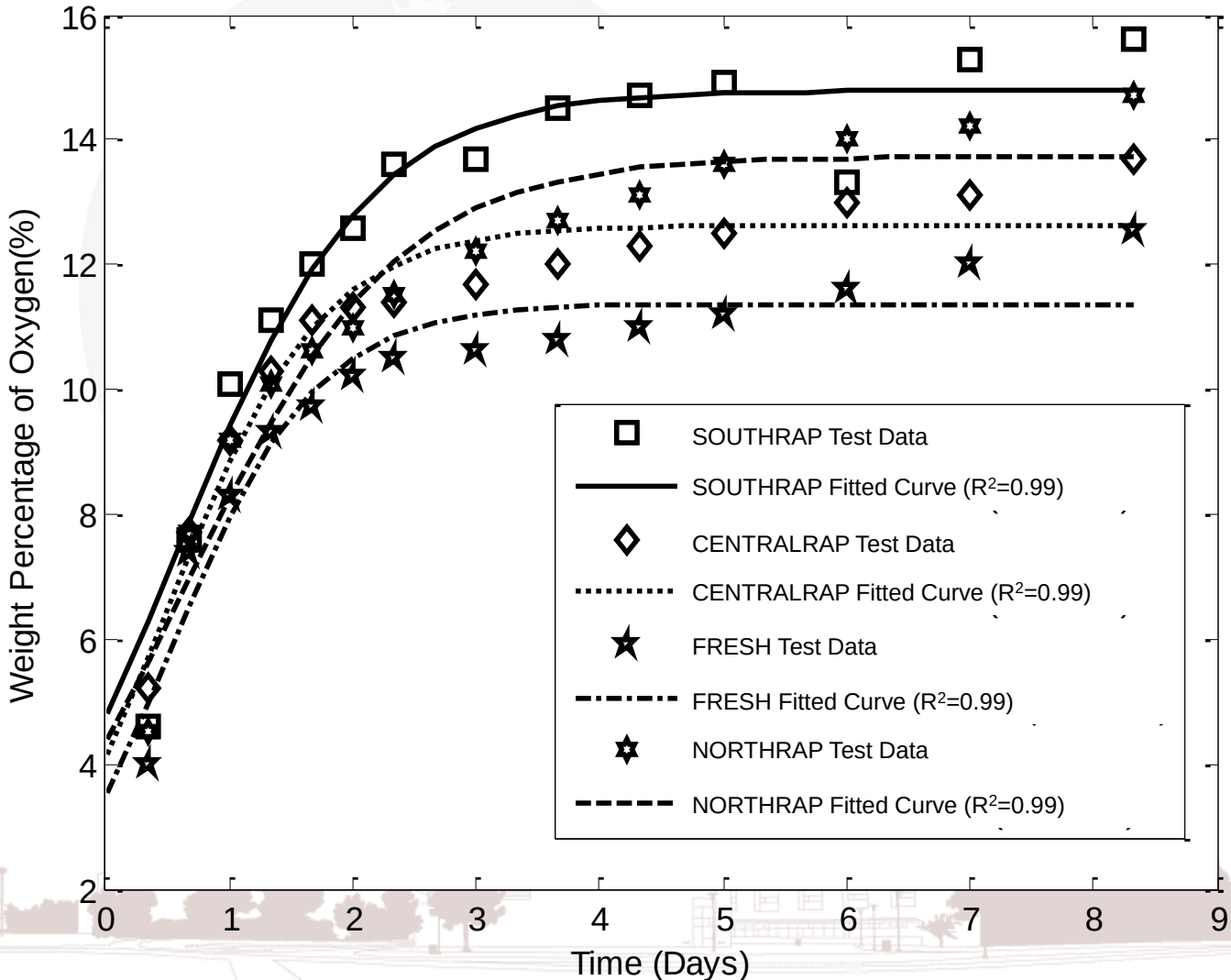
Q-Lab UV Tester

RAP Weathering Procedures

- ASTM D4799 Standards were employed:
  - Four hours of UV at 140°F (60°C) with a radiation intensity of 0.89 W/m^2·nm.
  - Fifteen minutes of water spray.
  - Three hours and 45 minutes of condensation at 122°F (50°C).
- Weight Percentage of Oxygen (WPO) was used as indicator of aging degree the RAP underwent after the weathering process is completed.

RAP Weathering Procedures

Energy Dispersive X-Ray Spectroscopy (EDX)



RAP Weathering Procedures

- It was found that the increase of WPO caused by the UV radiation during the UV/Heat/Moisture aging tests *was lower* than that during the continuous UV aging tests.

- This indicates that condensation and moisture will effectively reduce the UV aging rate.

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Batch, Column, and Air Chamber Experiments

Goal of Experiments

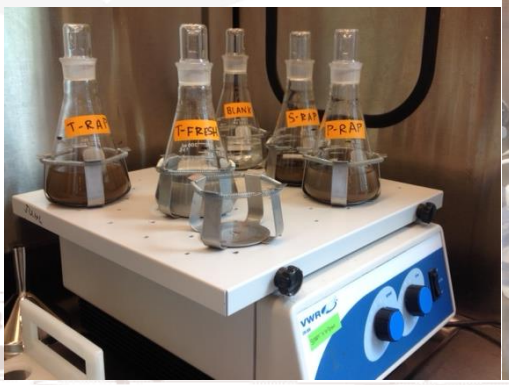
- Goal of the elution (Batch and Column) and emission experiments (Air Chamber) was to evaluate the amount of pollutants that might possibly be released from RAP, including various heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs).
- Particularly, focus was on:
  - Levels of metals and PAH compounds
  - Levels of Particulate Matter ($PM_{2.5}$)
  - Volatile Organic Compounds (VOCs)

Description of Materials

- Both weathered and unweathered RAP samples.
- Natural soil samples were also collected from NJ to evaluate the adsorption capability of soil particles for pollutants eluted from RAP.
- Artificial NJ rain water was also developed and used in the elution experiments.

Batch Extraction Experiment

- Samples were placed on an orbital shaker (~350 RPM for 18 ± 2 hours).
- Liquid extract was separated from the solids by filtration through a 0.7 um glass fiber filter.
- A liquid-liquid extraction was then performed on the water-based extract using dichloromethane.



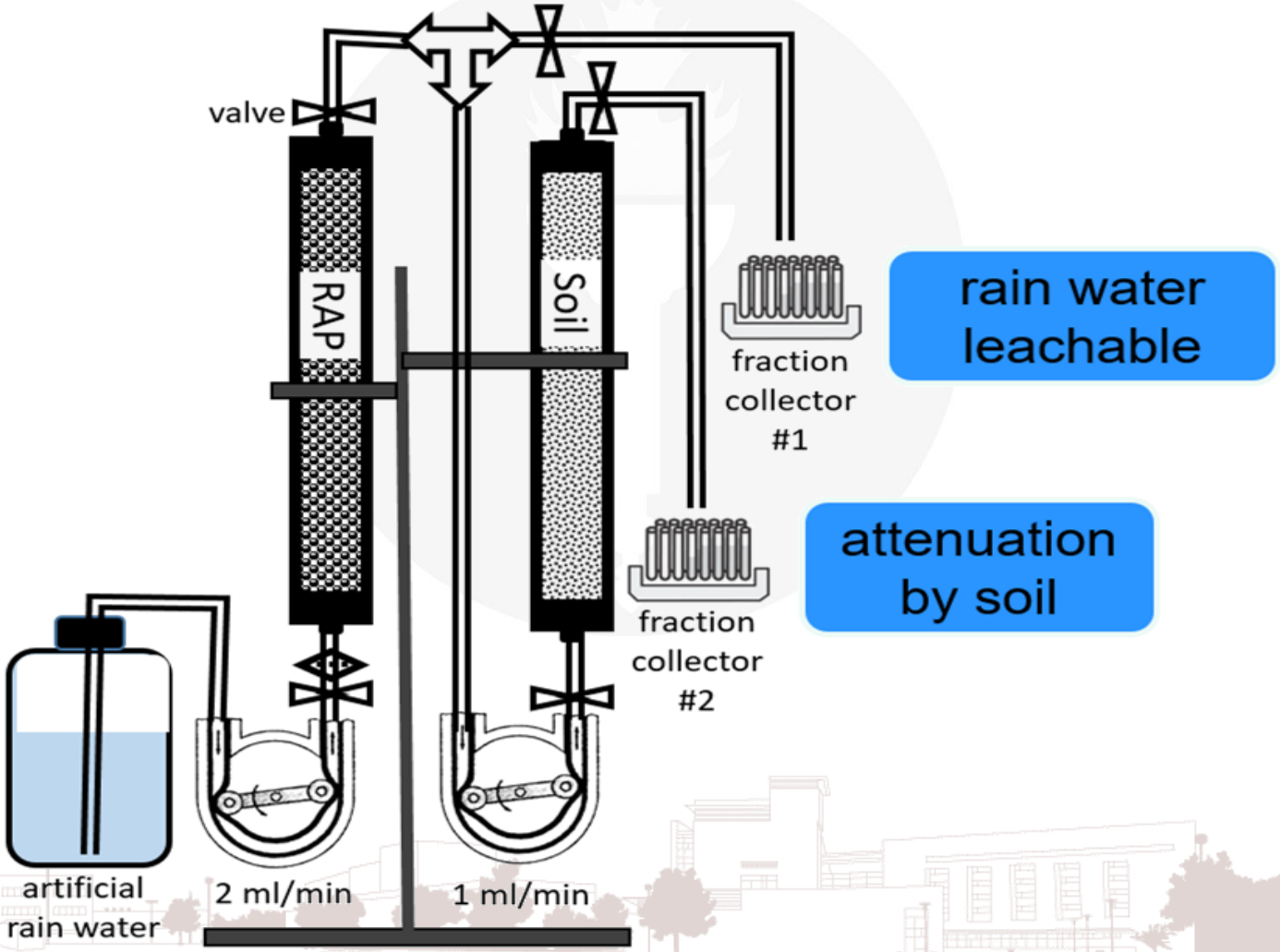
Column Experiments

- A two-column experiment was designed to investigate the release of metals and PAHs from RAP samples.
- Attenuation effect of soil on these potential pollutants before they could enter groundwater systems was also evaluated.
- The aforementioned artificial NJ rain water was introduced by a pump at about 2 mL/min flow rate from the bottom into the RAP-filled column first.

Column Experiments

- For quality control, before running column experiments, an Equipment Blank Test of running Milli-Q water through the two columns without filling of RAP or soil in any column was conducted for baseline definition and comparison.

Column Experiments



Chamber Inhalation

- Approximately 1–1.5 kg of RAP material is placed inside a chamber, on top of a shaker table.

- Chamber outlet is connected to two different types of samplers, which collects samples every three hours while the chamber is agitated on the shaker table.

Sample Processing

- *Element analysis of solution samples:*
  - Combined solution samples were filtered through 0.7 µm pore space glass fiber filter
  - Samples acidified to 1 percent HNO3 (Optima grade) for analysis of 32 elements on HR ICP-MS (Thermo Scientific Element XR) following a modified EPA method 200.8 (Cheng et al., 2004).

Sample Processing

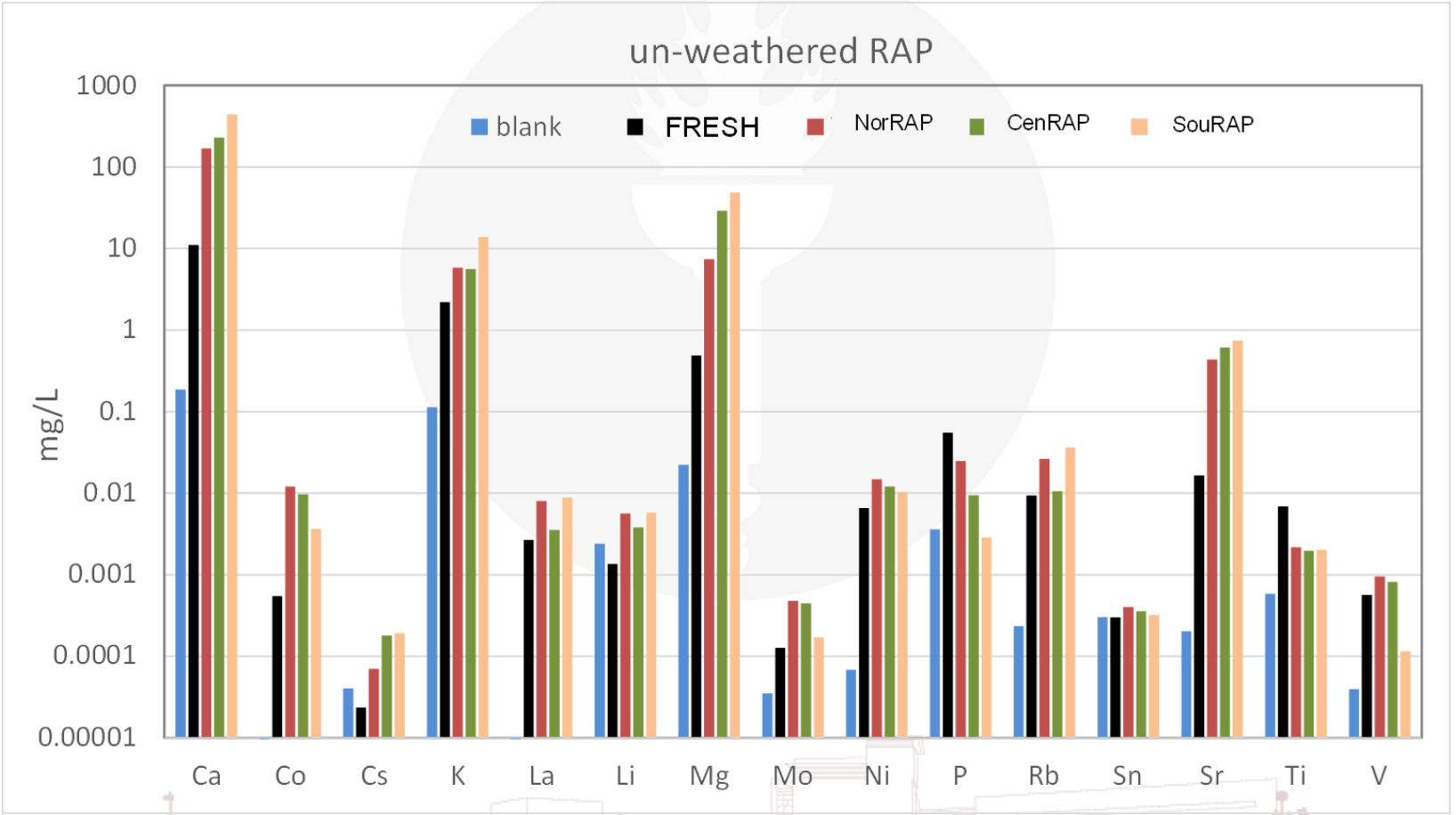
- *PAH analysis of solution samples:*
  - Combined solution samples were filtered through 0.7 µm pore space glass fiber filter, extracted with dichloromethane.
  - Then dried with anhydrous sodium sulfate for analysis of 29 PAHs on GC-MS (Varian – now Agilent 1200L MS) following the method in Yan et al. (2005).

Sample Processing

- *PM2.5 of inhalable samples:*
  - The PM2.5 samples were collected on 25 mm diameter Teflon filters, which were gravimetrically analyzed for particle concentrations.
- *VOC analysis of inhalable samples:*
  - The charcoal sorbent tubes were extracted and analyzed following NIOSH Method 1501.
  - The sorbent was extracted in carbon disulfide, which was then analyzed on GC-FID for a profile of 31 VOCs.

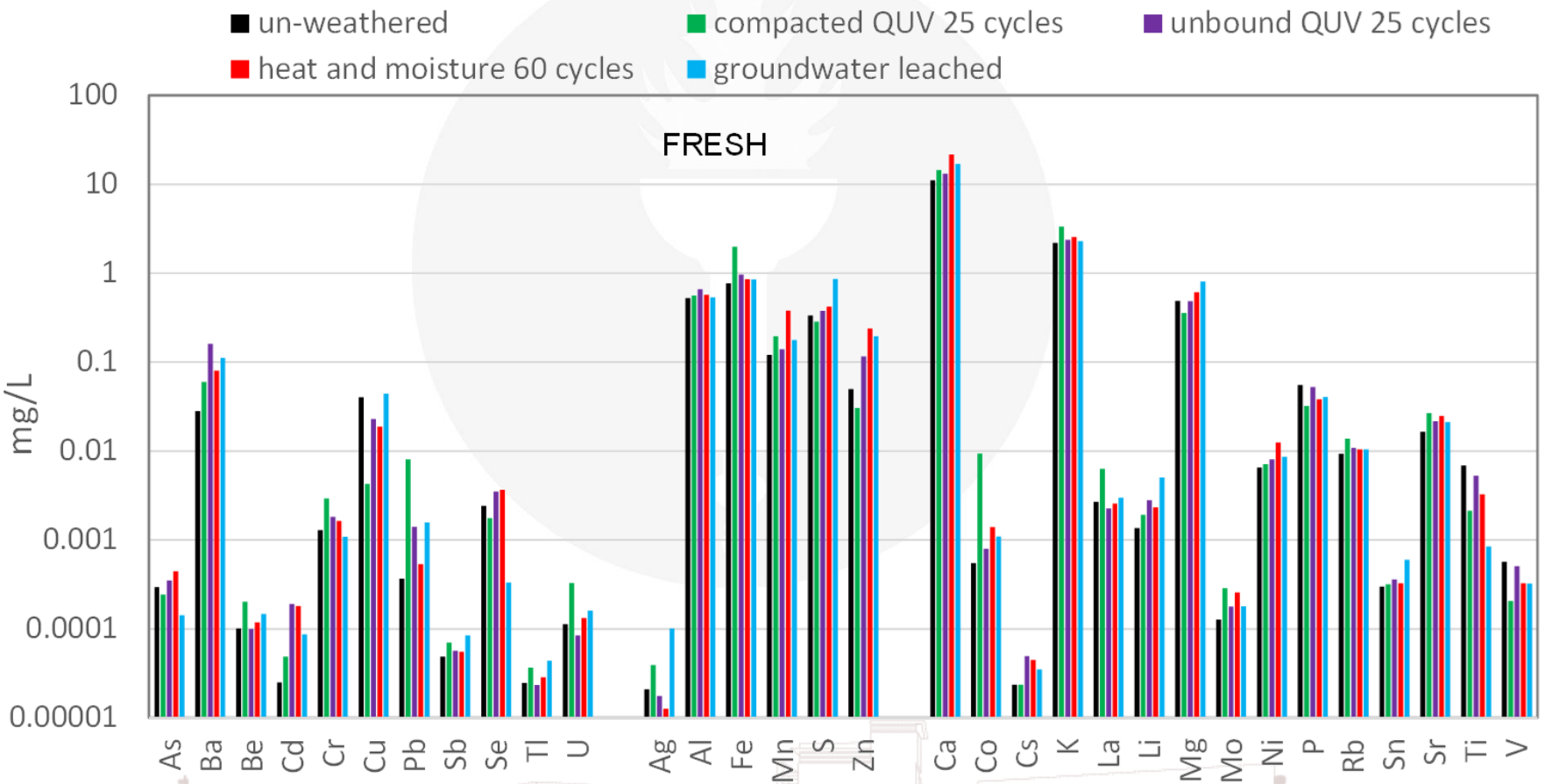
Chemical Analysis Results

Element Analysis (Batch)



Water Extractable Concentrations of 32 Elements in Un-weathered RAP Samples

Element Analysis (Batch)



Water Extractable Concentrations of 32 Elements in Weathered FRESH Samples

Element Analysis (Column)

- No major or trace elements were found exceeding the US EPA's primary drinking water MCLs from RAP column.
- Only Al and Fe from soil column exceeded the secondary MCLs in very few samples.
- NORTHRAP showed elevated levels of As, Ba, Cu, Mo, and V than fresh asphalt samples; suggesting a road source.

PAH Analysis (Column)

- PAHs with EPA standards were detected at concentrations less than the EPA guidelines (e.g., 0.0001 mg/L for benz[a]anthracene).

- Low molecular weight PAH compounds showed relatively high concentrations up to 1.4 E-4 mg/L in the solutions collected after soil column or were detected in soil solution earlier than in RAP solution; suggesting their major sources from soil.

VOC Analysis (Inhalation)

- In chamber inhalation experiments, only NORTHRAP emitted toluene at a level around 0.8 mg/m^3, but not in its weathered product.
- This level is well below the EPA's 6-hour exposure standard of 37 mg/m3 for general public.
- Low VOC emission from RAPs is expected (asphalt is the residue from petroleum refining).

Conclusions & Recommendations

Weathering

- Weathering, especially UV light, increased the oxygen levels in RAP.

- Weathering experiments showed that weight percentage of oxygen (WPO) is linearly can be used as an aging index.

Column Experiments

- Acidic leaching (e.g., in landfills where organic materials decompose creating an acidic environment) can lead to elution of lead (Pb) at a level higher than Maximum Contaminant Levels (MCLs).

- NJ rainwater elutes negligible metals, indicating RAP can be used as unbound aggregates in surface, base, and subbase (except landfills).

- Column elution experiments showed that the concentrations for major or trace elements were below the US EPA's primary drinking water standards.

Chemical analysis of weathered RAP

- In column elution experiments showed that PAHs can leach out from weathered RAP.

- The concentrations of these PAHs were significantly reduced (reached baseline levels) after the soil column as they were attenuated by the soil.

Microtox® screening analysis

- Both weathered and un-weathered RAP samples were more toxic than the blank extraction material,
  - Although did not differentiate among them.

- Tests appeared to be very sensitive to the acidic solution used in the RAP extractions even after readjustment of pH prior to testing.

Recommendations

- RAP may be used as an unbound material in all environments
- Except those which are highly acidic (pH ≤ 4)
- Such as, but not limited to,
  - mines with sulfur-containing minerals or
  - landfills where other materials may decompose creating an acidic environment

Recommendations

- Acceptable, beneficial, uses of unbound RAP materials may include but are not limited to,
  - using the unbound RAP as surface materials for parking lots, farm roads, or pathways;
  - for quarry reclamation;
  - as non-vegetative cover underneath guiderails;
  - and mixed with other materials for subbase or base materials;
  - in addition to the current uses in hot mix asphalt applications.

Recommendations

- As a precautionary measure, to determine the releasable levels of metals and PAHs for RAP stockpiles before using RAP in highly acidic environments

- Extract leachate samples using batch experiments and measuring pollutants (PAHs and metals) levels.

Recommendations

- If the releasable levels of pollutants are below US EPA drinking water standards, unbound RAP can be used in acidic environments.

Recommendations

- If the releasable levels of metals and PAHs exceed US EPA drinking water standards, it is recommended to ensure that there is a soil layer between the RAP and the groundwater aquifer.
- *It is important to note; however, that it was beyond the scope of this study to determine the type and thickness of the soil layer that is appropriate for the use of RAP.*

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Thank you from the CREATEs team

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