Wet-Weather Pollution from Commonly-Used Building Materials

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Photos taken approximately 60 years apart of this statue show evidence of severe deterioration due to the effects of acid rain.
QUESTIONS TO BE ANSWERED

• What is the potential pollutant release from common building materials both when new and after aging?
  – How does exposure to road salt and other adverse conditions affect pollutant release?
• Can we use short-term laboratory testing to predict long-term pollutant release in the field?
• Can we modify existing roofing materials or develop a more environmentally-friendly roofing material? (focusing on those materials that are used in large quantities as roofing surfaces and substrates)?
Galvanized (Galvalume) Roofing – Airport Facility

- 7 storms sampled of direct roof runoff
- Zinc
  - 0.42 to 14.7 mg/L (average 88% dissolved; COV = 7%).
- Copper
  - 0.01 to 1.4 mg/L (average 75% dissolved; COV = 24%).
- Lead
  - Not detected

Galvanized metal roofing panels used on a building in Denali, Alaska.
Categories of Materials Investigated: Laboratory and Field Testing

- Galvanized metal (both painted and unpainted)
- Aluminum gutters/siding
- Vinyl roofing panels
- Asphalt roofing shingles
- Roofing felt
- Roofing sealants
- Membrane/rubberized roofing
- Cedar shingles
- Faux slate shingles (made from recycled materials)
- Untreated wood (with and without paint)
- Treated wood
Laboratory Testing
Analytes

- pH
- Conductivity
- Chemical oxygen demand (COD)
- Heavy metals and major cations (copper, chromium, cadmium, lead, zinc, arsenic, calcium, magnesium, sodium, potassium)
- Nutrients (nitrate, ammonia, total nitrogen, total and reactive phosphorus)
- Semi-volatile organics – laboratory testing only
Methodology

- Summer 2002 – Summer 2003: Laboratory TCLP (acid rain simulation)
- Winter 2004 – Laboratory-testing of 60-year-old outdoor painted-metal roofing panels
- Spring 2005: Design and construction of test frames at PSH and UAB
- Summer 2005 – indefinite: Long-term, outdoor investigation from intact installations on test frames
  - Runoff samples analyzed regularly (every storm first two months; periodic sampling thereafter).
Results: Laboratory Testing

- pH data shows test materials did not neutralize simulant water pH.
- Conductivity (not shown) – most samples near background; but metal roofing panels generated elevated conductivity.
- Organic data (not shown) – only bis(2-ethylhexyl phthalate) in concentration greater than background from roofing felt.
  - COD used in the future as a surrogate for VOC and SVOC analysis.
Nitrate
NO₃-N

Laboratory-Scale Tests
Phosphate
(PO₄-P)

Laboratory-Scale Tests
Copper

Laboratory-Scale Tests
Lead

Laboratory-Scale Tests
Zinc

Laboratory-Scale Tests
Aged Roofing Panels
60+-Year Roofing Panels: Heavy Metals

- **Cu**
- **Cr**
- **Pb**
- **Zn**
Testing Set-Up at Penn State Harrisburg
Testing Set-Up at UAB
During Rain Storm, August 2005
Results: Field Testing

- 2.5 months of sampling complete
- pH, conductivity, and COD values showed little variability between storms
- Conductivity stabilized after ~20 days
- Physical degradation of roofing panels, particularly the metal panels, is visible after two weeks of exposure
Ammonia
Reactive Phosphorus

Wood Products, Roofing Felt and Asphalt Shingles

Vinyl, Rubber, PVC, and Corrugated Metal Roofing
Total Phosphorus

Wood Products, Roofing Felt and Asphalt Shingles

- Untreated Plywood
- Pressure Treated Wood
- Water Proofed Wood
- Cedar Shakes
- Roofing Felt
- Asphalt Shingles

Vinyl, Rubber, PVC, and Corrugated Metal Roofing

- Red Vinyl
- Rubberized
- Corrugated PVC
- Corrugated Aluminum
- Galvalume™
Summary of Results to Date: Laboratory TCLP

- **Nutrients:**
  - Elevated nitrate in roofing felt, wood, and one sealant
  - Phosphate elevated: galvanized metal and Gardner Wet-R-Dri

- **Metals:**
  - Copper highest in woods with CCA-based preservative.
  - Zinc highest: galvanized metal (Zn is sacrificial cation)
  - Others elevated but four orders of magnitude less: waterproof wood, Leak Stopper, faux slate, and Kool-Seal White Acrylic

- **Aged roofing panels for both dissolution and TCLP:**
  - 1 – 5 mg/kg of Cu
  - 1 – 10 mg/kg Cr
  - 30 – 70 mg/kg Pb
  - Zinc 3 orders of magnitude higher than Pb (10 – 40 g/kg)
Comparison of Galvanized Metal Roofing

New

60+ years old
Summary of Results to Date: Outdoor Testing

- Exposure for at least 50 days to atmospheric conditions in Harrisburg area. (rainfall pH varied between 3.9 and 6.0)

- pH: Runoff pH between 5 – 6.5, except for roofing felt, rubberized roofing, and cedar shakes (runoff pH < 5)
  - No correlation seen to date with rainfall pH (limited rainfall pH data)

- Roofing felt, cedar shakes, and water-proof wood highest NO₃-N concentrations. Water-proof wood also had high NH₃-N releases

- Asphalt shingles: TP four times greater than other materials. TP and RP concentrations now leveling off to lower background levels

- Roofing panel degradation noticed within 2 weeks of the onset of environmental exposure
Conclusions and Future Research

• Materials with metallic preservatives or metal skin coatings tend to leach more of the measured metals.

• Laboratory shows that nutrient contributions could be considerable. This has been seen in the field installations, especially shortly after installation.

• This is the beginning of a long-term monitoring activity since the available data is on either new or old materials, but limited information on behavior over complete life cycle.
Questions?
Vinyl, Rubber, PVC, and Corrugated Metal Roofing

Nitrate (mg/L)

Days Since Installation (Age)

- Red Vinyl
- Rubberized
- Corrugated PVC
- Corrugated Aluminum
- Galvalume™
Wood Products, Roofing Felt and Asphalt Shingles

- Untreated Plywood
- Pressure Treated Wood
- Water Proofed Wood
- Cedar Shakes
- Roofing Felt
- Asphalt Shingles

pH vs Days Since Installation (Age)

pH = 7
Wood Products, Roofing Felt and Asphalt Shingles

Upper Valid Analytical Limit
= 1500 mg/L

- Untreated Plywood
- Pressure Treated Wood
- Water Proofed Wood
- Cedar Shakes
- Roofing Felt
- Asphalt Shingles

COD (mg/L)

Days Since Installation (Age)