URBAN Waterways

Water Quality of Rooftop Runoff:
Implications for Residential Water Harvesting Systems

The presence of various pollutants in rooftop runoff establishes a need for some general guidelines, discussed in this publication, regarding the use of collected rainwater in North Carolina.

Much of the southeastern United States, including North Carolina, experienced moderate to severe drought throughout 2007, 2008, and 2009. Thus, water harvesting systems, including rain barrels and cisterns, have become very popular among N.C. residents as ways to conserve potable water and help reduce the impact of restrictions on outdoor water use. Cisterns collect and store rainwater that drains from roofs. The harvested water can be used for irrigation, vehicle washing, toilet flushing, and other nonpotable (nondrinking water) uses. (For more information on water harvesting systems, see *Rainwater Harvesting: Guidance for Homeowners*, publication number AGW-588-11 in the Urban Waterways series.) Many homeowners use harvested water to irrigate edible plants and vegetable gardens, thereby raising questions regarding the cleanliness of roof runoff. Although runoff from roof surfaces is much cleaner than most stormwater runoff, it is not completely free of potentially harmful contaminants.

Primary substances of concern in roof runoff include heavy metals, polycyclic aromatic hydrocarbons (PAHs), microbes, pathogens, and pesticides. In areas of heavy traffic and industry, dust and particulate matter from vehicle exhaust and the burning of fossil fuels can collect on roof surfaces, producing elevated PAH levels in runoff. Birds, insects, and small mammals deposit fecal matter on rooftops and in gutters, contributing bacteria and pathogens to runoff. On metal roofs, water can react with the roof surface and adsorb metals, such as zinc, copper, and aluminum, especially where acid rain is prevalent. Roofs with wooden or asphalt shingles can increase concentrations of chemicals used for waterproofing and weathering treatments.

Figure 1. A rainwater harvesting system being used for watering flowerbeds

NC State University
A&T State University
COOPERATIVE EXTENSION
Empowering People • Providing Solutions

Pesticides have also been detected in roof runoff. Their presence is attributed to atmospheric deposition and precipitation. Finally, the herbicides commonly used in roofing materials to prevent root penetration often leach into water as it flows across a roof surface. Experimental studies have been conducted worldwide to test the quality of rainwater that drains off roof surfaces. However, few of these studies were conducted in the United States. Differences in roof materials, construction regulations, and rainwater composition may lead to discrepancies between international study results and U.S. conditions. This preliminary assessment of rooftop runoff in North Carolina refers to studies conducted within the United States. Table 1 summarizes average concentrations of common roof runoff pollutants from six studies conducted in the United States that involved a wide array of roof types and land uses. In two of the studies, researchers also tested rainwater to determine the concentration of each constituent in rainfall *before* it touched the roof.

ROOF RUNOFF FOR NONPOTABLE USES

As indicated in Table 1, regardless of roof type, the following constituents have been shown to exceed the freshwater standards for Class C waters developed by the N.C. Department of Environment and Natural Resources (N.C. DENR): copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), fecal coliforms (FC), and pH. Class C waters have the following designated uses: propagation and protection for aquatic life; agriculture; and fish consumption and secondary recreation by humans, including boating, fishing, and wading. These designated uses allow for human contact but do not include drinking or activities that could allow for ingestion (such as swimming).

Most of the metals (Cu, Cr, Cd, Pb) detected in rooftop runoff are also detected in rainwater that has yet to contact the rooftop. As such, these contaminants are unlikely to result in intolerable residues in edible plants, fruits, and vegetables, especially when they bind with soil particles and organic matter on the ground; however, Table 1 indicates zinc concentrations in rooftop runoff *are* substantially higher than those in rainwater. High concentrations of zinc in runoff can cause an accumulation of zinc in soils when harvested water is used for irrigation. Elevated levels of zinc in soils may lead to *phytotoxicity* (the poisoning of plants), which is a concern when portions of plants will be consumed. Regular soil testing should be performed in areas where edible plants are grown and irrigated with cistern water. Soil test results will indicate if zinc concentrations are high enough to harm plants. If this occurs, it is recommended that plants within the affected area not be consumed. See *A Gardener's Guide to Soil Testing* (AG-614) for more information regarding soil testing.

In several studies, the measured concentrations of total phosphorus and total nitrogen in rooftop runoff have been comparable to samples of rainfall before roof contact. Therefore, it is assumed that harvested rooftop runoff in a given area has no more risks or benefits to human or plant health than natural rainfall in the same area.

All N.C. DENR standards shown in Table 1, except the standard for fecal coliforms, reflect the maximum allowable concentration required to protect aquatic life. Only the fecal coliform standard has implications for human health in Class C waters. Fecal coliforms do not make humans sick; however, their presence in water indicates the probability that other more harmful bacteria are also present. These harmful bacteria can cause an open wound or cut to become infected, or they can cause intestinal illness if ingested. Limited research indicates that harvested rainwater might have somewhat high bacteria concentrations. Any part of the body that comes into contact with collected rainwater should be washed thoroughly with warm soapy water to prevent bacterial infections and the transfer of bacteria to the mouth or food. For more information on pathogens in stormwater, see *Removal of Pathogens in Stormwater* (AG-588-16).

ROOF RUNOFF FOR POTABLE USES

Rooftop runoff has been shown to exceed U.S. EPA drinking water standards for pH, fecal coliforms, aluminum (Al), lead (Pb) and zinc (Zn). Aluminum, zinc and pH are assigned *secondary* standards, which serve as guidelines to minimize offensive odor, taste, or aesthetic issues. "Secondary" contaminants do not pose a risk to human health. Concentrations of aluminum above the secondary standard may lead to colored water and staining of fixtures. Excess zinc produces a strong metallic taste, and low pH levels can lead to a metallic, bitter taste, possible corrosion of pipes and fixtures, or both.

As described in the previous section, the presence of fecal coliforms indicates a probability that other

Table 1. Average concentrations of common pollutants in rooftop runoff: pH, fecal coliform bacteria (FC), aluminum (Al), magnesium (Mg), manganese (Mn), chromium (Cr), cadmium (Cd), copper (Cu), lead (Pb), iron (Fe), and zinc (Zn). Red values exceed N.C. DENR freshwater standards for the protection of aquatic life; underlined values exceed U.S. EPA drinking water standards.

	Location	Roof Type	pH	FC (CFU/100mL)	Al (mg/L)	Mg (mg/L)	Mn (mg/L)	Cr (mg/L)	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Fe (mg/L)	Zn (mg/L)
N.C. DENR Freshwater Standards (Class C Waters)	—	—	6.0 – 9.0	200	none	none	0.2	0.05	0.002	0.007	0.025	1	0.05
U.S. EPA Drinking Water Standards (Primary standard unless otherwise noted)	—	—	6.5 – 8.5*	0	0.2*	none	0.05*	0.1	0.005	1.3 (1.0*)	0.015	0.3*	5*
Chang et al., 2004	Texas	Rainwater (prior to contact with roof)	5.55	—	0.354	0.823	0.030	—	—	0.043	0.034	—	0.139
Chang & Crowley, 1993	Texas	Rainwater (prior to contact with roof)	—	—	—	—	—	—	—	—	0.023	—	0.98
Chang et al., 2004	Texas	Aluminum	6.2	—	0.381	0.372	0.015	—	—	0.026	0.037	—	3.230
Chang & Crowley, 1993	Texas	Asphalt Shingle	—	—	—	—	—	—	—	—	0.056	—	2.33
Chang et al., 2004	Texas	Composition Shingle	6.69	—	0.495	0.713	0.028	—	—	0.025	0.038	—	1.372
Chang, et al., 2004	Texas	Galvanized Iron	6.6	—	0.435	0.362	0.017	—	—	0.028	0.049	—	11.788
Tobiason, 2004	Washington	Galvanized Metal	—	—	—	—	—	—	—	1.4†	0	—	14.7†
Good, 1993	Washington	New anodized Alum.	—	—	—	—	—	—	—	0.025	0.01	—	0.297
Good, 1993	Washington	Old Metal w/ Alum. Paint	4.1	—	—	—	—	—	—	0.02	0.302	—	12.2
Good, 1993	Washington	Plywood w/ Tar Paper	4.3	—	—	—	—	—	—	0.166	0.011	—	0.877
Chang & Crowley, 1993	Texas	Rock and Tar	—	—	—	—	—	—	—	—	0.05	—	4.88
Good, 1993	Washington	Rusty Galvanized Metal	5.9	—	—	—	—	—	—	—	—	—	—
Good, 1993	Washington	Tar w/ Alum. Paint	5.9	—	—	—	—	—	—	0.011	0.01	—	1.98
Chang & Crowley, 1993	Texas	Terra Cotta	—	—	—	—	—	—	—	—	0.028	—	1.08
Chang et al., 2004	Texas	Wood Shingle	5.07	—	0.382	0.982	0.044	—	—	0.029	0.045	—	16.317
Chang & Crowley, 1993	Texas	Wood Shingle	—	—	—	—	—	—	—	—	0.045	—	5.64
Pitt et al., 1995	Alabama	Assortment	6.9	—	6.85	—	—	0.085	0.0034	0.11	0.041	—	0.25
Bannerman, et al., 1993	Wisconsin	Assort. (Industrial Area)	—	144	—	—	—	—	—	0.006	0.008	—	1.155
Bannerman, et al., 1993	Wisconsin	Assort. (Commercial Area)	—	1117	—	—	—	—	—	0.009	0.009	—	0.33
Bannerman, et al., 1993	Wisconsin	Assort. (Residential Area)	—	294	—	—	—	—	—	0.015	0.021	—	0.149

* Secondary drinking water standard; †Maximum reported concentration

more harmful bacteria and pathogens occur in the water. Ingesting these harmful bacteria and pathogens can lead to a number of illnesses, including diarrhea, pneumonia, and intestinal illness.

Lead is regulated by a *primary* standard, meaning it is harmful to humans above a certain concentration when ingested. Drinking water with lead concentrations higher than the U.S. EPA standard can lead to high blood pressure in adults. Infants and children can experience delays in physical or mental development and decreased learning abilities. Long-term effects of drinking water with elevated lead levels include stroke, kidney disease, and cancer. The majority of studies (65 percent) presented in Table 1 reported lead concentrations greater than the U.S. EPA drinking water standard. **Due to the serious health consequences of drinking lead-contaminated water, it is strongly recommended that collected roof runoff *not* be used for drinking or potable uses without proper filtration and treatment.**

Harvested rainwater may be used for potable uses ***if*** it is appropriately treated. There are several methods of treating collected water; however, the most common is filtration and ultraviolet light disinfection. A combination of large- and small-pore filters with a maximum filtration level of 5 microns will remove particulate matter and most dissolved solids, including lead. A maximum filtration level of 1 micron will remove particulate matter and dissolved solids, as well as most parasites and bacteria.

Different types of filters exist, including sediment, ceramic, and activated carbon filters. Each has their advantages and disadvantages. Homeowners should research each type to decide which is most appropriate for the intended application of harvested water. Ultraviolet light disinfection is commonly used as the final step in the purification process, as it removes some organic contaminants, pathogens, and nuisance microorganisms. Information and components for filtration systems may be obtained at a local plumbing supply store. When using harvested rainwater for potable uses within a residential or commercial building, be aware of applicable plumbing codes and regulations as well as necessary permits. If connecting nonpotable pipes from a rainwater harvesting system to municipal and other potable water lines, backflow protection must be provided. Information about these requirements, codes, and permits can be found at the local public utilities office.

CONCLUSIONS

Rainwater harvesting systems conserve water and help with stormwater management. Their ease of use and economic benefits make rain barrels and cisterns popular among homeowners. Research conducted on the quality of rooftop runoff leads to the following recommendations for using collected rainwater:

Harvested rainwater can be safely used for nonpotable activities, such as irrigation, washing vehicles, and flushing toilets. Wash hands and other body parts with soap and treated water after coming into contact with harvested rainwater to prevent bacterial infections and transmission, particularly if harvested rainwater contacts skin abrasions.

If collected water is used to irrigate edible plants, wash the food thoroughly with treated water before consuming any part of the plant to prevent the ingestion of potentially harmful bacteria. Drip irrigation, or some other method of applying water to the soil rather than the plant, might decrease the amount of bacteria and pathogens present on the plant's surface, although this has not been documented.

Cistern water should NOT be used for drinking or other potable purposes if it is not filtered and disinfected before use. Elevated concentrations of harmful bacteria, pathogens, and lead can cause severe health problems if untreated rooftop runoff is ingested.

As the accumulation of Zn in soils can lead to phytotoxicity, soil testing should be performed in areas being irrigated with cistern water where edible plants are grown. Test results will indicate if Zn concentrations are elevated and pose a threat to plant health. While harmful levels of Zn are not considered likely, if such levels are discovered, do not eat vegetables grown in that soil.

Cisterns potentially can decrease the concentrations of constituents that bind to sediment particles, as these particles settle out of the water and collect in the tank's bottom. Researchers are now studying the extent to which these concentrations are improved.

As most of the contaminants detected in rooftop runoff are also detected in rainwater that has not contacted the rooftop, it is unlikely that using harvested rainwater for irrigation will lead to intolerable residues in edible plants, fruits, and vegetables. Further research is being conducted to confirm this.

REFERENCES

Bannerman, R. T., D. W. Owens, R. B. Dodds, and N. J. Hornewer. 1993. Sources of pollutant in Wisconsin stormwater. *Water Science and Technology*. 28(3-5): 241-259.

Chang, M. and C. M. Crowley. 1993. Preliminary observations on water quality of stormwater runoff from four selected residential rooftops. *Water Resources Bulletin,* 29(5):777-782.

Chang, M., M. McBroom and R. Beasley. 2004. Roofing as a source of nonpoint water pollution. *Journal of Environmental Management*. 73:307-315.

Good, J.C. 1993. Roof runoff as a diffuse source of metals and aquatic toxicity in stormwater. *Water Science Technology*. 28(3-5):317-321.

Pitt R., R. Field, M. Lalor, and M. Brown. 1995. Urban stormwater toxic pollutants: Assessment, sources and treatability. *Water Environment Research*. 67(3):260-275.

Tobiason, S. 2004. Stormwater metals removal by media filtration: Field assessment case study. *Proc., Watershed 2004 Conf. Proc.,* (CD-ROM), Water Environment Federation, Alexandria, VA.

RESOURCES

Lye, Dennis J. 2009. Rooftop runoff as a source of contamination: A review. *Science of the Total Environment* 407: 5429-5434.

U.S. Environmental Protection Agency (U.S. EPA). (2003). *National Primary Drinking Water Standards*. EPA 816-F-03-016. Washington, D.C.: Office of Water.

U.S.EPA. (2009, Sept. 11). List of National Secondary Drinking Water Regulations. Washington, D.C.: Office of Water. Online: http://www.epa.gov/safewater/contaminants/index.html#listsec

N.C. Department of Environment and Natural Resources (N.C. DENR). (2007.) North Carolina Freshwater Standards. Raleigh, N.C.: Division of Water Quality. Online: http://h2o.enr.state.nc.us/csu/documents/ncactable290807_000.pdf

RELATED FACT SHEETS

North Carolina Cooperative Extension Service, N.C. State University:

Jones, M. P. and W. F. Hunt. 2008. *Rainwater Harvesting: Guidance for Homeowners* (AGW-588-11). Online: http://www.bae.ncsu.edu/stormwater/PublicationFiles/WaterHarvestHome2008.pdf

Hathway, J. M. and W. F. Hunt. 2008. *Removal of Pathogens in Stormwater* (AGW-588-16W). Online: http://www.bae.ncsu.edu/stormwater/PublicationFiles/PathogensSW.2008.pdf

Evans, E. and D. Osmond. *A Gardener's Guide to Soil Testing* (AG-614). Online: http://www.cals.ncsu.edu/agcomm/publications/Ag-614.pdf

NC STATE UNIVERSITY

Prepared by

Kathy M. DeBusk, *Extension Associate*
William F. Hunt, Ph.D., PE, *Associate Professor and Extension Specialist*
Department of Biological and Agricultural Engineering
Deanna L. Osmond, Ph.D., *Professor and Extension Specialist, Department of Soil Science*
Gregory W. Cope, Ph.D., *Associate Professor and Extension Leader, Department of Toxicology*

Published by
NORTH CAROLINA COOPERATIVE EXTENSION

COLLEGE OF
AGRICULTURE & LIFE SCIENCES
ACADEMICS • RESEARCH • EXTENSION

E10 51863
10/09—BS/KEL

AG-588-18W