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WET-WEATHER POLLUTION FROM COMMONLY-USED BUILDING MATERIALS

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ABSTRACT

Development in sensitive watersheds continues to pose environmental problems for receiving waters. One contributor to the long-term pollution of sensitive waterways is building and construction materials. However, the long-term effect of many building materials on the environment has not been quantified. Prior testing of these materials in the laboratory has indicated that the potential for release (primarily nutrients, lighter hydrocarbons, pesticides, and metals) is significant. Additional testing for metals' release from aged roofing panels also has shown that the potential for pollutant release still exists after 60 years of exposure to the environment. The data that is missing from a complete evaluation of specific building materials is behavior over the lifespan of the material, including the critical period of initial exposure. This paper provides an overview of the limited literature available on the subject, results from laboratory testing of common building materials and aged roofing panels, and an overview of the next phase of needed research. Ongoing work at campuses in two rainfall/climate zones in the U.S. have been designed fill in the data gap.

KEYWORDS: Stormwater pollution, roofing materials, urban runoff, roof patch materials

INTRODUCTION

Past studies have identified urban runoff as a major contributor to the degradation of many urban streams, rivers, and estuaries (Field and Turkeltaub, 1981; Pitt and Bozeman, 1982; Pitt and Bissonnette, 1984; Pitt, 1994, and Burton and Pitt 2001 which includes an extensive literature review). Studies have also specifically found organic and metallic toxicants in urban storm water discharges that can contribute to receiving water degradation (EPA 1983; Hoffman *et al.*, 1984; Fram *et al.*, 1987).

Pitt *et al.* (1995) investigated the toxicity of source-specific urban wet weather flowsRoofs, storage areas, streets, and loading docks had the highest frequency of moderately toxic and highly toxic samples. Roof runoff and paved surfaces were found to have the greatest organic toxicant detection frequencies, and the highest levels of detected metals. What cannot be determined from these results is the contribution to toxicity from the various roofing, building and paving materials themselves. However, laboratory studies of common construction materials (Pitt *et al.*, 2000; Clark 2000) have demonstrated the potential for many construction materials to leach pollutants into the environment. Other studies have confirmed the important role played by roofs, paved surfaces, treated woods, and other construction materials to wet weather flow pollutant contributions. The following is a summary of some of the literature available on building material contributions to stormwater and on the building material compositions.

Roofing and Paving Materials. Boller (1997) identified heavy metals such as cadmium, copper, lead and zinc as the critical metals in domestic wastewaters and, based on flow studies, concluded that runoff from roofs and streets contribute 50-80% of these metals to the total mass flow in Swiss combined sewer systems. Roof runoff samples (tile, polyester, and flat gravel roofs) were analyzed and metal concentrations were found to vary tremendously with roof type. First flush analyses showed polyester roofs contributing highest concentrations of copper (6,817 µg/L), zinc (2,076 µg/L), cadmium (3.1 µg/L) and lead (510 µg/L). Concentrations in runoff from tile roofs were copper (1,905 µg/L), zinc (360 µg/L), cadmium (2.1 µg/L) and lead (172 µg/L). Runoff from flat gravel roofs also contributed copper (140 µg/L), zinc (36 µg/L), cadmium (0.2 µg/L) and lead (22 µg/L). Runoff from roofs was found to contain not only heavy metals, but polyaromatic hydrocarbons (PAHs) and organic halogens as well.

Good (1993) reported on the one-time sampling of runoff from a rusty galvanized metal roof, a weathered metal roof, a built-up roof of plywood covered with roofing paper and tar, a flat tar-covered roof which had been painted with a fibrous reflective aluminum paint, and a relatively new anodized aluminum material at a sawmill facility on the coast of Washington. Differences in contributions of copper, lead, and zinc were noticed between each roof type. Built-up roofing contributed the highest concentrations of dissolved copper (128 µg/L) and total copper (166 µg/L), approximately 10 times higher than levels detected in runoff from the other roofs sampled. Runoff from the rusty galvanized metal roof contained the highest concentrations of dissolved lead (35 µg/L) and total lead (302 µg/L), dissolved zinc (11,900 µg/L) and total zinc (12,200 µg/L). Dissolved metals concentrations and toxicity remained high in roof runoff samples collected three hours after the beginning of the storm event, indicating metals leaching continued throughout storm events. All roof runoff samples were found to be highly toxic to rainbow trout.

Asphalt. Coal tars and pitches are rich in PAHs, including recognized human carcinogens such as benzo[a]pyrene. In addition to the components of the bitumens and asphalts, other compounds are added to paving and roofing materials. Chemical modifiers have been used both to increase the temperature range at which asphalts can be used and to prevent stripping of the asphalt from the binder (Shashidar, *et al.* 1995; Tarrer, *et al.* 1989; Lesueur, *et al.* 1995; Stuart and Malmquist 1994). The long-term environmental effects of these chemicals in asphalts are unknown, and the potential pollutant release of these chemicals to stormwater needs to be considered. Nelson *et al.* (2001) investigated the potential pollutant contributions from asphalt highways as part of an NCHRP project and did not find an impact from new materials, but limited data was available for aged asphalt.

Concrete. Much of the current work on wet-weather pollutant contributions from materials has focused on the potential for incorporating waste materials into concrete mixes (Wiebusch, *et al.* 1998). One common method for testing mixtures for environmental compatibility is the Toxicity Characteristics Leaching Procedure (TCLP). However, work by Janusa, *et al.* (1998) has shown that inconsistency in the testing procedure can greatly influence the results, with a 50% decrease in the amount of waste released when particle sizes of 8 to 9.5 mm were used compared to using all particles less than 9.5 mm. In addition, results indicated that as the contact time between the leachant and waste increased, the amount of waste leached increased.

Exposed Wooden Material/Treated Wood. The literature supports the examination of toxicant leaching potential associated with a variety of woods, especially treated woods, used for utility poles, recreational and other wooden structures. Typical treated woods include chromated-copper-arsenate (CCA), ammoniacal copper zinc arsenate (ACZA), pentachlorophenol (PCP), and creosote. The volume of treated wood produced in the United States in 1987 was as follows:

CCA/ACZA – 11.9 million cubic meters, PCP – 1.4 million cubic meters, Creosote – 2.8 million cubic meters (Micklewright, 1989).

Lebow, et al. (1999) tested CCA-treated wood in seawater and deionized water, and found that the steady-state release rate of copper was much greater in seawater than in deionized water. In contrast, the steady-state release rate of arsenic was greater in deionized water than in seawater. Seawater testing may be indicative of material behavior when exposed to salt-laced snowmelt runoff. Testing of treated and untreated wood panels in freshwater showed that the metals leached from CCA-treated wood could be taken up by epibiota and trophically transferred (Weis and Weis 1999). Arsenault (1975) and Stranks (1976) reported PCP around the base of, and in drainage ditches near, treated utility poles. Stranks reported ditch waters with 1.8 times the 96-h LC_{50} of chlorophenol for salmonids near treated utility poles.

Paints. Davis and Burns (1999) investigated lead concentrations from 169 different painted structures. They found that the order of lead release was (geometric mean, median, 10th and 90th percentiles): wood (40, 49, 2.6 - 380 µg/L) > brick (2, 16, 3.3 - 240 µg/L) > block (9.7, 8.0, < 2 - 110 µg/L). Lead concentration depended strongly on paint age and condition. Lead levels from washes of older paints were much higher than from freshly painted surfaces. Lead in the stormwater was found to be 70% or greater in the particulate form.

METHODOLOGY

A variety of new construction materials and aged metal roofing panels were tested in a laboratory setting to determine potential pollutant release. The project focused on materials that are commonly used in the construction of commercial and industrial facilities. The categories of materials investigated during the laboratory-scale survey include the following:

- Asphalt and concrete pavements and their sealers
- Roofing materials (galvanized metal, asphalt/tar shingles, cedar shingles, plastic/vinyl/fiberglass roofing panels, fake slate roofing, and roofing sealers)
- Woods (treated with CCA and with an alternative water-proofing compound [organic-CCA combination])

The new construction materials were purchased from Lowes Home Improvement Stores in Birmingham, Alabama. The aged (documented age: 60 years) metal roofing panels were obtained from a barn in Lancaster County, Pennsylvania. One of the two panels had been on the roof for the entire time and was rusted. The second panel had been stored in the barn as a replacement, and still had its paint intact.

The first series of tests was performed during the 2002 – 2003 academic year, and consisted of a modified TCLP test, where exposure to acid rain was simulated. The materials were analyzed for the following constituents: pH, conductivity, chemical oxygen demand, semi-volatile organics and pesticides, heavy metals and major cations, and nutrients. The roofing panels were analyzed for heavy metals only.

RESULTS AND DISCUSSION

The results from the nutrient testing showed release of nitrate and phosphate to the leachate (Figure 1 – NO_3). The organic data (data not shown) indicate very little potential contributions of semi-volatile organics. The highest concentration of organics found was 315 µg/L of bis (2-ethylhexyl) phthalate in roofing felt. The metals results show that significant potential exists for metals to be leached from these materials as they degrade (Figure 3 – zinc). The laboratory results (showing averages of triplicate samples for each material) are given in Table 2.

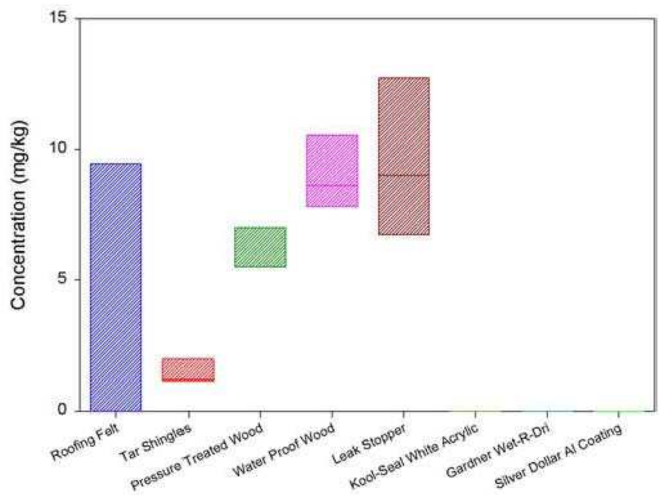

Figure 1. Nitrate Concentration Data.

The laboratory-scale research showed that there is significant potential for pollutants (especially nutrients and metals) to be released from common building materials. However, this research did not mimic the cyclic wet-dry weathering to which these materials are exposed. The weathering phenomena, including exposure to UV, acid rain and/or snowmelt water will impact the pollutant release over time. This information will be crucial for modeling and for translating the laboratory leaching test results to actual behavior in the environment.

During the winter of 2003, two painted metal roofing panels (age approximately 60 years) were evaluated. One panel had been exposed to the atmosphere since installation and was rusted across approximately 75% of the panel, while the other was a replacement panel. The panels were subjected to the following tests: 1) a dissolution test in which the panel was dissolved in concentrated nitric acid, 2) a leaching test similar to the previously-discussed laboratory work, and 3) a simulated rain exposure test. The results for zinc are shown in Figure 2. Results indicate that significant quantities of zinc are released from the material during both the dissolution and leaching tests. It is also apparent that "raining" on the material caused some zinc to be released to the environment, although the magnitude of the release is >2 log less than the release from dissolution and leaching. Iron, as the underlying metal, was significantly more stable in the formulation during "rain", although its leaching in the laboratory tests were equivalent to zinc's leaching. The lead's releases were an order of magnitude less than zinc's, but unlike iron, lead appeared in the "runoff", likely due to lead paint on the panels.

The analysis of these roofing panels confirmed the laboratory tests and the literature. They showed that metals are still being released from materials that are well into their lifespan, and indicate that measurable quantities of pollutants may continue to be released throughout the material's useful life. Prior assumptions have been that releases stabilize to negligible levels over a product's lifespan. Given the large quantity of these materials installed in the environment, the overall contribution may be significant and deserves further investigation. **Table 2.** Laboratory leaching of building materials.

MATERIAL	PO_4 (mg/kg)	NO_3 (mg/kg)	NH_3 (mg/kg)	COD (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Fe (mg/kg)
Asphalt/Tar Shingles	29.4	1.52	0.83	2698	0.66	0.34	1.22	46.7
Roofing Felt	44.6	4.2	108	26367	0.026	0.11	0	1.87
Ondura™ Red Vinyl Roofing	0	2.44	1.44	13161	0	0	0	0
Fiberglass Roofing	0.86	0	0	0	0.017	0.005	0.53	0
White Plastic Roofing	0	0.99	0	6842	0.076	0	1.42	2
Cedar Roofing Shingles	1.23	0	0	18852	0.033	0.11	0.64	1.64
Galvanized Metal Roofing	53.8	58.4	12.1	20471	0.44	0.16	16500	9400
Galvanized Metal Roofing (replicate)	30.8	na	1.14	0	0	1.61	11900	3300
Water Proof Wood	0	9.12	0	0	161	0.29	3.72	3.22
Pressure Treated Wood	62.2	6.47	0.38	53002	191	0	1.35	2.69
Fake Slate Roofing Shingle	0.07	2.71	0	0	0.2	0.42	1.81	20.1
Leak Stopper™ Rubberized Roof Patch	0.05	9.43	0	726	0.13	3.78	2.61	2.25
Kool Seal™ Acrylic Patching Cement	21.6	0	0	2297	0.15	0.65	2.94	229
Gardner Wet-R-Dri™ Roofing Patch	203	0	0	0	0	0.094	0	1.39

Silver Dollar Aluminum Roof Coating	0	na	na	21520	1.14	0.3	0	151

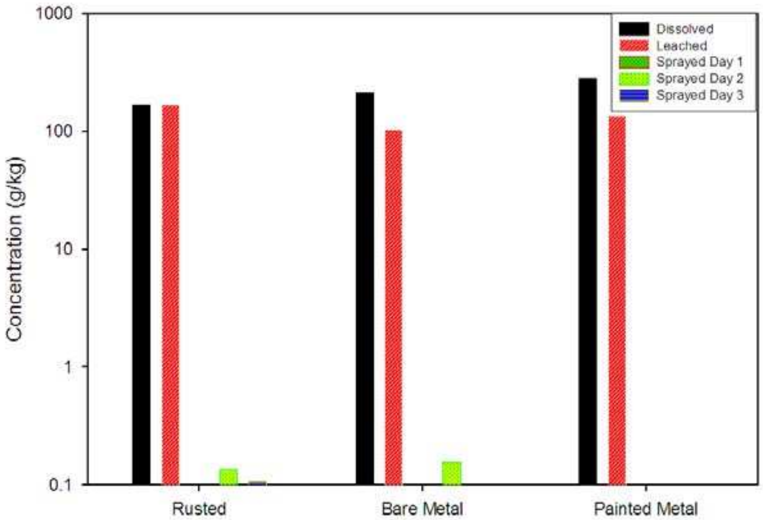

Figure 2. Zinc in roofing panels.

CONCLUSIONS

Preliminary results showed that galvanized metal roofing contributed the greatest concentrations of many of the pollutants of interest – conductivity, cations, metals and nutrients. In addition, the metals analysis showed that the pressure-treated and waterproof wood contributed a significant metals load. COD was also elevated in the leachate from the waterproof wood. Other roofing materials investigated to date appeared to be leaching phthalate esters from the plasticizers. Tests conducted on the aged roofing panels indicated that this pollutant release can occur for an extended period of time (Figure 3 compares zinc release from new galvanized metal panels and from the exposed roofing panels).

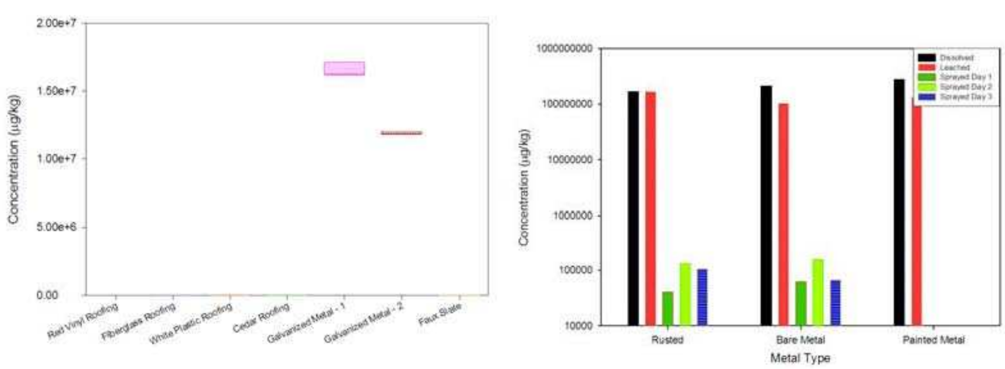

Figure 3. Comparison of zinc release in laboratory (left) on new materials and from environmentally-exposed materials (right).

In general, nutrient leaching from construction materials has not been investigated. The preliminary results of this project demonstrate that nutrient leaching may be significant in the right environmental conditions. Potential testing for environmental compatibility should include a wide range of potential pollutants, rather than simply focusing only on the expected organic and metallic pollutants.

Future Research. Pilot-scale field monitoring of installed construction materials in Birmingham, Alabama, began in the fall of 2004. Identical test frames will be constructed in late winter 2005 in Harrisburg, Pennsylvania so that dual-site testing of these materials can occur. This will allow for an evaluation of environmental factors affecting aging and pollutant release, since the two sites are in different EPA rainfall zones and are climatically different. It is anticipated that long-term monitoring of field-installed construction materials will indicate if laboratory-scale test results can be used to anticipate behavior in the field. If so, a protocol can be established that will enable rapid laboratory testing results to predict the pollutant release over time, based on initial degradation releases and information about release behavior, e.g., a mathematical expression of the release based on parameters such as UV exposure, rainfall exposure (duration and intensity), etc. The development of such a standard protocol would enable manufacturers to test their materials for environmental “friendliness” prior to marketing.

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