Stormwater Non-potable Beneficial Uses; a Review of International and United States Practices

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Outlines

- Objectives
- Review of Case Studies of Beneficial uses of Stormwater
  - Asia
  - Africa
  - Europe
  - Australia
  - North America
- Regulations Restricting Beneficial uses of Stormwater
- Household Water Use
  - Toilet flushing and irrigation

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Objectives

- Study U.S.A and international practices of recycling of general urban stormwater runoff;
- Illustrate the range of technologies being used in developing and in developed countries
- Identify different components of stormwater systems, treatment and recycling systems the U.S.;
- Identify each component's key design parameters, performance, current knowledge gaps, and obstacles to their implementation;
- Review possible uses of the harvested runoff: The research focused primarily on non-potable water use (e.g. irrigation, non-potable in-house use)

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Background

- This presentation is part of a current project supported by the Water Environment Research Foundation and the Wet Weather Flow Research Program of the US EPA
- The project is investigating whether increased beneficial uses of runoff would be a more efficient use of the water instead of infiltrating into the shallow groundwaters.
- This EPA project in Millburn includes monitoring the water levels in several dry wells and concurrent rainfall conditions. This information is also being used to calibrate WinSLAMM for detailed evaluations of alternative stormwater management options, including beneficial water uses (irrigation and groundwater recharge).

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Representative Case Studies of Stormwater Beneficial Use Examined

- Asia (Singapore, Japan, Thailand, Indonesia, Philippines, Bangladesh, China, South Korea, and India)
- Africa (South Africa, Kenya, and Tanzania)
- Europe (Germany and Ireland)
- Australia (South Australia, Queensland, Victoria, and New South Wales)
- North America (US Virgin Islands, Florida, Hawaii, Washington, New York, Maryland, California, Missouri, Oregon, Washington, D.C., and North Carolina)

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Place	Project name	Stormwater type	Study area (catchment)	Storage capacity	Purposes	Benefits	Cost	Annual saving	Treatment
Singapore	Residential area	Rooftop cisterns	742 ha (7,420,000 m^2)		Non-potable	Saving 4% of total water used	\$0.74/m^3		
Singapore	Changi Airport	Runoff from the runways and the surrounding green areas is diverted to two impounding reservoirs			fire-fighting drills and toilet flushing	Saving 28%-33% of total water used		\$300,300	Treating before reusing
Japan	RyogokuKokugikan	Collecting runoff from rooftop	8,400 m^2	1000 m^3 (underground tank)	toilet flushing and air conditioning				Sedimentation tank prior to storage tank
South Korea	Star City (Seoul)	Collecting runoff from rooftop and ground	6.25 ha (62,500 m^2)	3000 m^3 (three 1000 m^3 tanks)	to irrigate gardens and for flushing public toilets		US\$ 450,000	\$80,000	
India	Delhi	Rooftop and surface runoff harvesting	113,000 m^2		Potable and non-potable		\$1800		
Tanzania	Makanya	Water is collected from the sheet-roof and stored in above ground plastic/RCC tanks		Ranges from 2 to 10 m^3	Domestic purposes or other productive activities such as small vegetable garden.	Irrigation potential increases by 39%.			

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Place	Project name	Stormwater type	Study area	Storage capacity	Purposes	Benefits	Cost	Annual saving	Treatment
Germany	Berlin; Belss-Luedecke-Strasse building	Collecting runoff from roofs and surface.	7,000 m^2 of roofs & 4,200 m^2 of streets, parking spaces	160 m^3 cistern	toilet flushing, garden watering	2,430 m^3 per year saving of potable water			Treated in several stages
Germany	Berlin-Lankwitz	Collecting runoff from roofs and surface.	12,000 m^2 (63% roof, 35% courtyards and sidewalks ,12% roads)	190m^3	for toilet flushing and garden watering				Biological treatment and UV disinfection
Germany	Frankfurt Airport	Rooftop cisterns	26,800 m^2	Six tanks, each is 100 m^3	toilet flushing, irrigation, cleaning the air conditioning system	and save about 100,000 m^3 of water per year	\$63,000		
Ireland	Queens University in Belfast	The roof runoff is collected from roof, is filtered, and stored in an underground tank.	3000m^2		toilet flushing			£13,000 For installing	Filtering prior to be storing in underground tank

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Place	Project name	Stormwater type	Study area	Storage capacity	Purposes	Benefits	Cost	Annual saving	Treatment
South Australia	Salisbury; Parafield	Diverts stormwater from drainage system to a storage basin. pumped to a holding basin, flows by gravity to a reed bed wetland	1600 ha		effluent is then discharged to an aquifer storage area, ensuring a continuous water supply during dry weather	nutrient and other pollutant load reductions are 90%	Aus \$3.7 million		Sedimentation and wetland treatment system
NSW	Black Beach Foreshore Park, Kiama	Stormwater is collected, treated and pumped to offline storage			to irrigate the two parks		\$175,000	\$80,000	Sand filter
Florida	West Palm Beach; Renaissance	collects stormwater runoff from different parts of the Convention Center and Pineapple Park Neighborhood to the Stub Canal, and to a settling basin			potable drinking water	more than 1,140,000 m^3 of treated stormwater is added to the City's water supplies each year	\$17.6 million		Traditional bar screens to remove heavy debris / Alum and polymers for the control of heavy metals, oils and grease.

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Place	Project name	Stormwater type	Study area	Storage capacity	Purposes	Benefits	Treatment
Hawaii	U.S. National Volcano Park	Collecting runoff from roofs and ground	0.4 ha (4000 m^2) rooftop & 2 ha (20000 m^2) of ground catchment	2 reinforced tanks each having 3,800 m^3 ,18 redwood tanks having 95 m^3 each	provide water for 1,000 workers and residents of the park and 10,000 visitors per day		
Washington	Seattle, King Street Center	collect stormwater from the building's roof	327,000 ft^2 (30380 m^2) building houses	three 5,400 gallon cisterns	toilet flushing and landscape irrigation	saves an estimated 1.4 million gallons of water per year, meeting over %60 of the building's estimated annual water needs	Filtering prior to being pumped to the building's toilets or irrigation system through a separate piping system
New York	Battery Park City; Solaire	Collecting stormwater from roof.		10,000 gallon cistern	Cooling, laundry, toilet flushing, irrigation	Stormwater reuse system is sized for 95 m^3/d (25,000 gpd) and provides approximately 30% of the total water use in the building.	Sand filtration and disinfection

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Place	Project name	Stormwater type	Storage capacity	Purposes	Benefits	Cost	Treatment
Maryland	Annapolis; Philip Merrill Building	Collecting runoff from roof		Washing hands, laundry, irrigation, and fire suppression	The building's design allows for a 90% reduction in water use over an otherwise comparable conventional office building.		Sand filters/ chlorination and bioretention
California	Santa Monica; SMURFF	Collect runoff from roofs and surfaces		Landscape irrigation and indoor commercial building use.	Provides approximately 4% of the City of Santa Monica's daily water use	$12 million including the distribution system for the recycled water	5-stage treatment train, consisting of bar screens, flow equalization, air floatation, microfiltration, and UV disinfection
California	Santa Monica; Robert Redford Building	Collect runoff from the building roof	3,000 gallons	Irrigation and flushing toilets.	The building uses 60 percent less water than a standard building of its size, resulting in an annual water savings of over 60,000 gallons		porous paving system and landscaping planters

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Place	Project name	Study area	Storage capacity	Purposes	Benefits	Cost	Annual saving	Treatment
Missouri	Overland, Alberici Corporate Headquarters	42,200 ft^2 (3,920 m^2)	30,900 gallon cistern	toilet flushing and the building's cooling tower	The stormwater reuse system saves 500,000 gallons of water each year, reducing potable water demand by 70%			Filtering and chlorinating prior to reuse
Oregon	Portland University, Stephen Epler Hall	21,400 ft^2 (1988 m^2) roofs & 7,600 ft^2 (706 m^2) turf and landscape plantings	8700 gallons	first floor restroom toilets and drip irrigation of 3,000 ft^2 (279 m^2)of native landscaping	in addition to serving as a demonstration project for a supplementary water source, the system delays and filters potentially polluted quick run-off that would otherwise flow through the city's stormwater pipes directly into the Willamette River	$71,800 initial, $310/year	$680	stormwater planters/ UV light

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Heavily Urbanized Developing Countries In Water Stressed Areas

- Most concerned with harvesting as much runoff as possible, with minimal concern related to water quality.
- Not only is roof runoff harvested, but also runoff from all urban areas. Usually, all paved areas are used to harvest runoff, as maximum volumes are needed to augment the poor quality and poorly available local sources.
- The water is stored in large ponds, or injected to shallow aquifers. These improve the water quality to some extent, greatly depending on the storage conditions.

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Developing Countries With Large Rural Populations

- Most of the runoff harvesting schemes focus on collecting roof runoff for storage in tanks near homes.
- The water is used for all domestic purposes and for irrigation of food subsistence crops during dry weather.
- The storage tanks are therefore relatively large to provide seasonal storage.

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Developed Countries With Large Urban Populations in Water Stressed Areas

- Runoff harvesting has long been used to augment the water supplies.
- In most cases, the runoff is collected from roofs and stored in large tanks adjacent to buildings where the water is used for non-potable uses.
- In some rural cases, the water is used for all domestic water uses. In large development water harvesting projects, runoff is collected from all areas and undergoes some pretreatment before storage in large (usually underground) storage tanks.
- The water then undergoes very sophisticated water treatment before use. In many cases, this highly treated harvested runoff is still restricted to non-potable uses.

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The U.S.

- Many of the U.S. stormwater harvesting projects are either part of a LEED® certified project, and/or to help reduce stormwater discharges to combined sewer systems.
- The collected water is not used for potable uses, but mostly for irrigation uses, and sometimes for toilet flushing or for fire suppression.

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Regulations Restricting Stormwater Beneficial Uses

		Coliform Bacteria	Chlorine	pH	Turbidity	Ammonia	Aluminum	Nitrate /Nitrite
WHO	Roof water harvesting	*E. coli.* <10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	Not relevant	<1.5 mg/L	Not relevant	Not relevant
	Surface Runoff	*E. coli.*<10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	<15 NTU	<1.5 mg/L	<0.2 mg/L	<50 mg/L and <3 mg/L
	Sand dams	*E. coli.*<10 cfu/100 mL	>0.2–0.5 and <5 mg/L	6.5–8.5	<5 NTU	<1.5 mg/L	<0.2 mg/L	<50 mg/L and <3 mg/L
New South Wales (Australia)	Level 1	<1 cfu/100 mL	1 mg/L Cl_2 residual after 30 minutes, or equivalent level of pathogen reduction	6.5–8.5	≤ 2 NTU			
	Level 2	<10 cfu/100 mL	1 mg/L Cl_2 residual after 30 minutes, or equivalent level of pathogen reduction	6.5–8.5	≤ 2 NTU			
	Level 3	<1000 cfu/100 mL		6.5–8.5	--------			
Berkeley, CA	Non-potable indoor/outdoor uses	Total coliforms <500 cfu per 100 mL Fecal coliforms <500 cfu per 100 mL						

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Regulations Restricting Stormwater Beneficial Uses

		Coliform Bacteria	Chlorine	pH	Turbidity
Texas (2006)	Non-potable indoor uses	Total coliforms <500 cfu per 100 mL Fecal coliforms <500 cfu per 100 mL			
UK (2008)	Non-potable indoor uses	Total coliforms 10/100 mL	<2 mg/L	6–8	≤ 10 NTU

✓ Bacteria standards are common, with *E. coli* limits ranging from 1 count per 100 mL for non-potable uses with public access to 1,000 counts per 100 mL for controlled access.

✓Chlorine residuals imply chlorination as a disinfectant, usually with a concurrent turbidity limit to allow more efficient disinfection.

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Summary of Reported Household Water Use and Amounts used for Toilet Flushing

Location	Per Capita Domestic Water Use per Day (L/c/d and date)	Toilet Usage of Indoor Water Supply (% of total supply and L/c/day)
Germany	126 (2004)	30% (38 L/c/day)
Ireland	148 (2006)	22% (33)
Poland	110 (2003) (Gdansk)	n/a
Denmark	131 (2005)	22% (29)
Finland	120 to 150 (2004)	14% (19)
The Netherlands	127 (2006)	29% (37)
Austria	125 to 135 (2007)	22% (29)
Hong Kong	230 (2004)	n/a
Nigeria	30 to 67 (cooking, drinking, bathing and washing only) (2002)	n/a
Israel	300 (1998)	n/a
Millburn, NJ	240 (2005)	n/a
Kansas City, MO	393 (2005)	n/a

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The Urban Water Budget and Potential for Beneficial Stormwater Use in U.S. Residential Areas

- Two working adults and one child, in the U.S. southeast, where the rainfall averages about 50 inches per year:
  - bathing 42%
  - laundry 11%
  - kitchen sink 15%
  - dishwasher 8%
  - bath sinks 12%
  - toilet flushing 12%

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Stormwater Beneficial Uses for a Typical House

- The estimated roof runoff for a typical 2,000 ft^2, 1- ½ level, house (roof area of about 1,300 ft^2) would be about 40,000 gallons per year, for this area having about 50 inches of rain a year.
- The total water use for this household is about 100,000 gallons per year, with the amount used for toilet flushing being about 12,000 gallons, with another 3,000 gallons used for landscaping irrigation.
- For this example, the roof runoff would supply almost three times the amount of water needed for toilet flushing and landscape irrigation.

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Conclusions

- The range of approaches is vast, with some situations simply concerned with capturing any available runoff possible to augment scarce local supplies, while other examples are in water-rich areas and the runoff is being harvested for beneficial uses to conserve already abundant water supplies.
- The methods used for storage and treatment are also seen to vary greatly, from local clay jars to vast underground reservoirs, and with many recharging aquifers for later withdrawal.
- The uses of the harvested runoff also vary from irrigation and toilet flushing only to all domestic water uses.

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Conclusions (cont.)

- Beneficial uses of stormwater are mainly for purposes having low potentials for human contact, such as irrigation;
- Treatment also is seen to vary from virtually none to very sophisticated water treatment systems. Treatment is generally based on general stormwater pollution control techniques, however, advanced techniques together with disinfection are used if there is a higher potential for human contact;
- Beneficial uses of stormwater is not effectively regulated at this time. Given the potential for beneficial uses of stormwater in many areas of the U.S., higher priority should be given to development of specific guidelines.

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Thank You

Questions?