Chapter 14

Developing a national rainwater harvesting standard

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14.1 INTRODUCTION

Considering the reality of diminishing availability of clean water, there are a number of reasons to consider rainwater harvesting and stormwater management as an alternative source for water: no water; bad water; stormwater management to reduce (prevent) flooding; reduce (prevent) combined sewer overflow (CSOs). By definition, rainwater is precipitation collected from an above ground, non-vehicular surface (the roof), and stormwater is recipitation that has come in contact with the ground (surface water).

While a rainwater collections system cannot 'make' water in the middle of a drought, or replace a dry well, the collection and management of rainwater serves to bridge the gap between rain events.

As wells are dug deeper, the quality of water can diminish, causing health issues for a community. Rivers and streams, too contaminated with heavy meals and harmful bacteria to be safely used, are not uncommon. Collecting rainwater as a stormwater management tool is growing in importance to diminish flooding and replenish ground water; and also serves to reduce overflows in combined storm and sanitation sewers.

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The benefits of harvesting rainwater are clear, but if rainwater catchment has been going on for millennia, why do we now need rules?

14.2 DISCUSSION

While rainwater collection for residential applications is common, when we expand applications to public buildings, more care is needed to manage the quality of the water. In a residential application, occupants become accustomed to their ambient waterborne bacteria. If we expand the applications to public buildings, more care is necessary to accommodate a lack of resistance to new ambient organisms.

Management of vectors such as vermin and mosquitos is also important. Unmanaged or improperly managed, rainwater collection can support water- and mosquito-borne disease. Examples of good intentions gone wrong occurred in rainwater collection systems built for New Orleans after Hurricane Katrina. Not enough attention was given to the water quality entering the cisterns, which was amplified by algae growth from improper screening of sunlight, served to make them better vehicles for mosquito breeding rather than potable water. As a result, rainwater collection, for a city built below sea level and surrounded by seawater, is not now allowed.

Aside from the safety aspects of having rules for safe rainwater collection, appropriate design and construction standards creates a level playing field for those designers and contractors. Without standards, a bad contractor can drive all the good contractors out of town. And as per the New Orleans experience, a bad job, where someone gets sick, can erase all the good jobs and create a negative impression of the rainwater collection industry.

The rainwater design standards developed in the United States (ARCSA/ASPE/ANSI Standards 63 and 78, the beneficial use of rainwater and stormwater, respectively) was an ARCSA collaboration to develop safe requirements suitable for application in public buildings. Rainwater harvesting standards in 2003 varied in the U.S. as cities attempted to address water shortages in their own way with no consistency. Some jurisdictions required chlorination of the water for toilet flushing, while others required no treatment at all. Some areas had objections that related to rainwater being perceived as a contaminated water source rather than the primary water source it is.

To obtain consistency, the best information available was gathered from research done in Australia, New Zealand, Britain, Germany and the United States. The primary objective was to standardize the inconsistent requirements that were prevalent at the time so it could universally be used safely. This included determining compatible system components and installation practices that would appease health and water utility officials.

The issues determined to be important in a rainwater collection system standard are: the rainwater collection surface and related water transport materials; the

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storage sizing and material; managing the water quality during storage and distribution; maintenance and periodic testing to assure ongoing water quality.

To be noted, in the United States there are important differences between a design guidelines, a standard, and a building code.

A Guide is a suggested design technique. It is an advisory, or a how-to design guide, that suggests design alternatives for multiple applications and recommended installation techniques. For example, design requirements for an above ground tank versus a below-ground tank, recommendations for sizing storage capacity, varying first flush volumes dependent upon site conditions, and water distribution options are included.

A Standard is a 'thou shalt' and 'thou shalt not' document. The emphasis is on protecting the public and not best design practices. It serves only to define the minimum passing grade for a system design and is intended to define requirements that will apply to all rainwater installations. A Standard serves as a reference document to a Building Code.

A Building Code starts with a Model Building or Plumbing Code that, in the United States, is provided by a national code writing body. The Model Codes are a collection of construction requirements that refer to many applications. Referring to the standards for each application (i.e. a rainwater collection system), rather than repeating or including the Standards, serves to reduce the size of the Code. The Code is further reduced as various jurisdictions review the Model Codes to modify, eliminate, or change for application in their respective jurisdiction. Only after the modified Model Code is agreed to and approved by local governmental bodies does it become a 'Building Code' and then have the force of law.

14.3 TECHNICAL

Standards for rainwater collection systems commonly focus on four factors: (1) the roof as a safe collection surface; (2) the quality of the storage tank; (3) the resultant quality of the water; (4) maintenance and testing to maintain the water quality.

14.3.1 The collection surface (roof)

The collection surface material needs to be non-toxic and not corrosive, which means that lead, ferrous, and biocide treated shingles are not allowed. Zinc (galvanized steel), is to be used carefully with an appropriate roof wash system to avoid health issues caused by high levels of zinc in the water. The roof material preferably should be a smooth surface, installed at an appropriate slope, in order to be self-cleaning, and with no overhanging trees for birds, animal residue, leaves˙ For flat roofs, there are NSF 61 compliant roofing membranes. NSF 61 (Formerly National Sanitation Foundation) defines the quality required for material in contact with potable water. Potable material requirements for

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rainwater collection systems were required, even for non-potable applications, so as to be available as a water source in an emergency situation.

The collection surface area is to be sized to compliment the storage capacity and the water need, with an appropriate safety factor applied consistent with alternative sources of water, i.e. availability of utility provided or a trucked-in water as an alternate supply. As a volume guide:

English: 640 gallons $=$ 1″ of rain per 1000 ft^2,
Metric: 1 liter $=$ 1 mm of rain per 1 m^2.

To transport the water, round bottom gutters are better than flat bottom gutters because they maintain a constant velocity at varying depths, which results in better cleaning of any sediment that might settle. To improve the water quality available for use, water entering the cistern should be properly filtered. If trees are adjacent, screened covers over the gutters are a good idea. As an alternative, a leaf filter may suffice to reject leaves and sticks from the inlet water (Figure 14.1).

A first flush device, that wastes the first part of a rain event, is beneficial to reduce the accumulated dirt and debris from the roof from entering the cistern. The First Flush Volume necessary to be wasted is dependent up on the site conditions and level of contaminants likely to be found on the roof (Figure 14.2).

Figure 14.1 Leaf Eater Debris Excluder. (Courtesy: Rain Harvest Systems).

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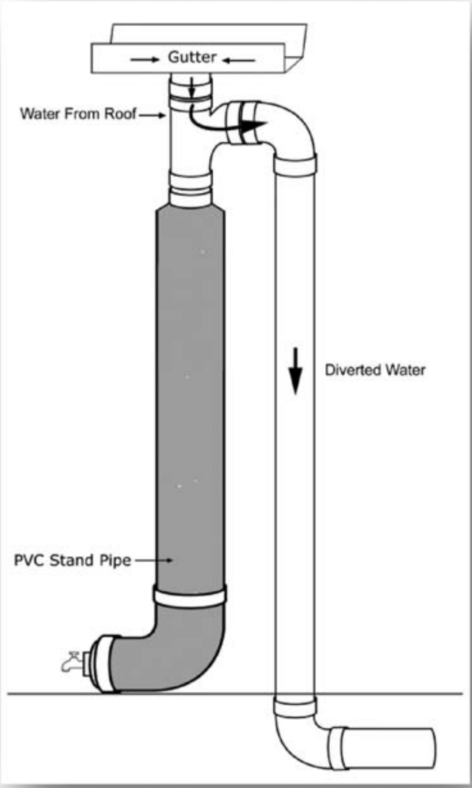

Figure 14.2 First flush device. (Texas A&M AgriLife Extension, s.f.).

For larger collection surfaces, the necessary water volume to provide a satisfactory roof 'first flush' can become large and unwieldy to be practical, making mechanical filters, such as provided by Graf and Wisy, a more appropriate means of cleaning the water entering the cistern (Figure 14.3).

These use mechanical features to allow debris to flow through the filter, thereby preventing the bulk of the debris from entering the tank, while pre-filtering to approximately 100 micron.

14.3.2 Water storage and distribution

Storage tanks, and the related distribution piping, need to be non-toxic and compatible with the storage of rainwater. The tank and related piping also need to be consistent for potable water applications. Since rainwater is similar to distilled water in regard to mineral deficiency, storage tanks need to be resistant to the

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Figure 14.3 Mechanical roof wash device. (Courtesy: Graf Corporation).

slightly negative pH and the absorption of minerals. Suitable materials for rainwater storage are concrete and plastic.

Concrete as a tank material has advantages of being usually available locally which offsets shipping cost from a plastic tank. Leaching of lime from the concrete into the water serves to neutralize the pH of the water. Plastic, made from virgin plastic and not recycled plastic, is also a satisfactory material due to the durability and resistance to corrosion. Redwood has been popular as a water tank storage material but is now less popular due to the expense and environmental concerns of using a wood of limited sustainability.

Access ports and air vents for underground tanks should be a minimum of 4″ above grade to reduce possibility of surface water entering the tanks. Rainwater entering the storage tank should preferably have what is called a 'quiet inlet' (Figure 14.4). This is achieved by using a fitting to divert the water upward in the tank to avoid stirring up any settled debris at the bottom of the storage tank. All outlets should be properly screened for mosquito and vermin prevention. Above ground tanks should be located such that the sun will not heat the water, thereby providing an environment for algae and bacteria to grow in the water. And to assure water availability for emergencies, the tank and related piping should preferably be suitable for potable water contact (NSF 61 compliant). The overflow should be appropriately routed to prevent undermining of adjacent structures and tank supports.

The preference for sizing the tank storage volume is that it be sufficient for the intended use. For the sizing and design of a rainwater storage tank there are four variables for consideration:

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- Water consumption needed – this can be approximated by calculating Monthly Demand;
- Monthly Demand = Volume/use × number of uses/day × 30 days/month;
- Time between rainfall events (to span dry season);
- Storage Capacity = Monthly Demand × time span (months).

This volume can be adjusted if an alternate water supply is available. In the US Virgin Islands 'Government Water' can be purchased if the water level runs out which would reduce the 'safety factor' needed in sizing the tank.

For underground tanks in areas of high water table, the upward force from the tank buoyancy needs to be considered to prevent the tank from floating when empty. The upward force (lift) is calculated as follows and can be offset by attaching the tank to 'dead men' or concrete ballast:

English: 62.4 lb/cubic feet…..8.33 lb/gallon;
Metric: 1 gram/cm^3…………. 1000 kg/1 m^3.

Distribution piping is generally same as traditional plumbing, with the exception that piping needs to be compatible with the slightly acid nature of rainwater. This means that piping should not be ferrous or copper and polyvinyl chloride (PVC) should be used with caution due to leaching of chemicals into the water.

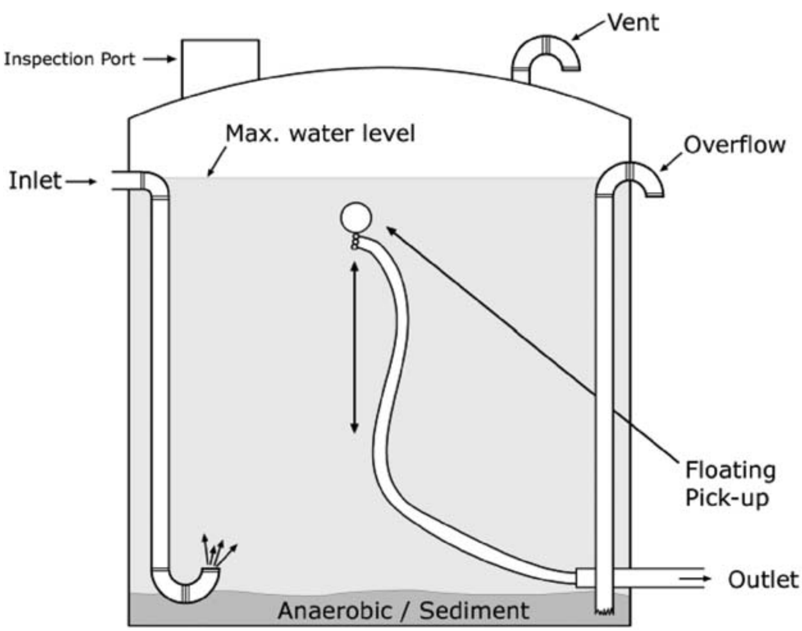

Figure 14.4 Typical rainwater storage tank piping with 'quiet inlet'. (*Source*: WC3 Design, 2013).

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Cross-linked polyester (PEX) is preferred due to chemical resistance to leaching and being cheaper and easier to install. A floating water pickup in the tank, that draws the water below the water surface, where the cleanest water is, is preferred for potable water.

14.3.3 Water sanitation – maintaining water quality

Local authorities may have varying standards for water quality, but the American Rainwater Catchment Systems Association (ARCSA.org) recommends standards used by the Texas Rainwater Catchment Design Guidelines for potable and non-potable water applications (Figure 14.5).

Options for sanitizing water include chlorine, nano-silver particles, ozone, ultraviolet. chlorine, sand filter and thermal disinfection, all have been an effective disinfectant for bacterial disinfection. Hypo-chlorate tablets are commonly used although direct gas injection is also a possibility. Nano-Silver is a developing technology that has been effectively used in small applications.

Ozone is an effective disinfectant although it has no long-term residual in the water. Similarly, ultraviolet light does a good job inactivating microscopic, protozoan parasite such as cryptosporidium and giardia. Like ozone, UV has no residual value and should be located as close to the point of use as possible, downstream of all filtration. Sand filters have been used for centuries as a means of water disinfection and suitable for filtering common bacteria believed to be harmful. Heating rainwater to 60°C (140°F) will also kill most bacteria considered harmful.

Something to note regarding maintaining water quality is the importance of the biofilm that is created during storage. Dr. Peter Coombes (University of Newcastle, Australia) has done considerable research on the effect of biofilm and concludes that

STORED RAINWATER MINIMUM QUALITY STANDARDS		
PARAMETER	INTENDED END USE QUALITY LEVEL	
	NON-POTABLE (Note 1)	POTABLE
Fecal Coliform (e.Coli)	< 100 CFU / 100 ml	None Detectable
Turbidity	< 10 NTU	< 0.3 NTU
Viruses and Protozoan Cysts	----------------	None Detectible

Note:
1. Suitable for toilet and urinal flushing, washing machine makeup, and other approved applications in occupied space for environments with non health impaired occupants.
2. Monitoring requirements vary. Consult state and local guidelines for monitoring requirements.

Figure 14.5 Potable and non-potable water quality standard. (Courtesy: ARCSA).

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Item	Roof	Tank Surface	Tank Outlet	HWS
Fecal Coliforms (CFUs/100 ml)	113	119	0	0
Total Coliforms (CFUs/100 ml)	310	834	127	0
HPC (CFUs/ml)	1318	3256	351	3
Pseudomonas (CFUs/100 ml)	49,825	6,768	4,433	0
Ammonia (mg/L)	0.39	0.1	0.11	0.18
Nitrate (mg/L)	0.25	0.06	<0.05	<0.05
Lead (mg/L)	0.015	<0.01	<0.01	<0.01
Zinc (mg/L)	0.55	0.25	0.17	0.15

Figure 14.6 Biofilm impact on water quality. (*Source:* Coombes, University of Newcastle, Australia).

Location or Criteria	FC (CFU/ 100 ml)	TC (CFU/ 100 ml)	Pseudomonas Spp. (CFU/ 100 ml)	Heterotrophic plate count (CFU/ml)
Surface	108	1,050	3,100	1,050
Mid depth	34	900	780	427
Bottom	55	862	4,060	1,252
Cold tap	<1	200	412	76
Hot tap	0	2	<1	<1
Guideline	0	0	NA	200

Figure 14.7 Bacteria count at varying tank water elevations. (*Source:* Coombes, University of Newcastle, Australia).

water coming out of a water storage tank can be cleaner than going into the tank (Figure 14.6). Furthermore, his research shows water in the middle of the tank has less bacteria than at the surface or bottom of the tank (Figure 14.7) which speaks to the benefits of obtaining water from below the water surface with a floating water pickup.

If water entering the tank is properly filtered with a first flush or other means, water quality in the tank, and the tank itself, can remain clean with minimal cleaning necessary. Keeping an above ground tank out of the sun to minimize tank water temperature is highly recommended to reduce the incidence of growing Legionella and other harmful bacteria in the tank. 32°C to 40°C (85°F to 105°F) is ideal breeding temperature for *Legionella* in a water storage tank, so care should be taken to keep stored water as cool as possible.

14.3.4 Maintenance and testing

For application of a rainwater collection system for a public building, it should be assumed that public scrutiny will be likely. Therefore periodic testing and proper record keeping of these tests is recommended.

After initial construction of a rainwater harvesting system, an 'initial commissioning' should be performed. This involves a thorough cleaning of all surfaces that come in contact with water. After a few rain events, the water should be tested to assure that the initial installation is capable of providing water to the intended level of quality.

At this point the system is turned over to the system owner/operator for his use and ongoing maintenance. Periodic water quality testing, to assure the collection surfaces and pre-filtration are properly maintained, with the test results retained to confirm the system is operating properly, is important. The frequency of testing may vary per jurisdiction, but testing potable water systems every three months, and non-potable yearly is a reasonable frequency of testing for most installations.

Cleaning of the tank is related to the quality of water entering the tank. If debris has been effectively removed from water entering the storage tank, the frequency of

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tank cleaning may only involve periodic inspection. If poor initial filtration is provided, a monthly cleaning may not be too frequent.

The above items represent issues that commonly need to be addressed by the Standard-writing Committee in developing a rainwater harvesting water standard. Once this is written, the next step is navigating the politics of getting the standard adopted as a public document.

14.4 POLITICS AND PUBLIC AWARENESS

Once the standard is established, it has no value if the public doesn't know about it.

Public Review (vetting) of the proposed standard is essential to gaining public acceptance of the proposed requirements and giving it credibility as a public document. Persons asked to review the document are those with a vested interest in rainwater collection and are being asked to review the document and voice their thoughts on proposed deletions, additions and changes. Those chosen to review the proposed standard would include designers, engineers, architects, contractors, city planners, related technical societies, health officials, and others interested in the safe implementation of rainwater collection systems.

The Standards Committee receives the written comments, reviews them, and votes whether to accept or deny the proposed changes. Because this is a public document, professional courtesy requires a public reply as to why the proposed modification was accepted or denied. 100% acceptance is not likely but a consensus appealing to the majority should be the goal and expectation.

Potential roadblocks to successful acceptance may include 'Old thinkers' (we've never done that before), public utilities (not wanting competition that will reduce sales), and competing special interests.

Once the standard is accepted by the public authorities, the education process of the public begins. Designers and engineers need to be taught about design methodology and architects need to be educated so that construction budgets can include a rain harvesting system. Building construction inspectors need to be familiarized so they know what to look for in a properly designed system. Building owners need to know about their systems so they are properly operated and maintained. And health officials need to be comfortable that safe water quality for the public will be maintained. All are necessary to be involved in the development, implementation, and acceptance of a rainwater collection standard.

14.5 SUMMARY

Developing a National Rainwater Harvesting Standard is a multi-step process for a public rainwater harvesting design standard (Building Code) to be effective. The technical issues that need to be addressed in a National Rainwater Harvesting Standard are: (1) collection from a safe (and approved) collection

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surface; (2) re-filtration to provide clean water into the tank; (3) quiet inlet so not to stir up debris; safe distribution of the water; and (5) appropriate filtration and sanitation of the water for delivery.

Once the standard is developed by the standard-writing committee, a constituency of stake holders need to review and approve the document to gain credibility before approaching 'Authority(s) Having Jurisdiction' for approval. When approval is obtained, the education of the public needs to begin to raise awareness about the rainwater collection systems, and the safe procedures necessary for their installation.

Once development and approval of the Rainwater Harvesting Standard is complete, those that participated can take pride in knowing that many people, now without a safe water supply, will be made better off from their efforts.

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