Effect of Roof Material on Water Quality for Rainwater Harvesting Systems –

Progress Report to the Texas Water Development Board (TWDB)

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Prepared for:
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The main objective of this research is to provide recommendations to the rainwater harvesting community in Texas regarding the selection of roofing material for rainwater harvesting and to support these recommendations with scientific data. In Task 1, we have identified roofing materials that are commonly used in Texas and those that are commonly recommended in Texas for rainwater harvesting. In Task 2, we are examining the quality of harvested rainwater from pilot-scale roofs constructed with traditional materials (i.e., asphalt fiberglass shingles, galvanized metal, concrete tiles) and alternative materials (i.e., green and cool roofs). In Task 3, we are examining the quality of harvested rainwater from two existing full-scale residential roofs. In Task 4, we will prepare and submit a final report for the research. The following provides a summary of our progress to date for Tasks 1 through 3.

Preliminary Data

Before initiating this project with the TWDB, preliminary data on metal concentrations in harvested rainwater were gathered from an existing metal roof and an existing asphalt fiberglass shingle roof. Dechlorinated tapwater was sprinkled on the roofs at the field sites, and the concentrations of arsenic, zinc, cadmium, and lead were measured (Table 1). As expected, the metal roof showed the highest concentration of metals among the sites tested.

Table 1. Metals Concentrations in Runoff from Different Types of Roofing Materials

Roof Type	**Metal concentrations (μg/L)**			
	Arsenic	**Zinc**	**Cadmium**	**Lead**
Blank (dechlorinated tapwater)	1.1	4.5	ND	1.4
Asphalt fiberglass shingle	1.2	8.5	ND	10.4
Metal (Galvalume®)	1.0	25.4	ND	17.1

ND: not detected

Task 1. Survey of Roofing Materials Commonly Used in Texas *(complete)*

A survey was conducted to determine which residential roofing materials are most commonly used in Texas and what products are used to adhere, seal, or coat roofing materials. To complete this task, contact information for 71 roofing contractors was collected from the National Roofing Contractors Association (NRCA) and the Midwest Roofing Contractors Association (MRCA); this information is summarized in the Appendix (Table A.1). Forty-five percent of the contractors agreed to participate, yielding a total of 23 residential and 9 commercial roofing contractors who participated in the survey. A brief summary of the survey questions and answers are provided in the Appendix (Table A.2). All commercial and residential roofing contractors confirmed that self-adhesive asphalt fiberglass shingles are the most commonly used residential roofing materials in Texas, being used on more than 80% of residential roofs (Jason Wright, personal communication, 2008). The second most commonly used residential roofing material used in Texas is a type of metal roof called Galvalume®, which is usually fastened with nails. In addition to shingles and metal roofs, it was also reported that concrete roofing tiles are used in

Texas. When asked what roofing materials should be recommended for rainwater harvesting, more than 80% of the contractors said that metal roofs should be used.
To conduct a more thorough investigation of the chemical composition of each roofing material, several material safety data sheets (MSDS) were retrieved from manufacturers that were recommended by commercial and residential contractors. According to the MSDS by Tamko, asphalt fiberglass shingles contain (by weight) <30% asphalt, <65% limestone, <40% mineral granules, <8% fiberglass, and <2.4% formaldehyde (Tamko 2007). This chemical composition is comparable to that listed in the GAF-Elk MSDS, which states that fiberglass shingles contain (by weight) 10-30% asphalt, 25-45% limestone, 20-45% granules, and a fiberglass mat (1-3%) (GAF-Elk 2008). In the toxicological information section of the Tamko MSDS, it is reported that shingles may contain small amounts of Polycyclic Aromatic Hydrocarbons (PAHs): some of these compounds have been classified as carcinogenic (Barone et al. 1996). In particular, it is mentioned that Benzo(a)pyrene has been identified in asphalt fumes. In Tasks 2 and 3, we will be analyzing harvested rainwater samples to determine if they contain selected volatile and semi-volatile organic compounds.

According to the MSDS by Dofasco, Galvalume® sheets contain (by weight) approximately 95% iron, <1.65% manganese, <1.1% chromium, and <0.12% nickel (Dofasco 2007). A variation of these chemical compositions is reported by other manufacturers; BlueScope Steel reports that Galvalume® sheets contain (by weight) 1-10% zinc, 1-10% aluminum, and the remainder is composed of iron (BlueScope Steel 2003); the United States Steel Corporation (USS) reports that Galvalume® sheets contain (by weight) <92% iron and a variety of alloying elements, including aluminum, copper, silicon, sulfur, and manganese, with <1.15% each (USS 2004). These three manufacturers mention that chromium is used as a metallic coating for surface treatment. As a result, it is possible that Galvalume® roofs may leach several types of metals. Thus, in Tasks 2 and 3, we will be analyzing harvested rainwater samples to determine selected metal concentrations.

A combination of organic and metallic constituents is reported in the chemical composition of concrete tiles. According to the MSDS by MonierLifetile Manufacturing, concrete tile is composed of (by weight) 20-30% cement, 50-60% sand and aggregate, 0-5% limestone, and 0-8% acrylic polymer; in addition, concrete tiles contain a mixture of metal pigments, including cobalt, chromium, and titanium, each ranging between 0-3%. (MonierLifetile 1999). Thus, in Task 2, we will be analyzing harvested rainwater samples to determine selected organic and metal concentrations from concrete tile roofs.

Task 2. Test Roofs *(currently underway and on schedule)*

Based on the results of Task 1, three roofing materials were selected for the test roofs to be installed at the Lady Bird Johnson Wildflower Center: GAF-Elk's asphalt fiberglass shingle, Berridge's Galvalume® standing seam metal, and MonierLifetile's concrete tile. Three wooden frames were constructed to hold a 4 ft by 8 ft plywood sheet that will support the roofing material. To simulate residential roofs, Austin contractors recommended that the pilot roofs have a pitch of 4:12 (Wilson Ralph, personal communication, 2009 and Harold Peterson, personal communication, 2009). As a result, the plywood boards were angled at 18.4 degrees. The frames are approximately 5-ft high with a 2-ft end for rainwater catchment (Figure 1).

Figure 1. Frames for Pilot-Scale Roofs

The three wooden frames were installed at the Lady Bird Johnson Wildflower Center, and they will be secured with concrete footings. D.L. Philips Construction Co., Inc. (Austin, Texas) has volunteered to install the three roofing materials on the frames, at no charge, by the end of March 2009 (David Philips, personal communication, 2009). Once the construction of the three roofs has been completed, we will construct a guttering system similar to that utilized in Task 3 (see **Error! Reference source not found.**). In addition, one of the six green roofs that are already installed at the Lady Bird Johnson Wildflower Center will be included in these pilot-scale experiments. Jeffrey Stump, an undergraduate student at the University of Texas at Austin (and the recipient of an Undergraduate Research Fellowship from the University), will also collect rainwater from a cool roof that is already installed onsite.

Task 3. Field Sampling *(currently underway and on schedule)*

The purpose of this task is to examine the quality of rainwater harvested from existing residential roofs in the Austin, Texas area. Two full-scale roofs were sampled: a twelve-year-old metal roof (Galvalume®) on a single-story residence and a five-year-old asphalt fiberglass shingle roof on a two-story residence. These sites allow us to investigate the quality of rainwater harvested from aged, full-scale roofs.

To collect the rainwater, the base of each roof was equipped with a simple sampling device that was inserted into the gutter (Figure 2). This insert consists of a clean 3-inch diameter PVC pipe (potable quality) cut lengthwise in half and fitted with end caps. Three-quarter-inch PVC pipe was used to direct rainwater collected from the sampling insert to a passive collection system (**Error! Reference source not found.**) that consists of a two-liter (L) tank to collect the "first flush" and two 10-L tanks in series to collect volume samples after the first flush.

Figure 2. Sampler Gutter Insert

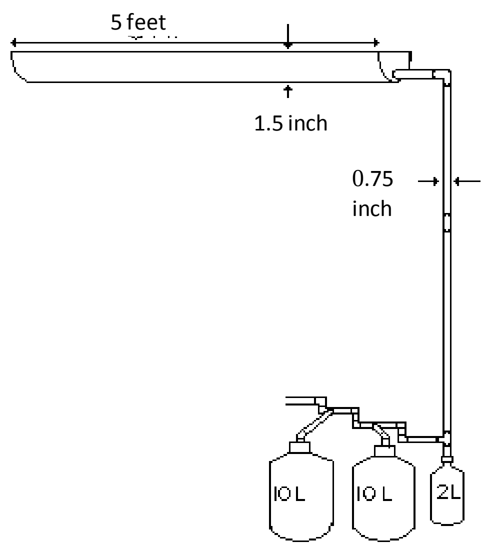

Figure 3. Sampler Design

It is recommended that the first flush divert a *minimum* of ten gallons for every 1,000 square feet of true collection surface area (TWDB 2005). Since each roof collection area used in this task was approximately 50 square feet, we diverted slightly more than half a gallon (two liters) to ensure that we met the minimum recommendation for first flush volume. The tank volumes were determined based on the estimation that one inch of rain will result in one half-gallon of collected water for every square foot of roof footprint area (TWDB 2005). Based on our collection data, the average rainfall in the Austin area has been approximately one half-inch for the majority of events in the past year. Therefore, we estimated that the system could collect approximately 13.5 gallons (about 50 liters) for a full rain event.

In addition, each site was equipped with a separate sampler to collect ambient rainwater that does not come into contact with the roof. This sampler (Figure 4) consisted of an 18-inch diameter polyethylene funnel attached to a 10-L polypropylene collection container.

Figure 4. Ambient Sampler

Each of the two residential roofs was sampled for three rainfall events (2/9/2009, 2/11/2009, and 3/11/2009). Between events, each sampling tank was thoroughly washed with soap, rinsed with deionized water, and autoclaved. The remaining pieces of the field sampler (e.g., PVC piping and funnel) were scrubbed and rinsed with deionized water on site.

Table 2 summarizes the analytical methods that are being used, and Table 3 lists the preservation methods and storage times for each type of sample.

Most of the analyses have been completed for the first two rain events; the remaining measurements for the first two rain events and the measurements for the third rain event (3/11/09) are currently being performed. The results for the analyses conducted thus far for the first two rain events are presented as follows: pH (**Error! Reference source not found.**), conductivity (**Error! Reference source not found.**), turbidity (Figure 7), total solids (Figure 8), total coliform (**Error! Reference source not found.**), fecal coliform (**Error! Reference source not found.**), nitrate (**Error! Reference source not found.**), and selected synthetic organic contaminants (Table 4). Samples for metals have been preserved with nitric acid and are being stored at 4˚C until analysis. In addition, DNA has been extracted from all samples and is being stored at -80˚C for future microbial community analysis (if additional funding becomes available).

Table 2. Analytical Methods

Parameter	Method Title	Meter/Method Type	Source
pH	pH Value	Potentiometry	*Standard Methods* (1998)
Conductivity	Conductivity (μS/cm)	Copenhagen Conductivity Meter	Copenhagen Radiometer
Turbidity	Turbidity (FTU)	Hach Turbidity Meter Model 2300	Hach (2003)
Total Solids		Filter and dry	*Standard Methods* (1998)
Total Coliform	M-Endo Broth		*Standard Methods* (1998)
Fecal Coliform	FC Agar		*Standard Methods* (1998)
Nitrate	Chromotropic Acid Method	Colorimetric	Hach (2003)
Synthetic Organic Compounds	Method 8260/8270	(See list in Appendix: Table A.3)	DHL Analytical Laboratories
DNA Extraction	MoBio UltraClean Microbial/Soil DNA Isolation Kit		MoBio

Table 3. Sample Preservation and Storage

Measurement	Preservation	Maximum Holding Time
pH	None required	N/A
Conductivity	None required	N/A
Turbidity	None required	N/A
Total Solids	None required	N/A
Total Coliform	Store at 4°C	6-8 hours
Fecal Coliform	Store at 4°C	6-8 hours
Nitrate	Acidify to pH < 2; store at 4°C	28 days
Synthetic Organic Compounds	Acidify to pH < 2; store at 4°C	7 days
DNA extraction	Refrigerate (-20°C after extraction)	2 days (indefinitely)

N/A: not applicable; analysis is conducted immediately.

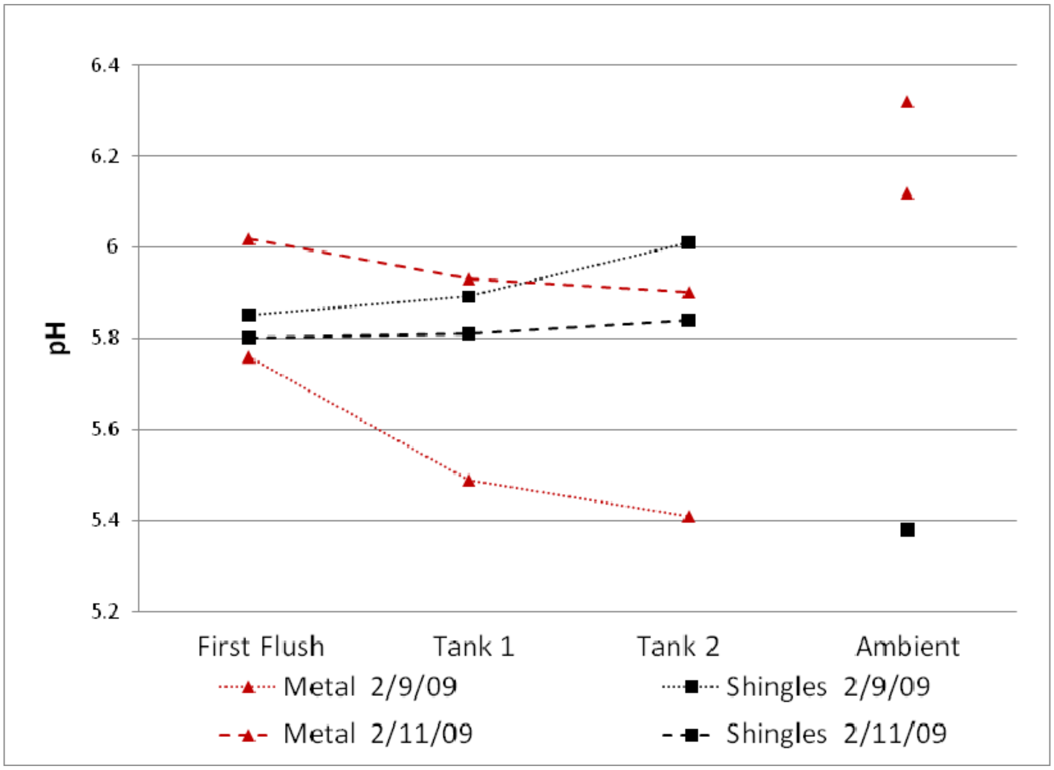

Figure 5. pH of Harvested Rainwater from a Metal Roof and a Shingle Roof

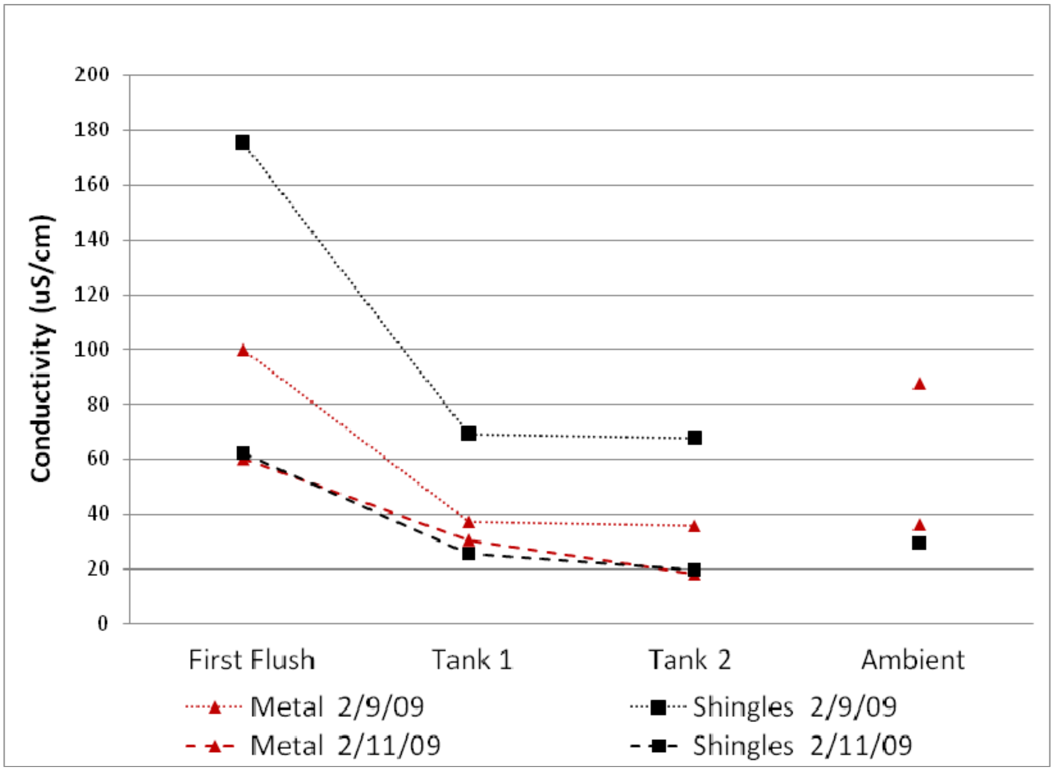

Figure 6. Conductivity of Harvested Rainwater from a Metal Roof and a Shingle Roof

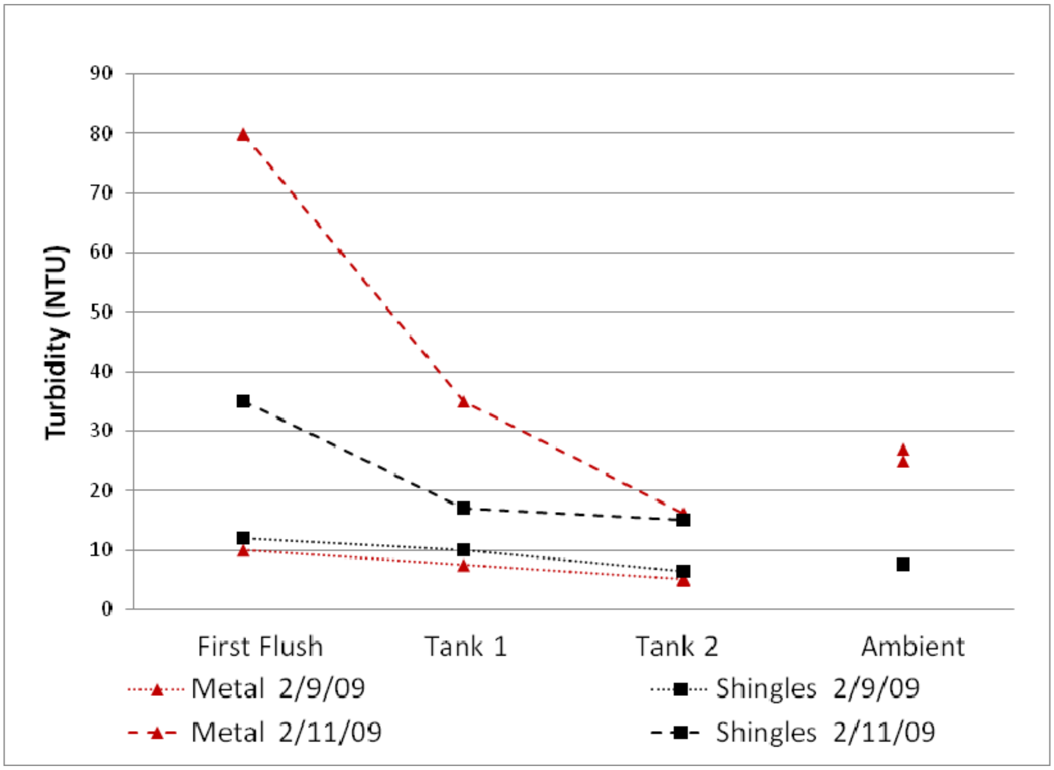

Figure 7. Turbidity of Harvested Rainwater from a Metal Roof and a Shingle Roof

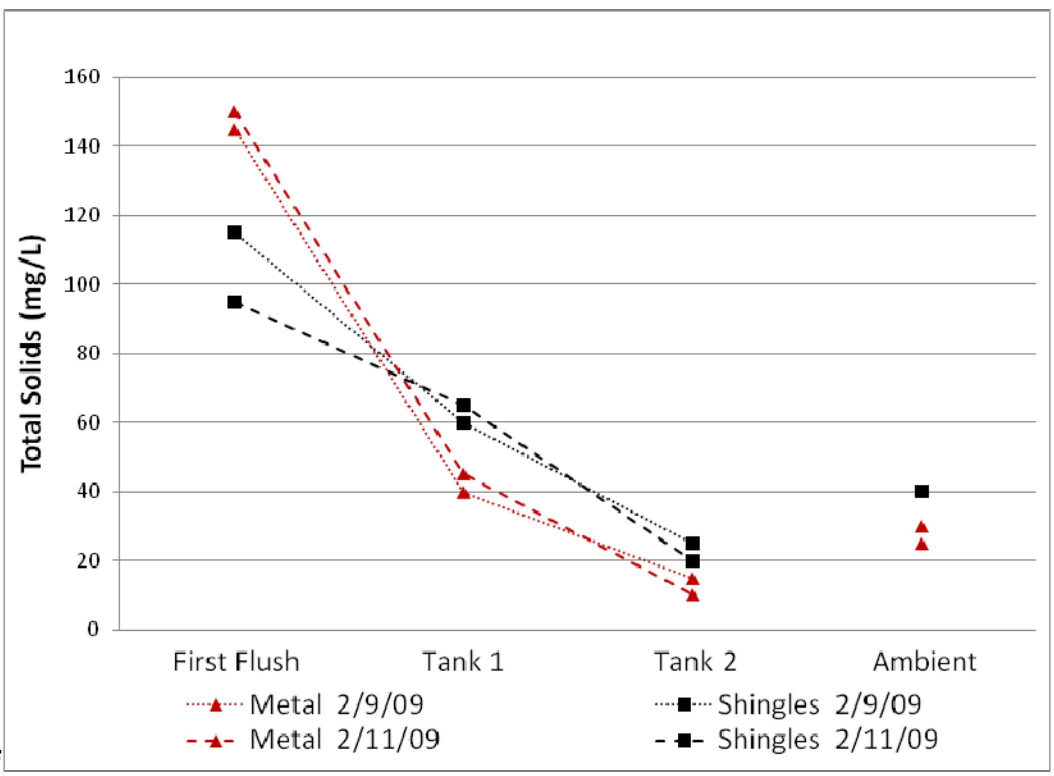

Figure 8. Total Solids of Harvested Rainwater from a Metal Roof and a Shingle Roof

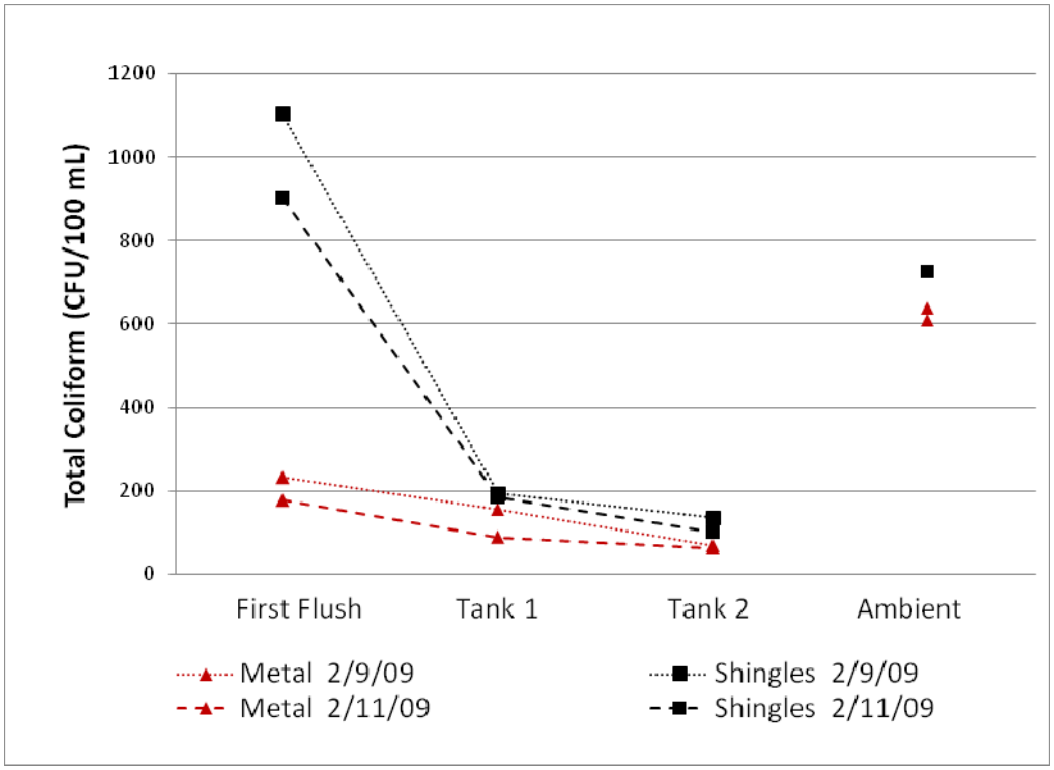

Figure 9. Total Coliform of Harvested Rainwater from a Metal Roof and a Shingle Roof

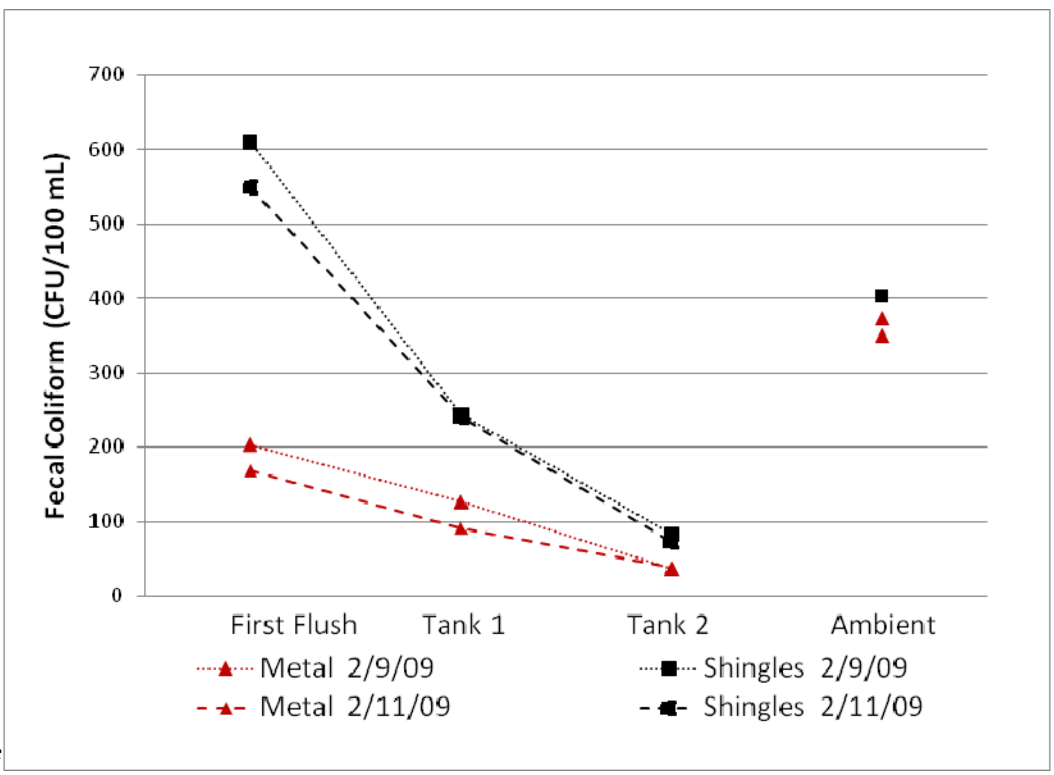

Figure 10. Fecal Coliform of Harvested Rainwater from a Metal Roof and a Shingle Roof

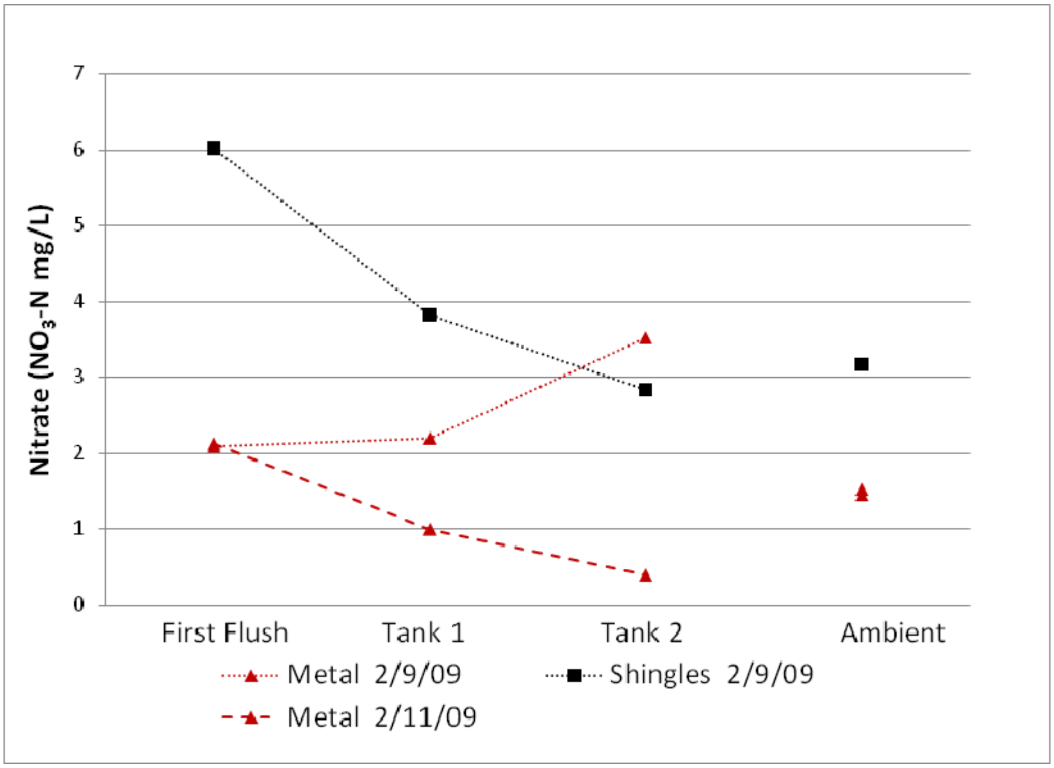

Figure 11. Nitrate of Harvested Rainwater from a Metal Roof and a Shingle Roof

Table 4. Synthetic Organic Compounds Detected in First Flush Samples

Contaminant	Roof Type	Date	Concentration (µg/L)
2,4 – Dinitrophenol	Metal	2/9/09	3.12
2,4 – Dinitrophenol	Shingle	2/9/09	2.88
Benzyl alcohol	Shingle	2/9/09	0.200

Error! Reference source not found. presents the pH of the ambient and harvested rainwater from two rain events on the metal and shingle roofs. The pH of rainwater is typically around 5.7 (TWDB 2005), and our data for ambient rain support this. In the case of the metal roof, pH decreased from the ambient rainfall to the harvested rainwater. In the case of the shingle roof, pH increased from the ambient rainfall to the harvested rainwater. The pH ranges from our samples are comparable to the pH of other rainwater studies such as Yaziz et al. (1989) and Simmons et al. (2001).

Error! Reference source not found. presents the conductivity of the ambient and harvested rainwater from two events on the metal and shingle roofs. The conductivity decreased from the first flush through the first and second tanks, with final conductivities that were similar to those of ambient rain. Note that the conductivity of the first flush on the 2/11/09 rain event was lower than that of the first flush on the 2/9/09 rain event. The conductivity values are within the same range found in the harvested rainwater studies of Yaziz et al. (1989) and Simmons et al. (2001).

Figures 7 and 8 present the turbidity and total solids, respectively, of the ambient and harvested rainwater from two events on the metal and shingle roofs. The turbidity and total solids decreased from the first flush through the first and second tanks, with final values of turbidity and total solids that were close to those of ambient rain. The total solids values in the first flush of the metal roof were higher than the total solids values in the first flush of the shingle roof; this might be attributable to particle retention in the porous surface of the shingle roof as compared to the non-porous surface of the metal roof. The turbidity and total solids values are within the same ranges found in the harvested rainwater studies of Yaziz et al. (1989) and Simmons et al. (2001).

Figures 9 and 10 present the total coliform and fecal coliform counts, respectively, of the ambient and harvested rainwater from two events on the metal and shingle roofs. Each roof site had similar conditions with respect to tree cover to minimize differences in potential fecal contamination (e.g., by birds). The total and fecal coliform counts decreased from the first flush through the first and second tanks. However, even the second tank for both roofing materials always had detectable total and fecal coliform, indicating that treatment is needed prior to potable use. The total and fecal coliform counts were always higher in the rainwater harvested from the shingle roof than from the metal roof; to determine if this is truly due to roofing material differences, rather than site variation, a pilot-scale metal roof and shingle roof will be compared side-by-side at the Lady Bird Johnson Wildflower Center in Task 2.

Figure 11 presents the nitrate concentrations of the ambient and harvested rainwater from two events on the metal roof and from one event on the shingle roof. From the shingle roof and from the 2/11/09 event on the metal roof, the nitrate concentrations decreased from the first flush through the first and second tanks. In the second tanks, the nitrate concentrations were less than those in ambient rain. The data from the 2/9/09 event on the metal roof are being reanalyzed since they show a different trend than do the other data sets. By comparison, a Dutch study looked at the nitrate concentration of rainwater (collected with a glass funnel and bottle) and found concentrations up to 1.02 mg/L NO_3-N (Van Maanen et al. 2000). Deng (1997), however, found nitrate levels in rainwater up to 420 mg/L in some areas of Florida due to anthropogenic pollution. Thus, the <6 mg/L NO_3-N concentrations found in our harvested rainwater samples are not unexpected.

We tested for a suite of 200 synthetic organic compounds (Appendix, Table A.3) on the first flush samples from the 2/9/09 rain event for the metal and shingle roofs. Only two compounds were detected: benzyl alcohol and 2,4-dinitrophenol, but the concentrations were very low (Table 4).

Samples have been preserved with nitric acid and are being stored at 4 ˚C for metals analysis. We will likely be measuring copper, lead, nickel, selenium, chromium, and iron.

In addition, we have extracted DNA from each sample. If additional funding becomes available, we will use the extracted DNA to look at the microbial communities that are present in harvested rainwater. This analysis will be done with terminal restriction fragment length polymorphism (T-RFLP). These data will allow us to compare the composition of the microbial communities between different roofing materials. For example, a metal roof might show reduced microbial community diversity, which would be consistent with the lower numbers of total and fecal coliform observed for the metal roof.

Acknowledgements

We are grateful to the Texas Water Development Board (TWDB) for funding this project. We would also like to thank Dr. Steve Windhager and Dr. Mark Simmons for giving us space to construct our pilot-scale tests roofs at the Lady Bird Johnson Wildflower Center. Finally, we would like to express our sincere thanks to Charles Perego for directing the construction of the pilot roofs and to everyone else who helped with the project, including Brett Buff, David Stump, and Jeffrey Stump.

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Appendix

Table A1. Summary of Contractor Information

Residential Roofing Contractors	Location	Phone	Reference
Ace Roofing Company LLC	Austin, TX	(512) 836-7663	NRCA*
All-Tex Roofing Corp.	Houston, TX	(713) 683-6775	NRCA
AmeriWest	Austin, TX	(512) 287-2130	NRCA
Austin Roofing and Siding	Austin, TX	(512) 372-8110	NRCA
Barker Roofing LP	Austin, TX	(512) 243-5244	NRCA
Barr Roofing Co	Abilene, TX	(325) 672-8417	MRCA
Beldon Roofing Company	San Antonio, TX	(210) 341-3100 or (800) 688-7663	MRCA**
Bentley Sheet Metal & Roofing Co Inc	San Antonio, TX	(210) 434-4184	MRCA
Billy Parker Roofing LLC	Amarillo, TX	(806) 352-1038	NRCA
Boyd Inc	Mansfield, TX	(817) 477-3436 or (888) 269-3462	MRCA
Brinkmann Roofing Co	Houston, TX	(281) 486-1660	MRCA
BRM Roofing & Construction Services Inc.	Houston, TX	(281) 820-8647	NRCA
Campos Roofing & Construction	El Paso, TX	(915) 755-3916	NRCA
Capco Inc.	Austin, TX	(512) 251-9516	NRCA
Carney Roofing Co. Inc.	Nacogdoches, TX	(936) 569-8241	NRCA
Castro Roofing of Texas LP	Dallas, TX	(214) 381-8108 or (800) 759-1879	MRCA
CBS Roofing Service	Denton, TX	(940) 387-7568	MRCA
Curtis McKinley Roofing and S/M Inc.	Longview, TX	(903) 757-7402	NRCA
D.L. Phillips Construction Co. Inc.	Austin, TX	(325) 672-0204	NRCA
Daniels Roofing Inc	El Paso, TX	(915) 772-6000	MRCA
Demarco Exteriors Plus, Inc.	San Antonio, TX	(210) 494-7587	MRCA
Disk Enterprises	Pearland, TX	(281) 485-7575	NRCA
Drury Roofing & Sheet Metal Inc.	Austin, TX	(512) 836-0634	NRCA
Empire Roofing	El Paso, TX	(915) 351-3550	MRCA
Empire Roofing Ltd	Fort Worth, TX	(817) 572-2250	MRCA
Energy Waterproofing & Roofing Systems Inc.	Spring, TX	(281) 376-5171	NRCA
Escalante Enterprises	El Paso, TX	(915) 860-2672	NRCA
Frazier Roofing & Guttering Co	Arlington, TX	(817) 261-1480	MRCA
Frontier/Scholten Roof Service	El Paso, TX	(915) 845-4151	NRCA
Fry Roofing Inc	San Antonio,	(830) 980-8103	MRCA

	TX		
Haeber Roofing Company	Corpus Christi, TX	(361) 851-8142	MRCA
Hamilton Roofing Company	Lubbock, TX	(806) 763-9375	MRCA
Harris Roofing Company	Mission, TX	(956) 638-0979	NRCA
Harrison Roofing Co. Inc.	San Angelo, TX	(325) 653-6786	NRCA
Hayes Miller Roofing Inc.	Longview, TX	(903) 758-2797	NRCA
HSR Construction Inc.	Austin, TX	(512) 458-4101	NRCA
Hynes Services Inc.	Rockport, TX	(361) 729-7180	NRCA
J. J. Flores Roofing & Construction	Laredo, TX	(956) 722-7688	NRCA
Jabeau Roofing	Wichita Falls, TX	(940) 723-1183	NRCA
Jay-Co Sheet Metal and Roofing Inc.	Houston, TX	(713) 738-4525	NRCA
J-Conn Roofing & Repair Service Inc.	Austin, TX	(512) 479-0510	NRCA
John A. Walker Roofing Inc.	Texas City, TX	(409) 935-5411	NRCA
John Bacon Roofing	Rockwall, TX	(972) 772-1999	MRCA
Johnson Roofing Inc	Waco, TX	(254) 662-5571	MRCA
KENTEX Roofing Systems LLC	Austin, TX	(512) 491-9000	MRCA
Long Horn Remodeling & Roofing	El Paso, TX	(915) 875-4603	NRCA
Lydick-Hooks Roofing Co of Lubbock Inc	Lubbock, TX	(806) 765-5577	MRCA
Lydick-Hooks Roofing Company of Brownwood Texas Inc.	Brownwood, TX	(325) 646-9581	NRCA
Lydick-Hooks Roofing Company of Wichita Falls Inc.	Wichita Falls, TX	(940) 322-6991	NRCA
Marant Construction Inc.	Wichita Falls, TX	(940) 761-1717	NRCA
Nations Roof Central	Garland, TX	(972) 278-9200	MRCA
Norton Roofing & Construction	Amarillo, TX	(806) 372-7663	NRCA
Oliver Roofing Systems	Austin, TX	(512) 834-7500	NRCA
Parsley's S/M & Roofing Co. Inc.	Pampa, TX	(806) 669-6461	NRCA
Perry Roofing Company	Austin, TX	(512) 794-0707	NRCA
Raintree Roofing Inc.	Midland, TX	(432) 570-1822	NRCA
Rhynehart Roofing	Amarillo, TX	(806) 622-0090	NRCA
Robles Roofing, LLC	San Angelo, TX	(325) 655-2416	NRCA
Roofs by Nicholas Inc.	Midland, TX	(432)520-7348	NRCA
Sechrist-Hall Company	Harlingen, TX	(956) 423-7086	MRCA
Sechrist-Hall Company	Corpus Christi, TX	(361) 884-5264	MRCA
Signature Exteriors LLC	Austin, TX	(512) 481-1888	NRCA
SLR Roofing Systems Inc	Fort Worth,	(817) 731-2001	MRCA

	TX		
Smith Roofing Co Inc	Brownwood, TX	(325) 646-7516	MRCA
Smith Roofing Company Inc.	Brownwood, TX	(325) 646-7516	NRCA
Storm Master Inc and SMI Commercial Roofing	Fort Worth, TX	(817) 589-7190	MRCA
Texas Fifth Wall Roofing Systems Inc	Austin, TX	(512) 926-3940 or (800) 749-8293	MRCA
Texas Roof Management Inc	Richardson, TX	(972) 272-7663	MRCA
Tower Roofing LLC	Baytown, TX	(832) 695-9474	NRCA
Vega Roofing Co.	McAllen, TX	(956) 686-4921	NRCA
Wilson Roofing Co. Inc.	Austin, TX	(512) 263-3157	NRCA

Highlighted contractors participated in survey
***National Roofing Contractor Association (NRCA)**
****Midwest Roofing Contractor Association (MRCA)**

Table A2. Summary of Survey Questions and Answers

1. What residential roofing materials do you most commonly use (i.e., shingles, tiles, metal)? -Residential roofers: asphalt fiberglass shingles. -Commercial roofers did not answer this question, did not have expertise in residential roofing.
2. In your experience, what residential roofing materials are most commonly used in Texas? -Commercial and residential roofers: asphalt fiberglass shingles.
3. Who manufactures these roofing materials? This information will be useful in case we want to purchase these materials for our pilot roofs. -Commercial and residential roofers: Johns Manville, Tamko, GAF/ELK, Owens Corning, USS, Dofasco, Capitol Roofing Company, Kemko, MonierLifetile, Roofing Supply Group, Bradco Supply.
4. Is there a regional record of what roofing materials are used? (online database or written manual) Commercial and residential roofers: information is not available; contact manufacturers or roofing associations: National Roofing Contractors Association, Roofing Contractors Association of Texas, Western States Roofing Contractors Association, Tile Roofing Institute.
5. What products are used to adhere, seal, or coat roofing materials? - Commercial and residential roofers: nails and self-adhesive products.
6. If you know that the roof will be used for rainwater harvesting, what roofing materials are used? -Commercial and residential roofers: anything besides asphalt based (shingles) and coal tar pitch products.
7. Is there a roofing material or adhesive that you think SHOULD NOT be used in rainwater harvesting because of its toxic nature? -Commercial and residential roofers: some said that asphalt-based (shingles) and coal tar pitch products should not be used.
8. What roofing system would you recommend for rainwater harvesting because of its limited toxic materials? -Commercial and residential roofers: more than 80% recommended metals; others said tiles or PVC.

***32 out of 71 contractors participated: 23 residential and 9 commercial roofing contractors**

Table A3. Synthetic Organic Compounds Tested

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dichlorophenol
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methylphenol
2-Nitroaniline
2-Nitrophenol
3,3´-Dichlorobenzidine
3-Nitroaniline
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Aniline
Anthracene
Benzo[a]anthracene
Benzo[a]pyrene
Benzo[b]fluoranthene
Benzo[g,h,i]perylene
Benzo[k]fluoranthene
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Carbazole

Chrysene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenz[a,h]anthracene
Dibenzofuran
Diethyl phthalate
Dimethyl phthalate
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno[1,2,3-cd]pyrene
Isophorone
N-Nitrosodi-n-propylamine
N-Nitrosodiethylamine
N-Nitrosodiphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Surr: 2,4,6-Tribromophenol
Surr: 2-Fluorobiphenyl
Surr: 2-Fluorophenol
Surr: 4-Terphenyl-d14
Surr: Nitrobenzene-d5
Surr: Phenol-d6 21.5 0 20 -
TIC: 2,2-Dimethyl-6-cyclohexanepropanol,
TIC: Ethyl cyclopropanecarboxylate,
1,1,1,2-Tetrachloroethane
1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,1-Dichloropropene
1,2,3-Trichlorobenzene
1,2,3-Trichloropropane
1,2,4-Trichlorobenzene
1,2,4-Trimethylbenzene
1,2-Dibromo-3-chloropropane
1,2-Dibromoethane
1,2-Dichlorobenzene

1,2-Dichloroethane
1,2-Dichloropropane
1,3,5-Trimethylbenzene
1,3-Dichlorobenzene
1,3-Dichloropropane
1,4-Dichlorobenzene
2,2-Dichloropropane
2-Chlorotoluene
4-Chlorotoluene
Benzene
Bromobenzene
Bromochloromethane
Bromodichloromethane
Bromoform
Bromomethane
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
cis-1,2-Dichloroethene
cis-1,3-Dichloropropene
Dibromochloromethane
Dibromomethane
Dichlorodifluoromethane
Ethylbenzene
Hexachlorobutadiene
Isopropylbenzene
m,p-Xylene
Methylene chloride
n-Butylbenzene
n-Propylbenzene
Naphthalene o-Xylene
p-Isopropyltoluene
sec-Butylbenzene Styrene
tert-Butylbenzene
Tetrachloroethene
Toluene
trans-1,2-Dichloroethene
trans-1,3-Dichloropropene
Trichloroethene
Trichlorofluoromethane
Vinyl chloride
Surr: 1,2-Dichloroethane-d4
Surr: 4-Bromofluorobenzene
Surr: Dibromofluoromethane

Surr: Toluene-d8

MATERIAL SAFETY DATA SHEET

MSDS Number: T029000 Revision Date: May 2007

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

TRADE NAME: Shingles
LABEL: TAMKO
USE & DESCRIPTION: Roofing Shingles
CHEMICAL FAMILY: Mixture

MANUFACTURED FOR:
TAMKO Building Products, Inc.
P. O. Box 1404
Joplin, MO 64802-1404

EMERGENCY TELEPHONE NUMBERS;
General Information: 1-417-624-6644 (8 a.m. - 5 p.m. CST)
Chemtrec: 1-800-424-9300

2. COMPOSITION/INFORMATION ON INGREDIENTS

			Exposure Limits*				
Components	Cas No.	% by Wt.	OSHA		ACGIH		
			TWA	STEL	TWA	STEL	Unit
Petroleum asphalt	8052-42-4	<30	5 fume	NE	0.5 fume	NE	mg/m^3
Limestone**	1317-65-3	<65	10 resp dust	NE	10 resp dust	NE	mg/m^3
Mineral Granules	NE	<40	NE	NE	NE	NE	
MAT		<8					
Fiber Glass	65997-17-3		NE	NE	1 fiber	NE	cc
Urea Formaldehyde Binder	9011-05-6	<2.4					
Formaldehyde	50-00-0	<0.1	0.75 ppm	2 ppm		0.3ppm	ppm
Polyester	NE		NE	NE		NE	
Felt	NE		NE	NE		NE	
BACKING		<10					
Sand**	14808-60-7			NE		NE	mg/m^3
Talc**	4807-96-6			NE		NE	mg/m^3
** contains:							
crystalline silica >5%		>0.1%					
quartz	14808-60-7		.05 resp dust	NE	.05 resp dust	NE	mg/m^3
crystobalite	14464-46-1		.05 resp dust	NE	.05 resp dust	NE	mg/m^3

NE = Not established
* Note: Due to the form of the product, hazardous exposures are not expected to occur. Exposure limits are provided for information purposes only.

DOFASCO **Material Safety Data Sheet**

Section 1- PRODUCT IDENTIFICATION

Material	**ZINC COATED SHEET STEEL**		***WHMIS Class***
Synonyms	Galvanized, Galvanneal, Galvalume, Galvalume Plus, Zincrometal		**D2A, D2B**
Manufacturer	Dofasco Inc., P.O. Box 2460, Hamilton, Ontario, Canada L8N 3J5		
Telephone No.	(905) 548-7200	***Material Use*** Manufacture of steel articles	

Section 2 – HAZARDOUS INGREDIENTS

Hazardous Ingredients	*Weight %*	*CAS No.*	*LD50*	*Exposure Limit (mg/m³)*
Steel:				
Iron (Fe)	~ 95	7439-89-6	30 g/kg (rat-oral)	5 (Fume)
Manganese (Mn)	≤ 1.65	7439-96-5	9 g/kg (rat-oral)	0.2
Chromium (Cr)	≤ 1.1	7440-47-3	U	0.5
Nickel (Ni)	≤ 0.12	7440-02-0	U	1.5
(Hazardous Ingredients – lists components which meet the reporting requirements of the Hazardous Products Act.)				
Coating:				
1. Galvanized				
Zinc (Zn)	99	7440-66-6	U	5 (Fume)
(Z-coating. Coating weights range from 15 to 500 g/m^2 or up to 20% total steel weight)				
2. Galvanneal				
Zinc (Zn)	88	7440-66-6	U	5 (Fume)
Iron (Fe)	11	7439-89-6	U	5 (Fume)
(Annealed Z-coating. Coating weights range from 20 to 100 g/m^2 or up to 10% total steel weight)				
3. Galvalume, Galvalume Plus				
Aluminum (Al)	55	7429-90-5	U	10
Zinc (Zn)	43	7440-66-6	U	5 (Fume)
(AZ-coating. Coating weights range from 50 to 150 g/m^2 or up to 15% total steel)				

Surface Treatments:

(Constitutes less than 0.5% of total steel weight)

1. Passivation - Chromic acid solution leaving a chromium residual of 11 to 40mg/m^2 per side.
2. Slushing Oil - (Ferrocote 61 MAL HCL-1G, Ferrocote 61-AUS, PL-7105-A)
   Hydrotreated naphthenic oils or petroleum based lubricating oils containing sulphonates and anti-oxidants.
3. Vanishing Oil - (Rustilo DW 924) Mineral oil and isoparaffin petroleum distillate.
   Oil Coating weights range from1.1 to 5.4 g/m^2 per side.
4. Pre Temper - (Qwerl 266-LV) White petroleum mineral oil.
   Galvalume Plus – (Oakite PC4610) Acrylic coating of polystyrene-acrylate copolymers.

Note: Supplier MSDS for surface treatment oils are available. Please contact Dofasco's Technical Service Manager.
Dofasco Steel products do not contain and are not manufactured with any Class I or Class II ozone depleting substances.
Dofasco products meet the Coalition of North Eastern governors' (CONEG) requirements for combined heavy metal content of less than 100 ppm.

Legend: U = Unknown NA = Not Applicable

MonierLifetile
MSDS - Material Safety Data Sheet

MonierLifetile
Changing the way people think about roofs.

SECTION I - PRODUCT AND COMPANY IDENTIFICATION	
Identity (As used on Label and List) **MONIERLIFETILE CONCRETE ROOF TILES**	Trade Names **Cedarlite, Duralite, Standard Weight Tile and Trim**
Manufacturer's Name **MonierLifetile, LLC**	Emergency Telephone Number **(949) 981-3319**
Address (Number, Street, City, State, and ZIP Code) **MonierLifetile, LLC** **7575 Irvine Center Drive, Suite 100** **Irvine, CA 92618 - 2930**	Telephone Number for Information **(800) 224-2024 ext.**
	Date Prepared **April 20, 1999** Revised : February 17, 2004, Revision G

SECTION II - HAZARDOUS INGREDIENTS/IDENTITY INFORMATION			
Hazardous Components/CAS Number	OSHA PEL (mg/m3)	ACGIH TLV (mg/m3)	% by weight
Portland Cement 65997-15-1	15 Total 5 Respirable	10 Total 3 Respirable	20-30%
Sand and Aggregate (variable crystalline Silica content) 14808-60-7	15 Total 5 Respirable	10 Total 3 Respirable	50-60%
Limestone 1317-65-3	15 Total 5 Respirable	10 Total 3 Respirable	0-5%
Fly Ash 68131-74-8	15 Total 5 Respirable	10 Total 3 Respirable	0-8%
Mold Release Agent (diesel/petroleum oil, vegetable oil)	None Established For Vapor	None Established For Vapor	Less than 1%
Acrylic Polymer	None Established	None Established	0-8%
Metal Oxide Pigments (various mixtures to produce color section): Cobalt Metal Pigments (blue) 1307-96-6 Iron Oxide Pigments (black, red and yellow) 1309-37-1 Titanium Dioxide Pigment (white) 13463-67-7 Chromium (111) Oxide Pigments (green) 1308-38-9 Aquis Dispersions	-- 0.1 10 (fume) 15 1 --	-- 0.05 5 (dust and fume) 10 0.5 --	0 - 3.0% < 1.0% 0 - 3.0% 0 - 3.0% 0 - 3.0% 0 - 3.0%

SECTION III - PHYSICAL/CHEMICAL CHARACTERISTICS	
Boiling Point **Not applicable**	Specific Gravity (H2O = 1) **Denser than water**
Vapor Pressure (mm Hg.) **Not applicable**	Melting Point **Not applicable**
Vapor Density (AIR = 1) **Not applicable**	Evaporation Rate (Butyl Acetate = 1) **Not applicable**
Solubility in Water **Negligible**	
Appearance and Odor **Concrete roof tiles in various colors. Heavy solid objects which can generate dust during cutting, grinding or drilling.**	