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Issue #2

Rainwater Harvesting

About the Australia-Pakistan Water Security Initiative

Duration	Budget	Location	Implementing Partners
April 2021 to June 2025	AUD 5.57 million (AusAID contribution AUD 5.0 million)	Farash Town, Islamabad and James Town, Rawalpindi	World Wide Fund for Nature (WWF-Pakistan) International Water Management Institute, Pakistan (IWMI) Hydrology and Risk Consulting, Australia (HARC)

The earth has an abundance of water, but unfortunately, only a small percentage (about 0.3 per cent), can be used by humans. The other 99.7 per cent is in the oceans, soils, icecaps, and floating in the atmosphere[1]. This fact emphasizes the significance of freshwater and the need to use it sustainably especially in the context of a burgeoning population. **Seventeen countries having one quarter of the world's population are extremely water stressed[2]. One of them is Pakistan.** The country is facing a water crisis due to poor water management practices, unregulated surface and groundwater use, urbanization, population growth and water pollution. To deal with the water security issues in Pakistan, particularly in urban areas, it is important to manage the available water resources wisely. There are various solutions that can help to deal with water stress, such as rainwater harvesting, groundwater recharge, recycling of greywater, establishing rain gardens and reuse of water from laundry, dishwashing, etc. In this issue of the knowledge series, rainwater harvesting, being one of the most economical and community-friendly approaches, is discussed in detail.

[1] https://www.ngwa.org/what-is-groundwater/About-groundwater/information-on-earths-water
[2] https://www.wri.org/insights/17-countries-home-one-quarter-worlds-population-face-extremely-high-water-stress

Rainwater harvesting

Rainwater harvesting is the process of collecting, filtering and storing rainwater that runs off from rooftops, open grounds, parks, roads, etc. for use at a later time. Rainwater tanks are above (surface) or under-ground (sub-surface) storage facilities, typically used in residential areas to retain rainwater from roofs. The rainwater collected can be reused around the building for non-potable purposes. See Figure 1 for a visual representation.

Rainwater Harvesting System

The basic components of a rainwater harvesting system are:

Catchment is the area on which the rain falls directly. It collects all the water that will be harvested. Rooftops, sloped roofs, courtyards, paved and unpaved areas can be catchment areas.

Transportation pipes move rainwater from catchment to a storage system. This includes down water pipes and drains.

First flush is a device to flush off the first shower of rain. It is vital to flush off this water as it contains contaminants and microorganisms from the catchment and atmosphere.

Filters for rainwater are important before its storage and use. The following filters may be used to make the water fit for non-potable use:

- **Gutter screens;** which are placed over gutters to prevent the debris from falling into the gutter while the rainwater flows through them.

- **In tank filters;** which are placed inside the under-ground or on-ground rainwater storage tanks as internal self-cleaning filters to filter gravel, sand, etc.

- **Sand filters;** which contain layers of sand with increasing coarseness downwards. These help filter out suspended matter, as well as floating and sinkable particles.

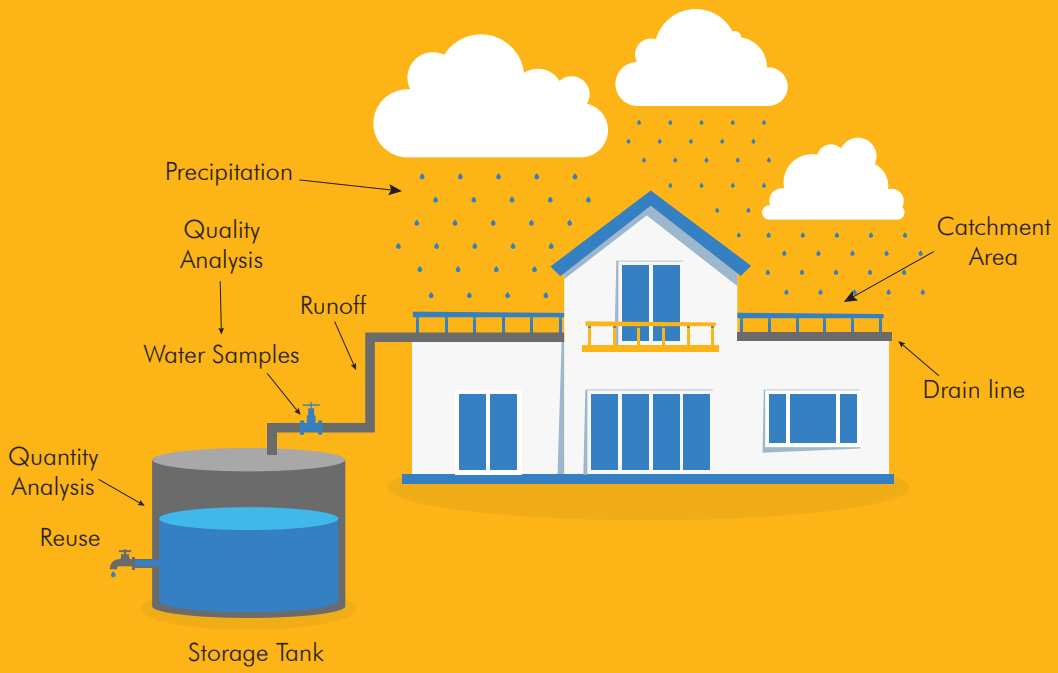
Storage tank is the tank that stores rainwater after its basic filtration.

Factors affecting rainwater harvesting

Several factors play a vital role in the amount of water harvested.
Some of these include:

- The quantum of runoff.
- Features of the catchments (rooftop type, gradient and area available).
- Impact of the rain drop on the environment (rainfall intensity over a period of time).
- The capacity of the storage tanks.
- Type of the roof, its slope, and the roofing material.
- The frequency and quantity of the rainfall.

Figure 1: Rainwater harvesting



Advantages and disadvantages of rainwater harvesting

ADVANTAGES

- Reduced demand on conventional water supply systems by supplementing rainwater.
- Increased decentralized water security and local self-reliance whilst encouraging family level operation and maintenance.
- Increased domestic water security by reducing unproductive labour, time and hazards faced mainly by women and children in fetching water from a distance, and improved accessibility to water for many marginalized communities.
- Retains water close to the source.
- Valuable water source for non-drinking purposes, hence reducing the demand for ground and surface water.
- Can be used for drinking purposes in case of an emergency but only if it is treated properly or boiled.
- Reduces runoff volume and can help to reduce downstream flooding.
- Restores groundwater reserves if the harvested rainwater is diverted towards a recharge well.
- Harvested water can be used for drier seasons.
- Cost-effective and eco-friendly.

DISADVANTAGES

- Dependent on unreliable rainfall pattern.
- The initial cost (mainly of the storage tank) may act as a deterrent.
- The poorer segment of the population may not have roofs suitable for rainwater harvesting.
- Sufficient space is needed to place the storage tanks.
- Proper analysis is needed to determine appropriate use of rainwater.

Potential end uses of harvested rainwater based on water quality

The end use of rainwater harvested depends upon the quality of water. Usually, this water is not recommended for potable purposes but could be used for a variety of non-potable requirements, such as showers, toilet flushing, laundry, floor cleaning, watering gardens, other outdoor use, etc.

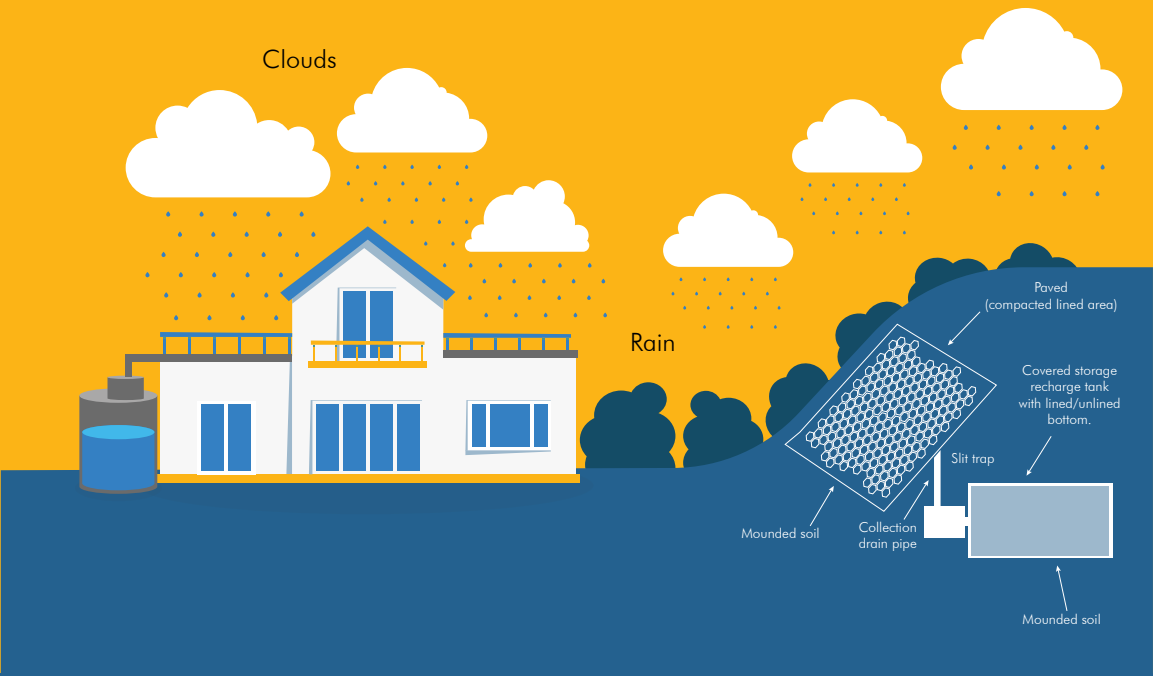
Rainwater quality and quantity

The quality of rainwater is assessed upon the basis of total coliform, faecal coliform (E. coli), nitrite/nitrate, hardness, lead, and zinc; while the quantity is assessed by urban water cycle models and hydrograph analysis which evaluates the performance of total rainfall and runoff, peak flow of rainfall and runoff, and delayed time parameters. This is in addition to the assessment of the use of rainwater tanks for capturing roof runoff in residential dwellings.

The quantity and quality of rainwater can be maintained by installing an appropriate high-quality system to harvest the rainwater. To ensure high quality and maximum quantity:

- The **catchment** such as rooftop, sloped roof, courtyards, paved/unpaved area must be built properly with no toxic materials, including lead paints and must be cleaned regularly.

Figure 2: Catchments



• The **pipes** installed for transporting water (water pipes and drains) must be made up of UV resistant materials and should be unclogged. Micro wire mesh must be placed at the mouth of each pipe or drain to prevent floating materials from passing through these pipes. See figure 3 for examples of pipes used for rainwater harvesting.

Figure 3: Pipes (Source: Interiorsinfo.com)

•The **first-flush** system is a must to flush off the first rain of the season that contains sediments, contaminants and microorganisms from the catchment and atmosphere. First flush diverter must be installed to prevent first washed off water from the roof entering the storage tank making it contaminated or unusable. See figure 4 for a visual representation.

Figure 4: First flush system (Source: bmigroup.com, permies.com)

•Installation of **filters** (see figure 5) is also mandatory to eliminate all sorts of small and large particles.

Figure 5: Filters (Source: NSassociates, 3ptechnik.co.uk)

•A large, cleansed, light-proof and covered storage tank (see figure 6) is needed to store rainwater for the drier season.

Figure 6: Storage tank (Source: Kyok et al., 2020

Australian best practices on rainwater harvesting systems

Australia has been working to manage their water resources by adopting the water sensitive approach with interventions such as rainwater harvesting since a long time. To ensure good quality of rainwater harvested, the Victoria Department of Health in Australia has recommended a few treatment and monitoring practices in order to manage rainwater in urban communities. See table 1 for details.

Table 1: Treatment and monitoring recommendations for rainwater in urban communities (Source: Victoria Department of Health, 2013)

Use	Risk of ingestion	Treatment	Recommended minimum monitoring			
			System Inspection	Treatment process	E.coli	Chemicals
Personal washing (shower, baths and hand basins)	Moderate	Recommended	Quarterly	Consult	N/A[3]	Every three years[4]
Swimming pool/spa	Moderate	See note below[5]	Quarterly	N/A	N/A[6]	Every three years[2]
Laundry Toilet fushing Garden watering and general outdoor use[7] Fire protection system open industrial system	Low	Unlikley to be necessary[8] (unless hazard identification and risk assessments indicate that significant risk require management)	Quarterly	N/A	N/A[4]	N/A[9]

Use	Risk of ingestion	Treatment	Recommended minimum monitoring			
			System Inspection	Treatment process	E.coli	Chemicals
Open industrial system		Require management				
Garden watering (subsurface or drip irrigation) Heating and cooling systems (including cooling towers[10]) Closed industrial systems	Extremely low	Unnecessary	Quarterly	N/A	N/A[4]	N/A[7]

[3] It may be appropriate to increase the frequency of E. coli monitoring if rainwater is used for susceptible groups, such as elderly, immune-suppressed or very young.
[4]More frequent monitoring of chemicals may be appropriate if the initial sampling and risk assessment indicates that chemical concentrations are close to levels of health concern, or if treatment processes are being used to remove chemicals of health concern.
[5]Swimming pool and spa water treatment processes, such as chlorination, should meet treatment needs in most cases (unless chemicals are assessed as being of concern. Public pool operators should refer to the Pool operators' handbook, available from the department's website, for further information.
[6]E. coli monitoring is usually unnecessary. However, if contamination is suspected, E. coli monitoring may be an appropriate indicator of treatment effectiveness.
[7]Garden watering includes vegetable gardens. General outdoor use includes car washing, dust suppression, construction, wash down, and filling water features and ponds.
[8]Treatment is generally considered unnecessary from a human health risk perspective. In some circumstances it may be necessary to treat rainwater to remove chemical contaminants that may damage appliances or industrial systems.
[9]Monitoring may be appropriate for chemicals of aesthetic or physiochemical concern.
[10]Under the Building Act 1993 a specific risk management plan is required to control the risk of Legionnaires disease from cooling tower systems. Contact the Department of Health for further information – refer to Appendix 2 for contact details. [This is specific to Australia; may vary elsewhere]

Rainwater system assessment (risk management)

To ensure good quality water, a thorough and regular rainwater assessment is mandatory. See table 2 for details.

Table 2: Rainwater system assessment

Hazard	Hazard event	Treatment	Monitoring	Corrective actions
Roof catchment and storage				
Microbial				
Faecal contamination from birds and animals	Overhanging branches	Prune tree branches	Check tree growth during inspection	Prune branches
	Birds and animal faeces on roof	Remove or modify structures that encourage bird perching (this is particularly important for schemes with moderate risk of ingestion)	Check during system inspection	Repair or modify as required
	Animal access to tank	Protect or screen all inlets, overflows and other openings to tank	Check access covers, inlets, overflows, and openings during system inspection	Repair gaps and secure access cover
		Maintain integrity of tank roof and body	Check structural integrity of tank during system inspection	Repair as required
Faecal contamination from humans and animals (below-ground tank)	Human access to tank	Prevent access Ensure tank is roofed and access hatches are secured	Check access covers during system inspections	Secure access covers
	Contamination of rainwater from surface water, leaking sewerage pipes or septic tanks	Use above-ground tanks or protect tank from over-ground flows and ensure tank walls are intact	Check structural integrity during system inspection	Repair or line inside of tank
			Check surface water does not enter tank during storm events	Improve barrier to surface water flow

Hazard	Hazard event	Treatment	Monitoring	Corrective actions
Growth in tank or rainwater system	Growth of microorganisms in rainwater storage tank	Keep roof catchment and gutters clean	Inspect roof, gutters and screens at tank openings during system inspection	Clean gutters
		Install a first flush diverter to minimise entry of nutrients and sediments to tank (this is particularly important for schemes with moderate risk of ingestion)		Repair or replace any damaged screens
		Use gutter guard and tank inlet screening to minimise entry of leaves and debris		
	Growth of microorganisms in rainwater system	Design system to prevent pooling and stagnation of water	Inspect gutters during system inspection, and periodically after rainfall	
	Growth of algae in rainwater storage tank	Ensure tank is light proof	Check integrity of roof	Repair roof
			Inspect water for presence of visible algal growth	Confirm algal species and risk to health; treat water to remove algae, if appropriate
Mosquitoes				
	Access to stored water	Protect all tank inlets with insect-proof mesh	Check access covers, inlets, overflows and openings during system inspection	Repair mesh to prevent access and if larvae are present, to prevent escape of mosquitoes
			Inspect water for presence of larvae	Add small amount of medicinal liquid paraffin to the tank if larvae are persistent (approx. 2 tablespoons for a 0-kilolitre tank)
	Access to pooled water	Design system so that potential for pooling of water (for example in gutters) is minimised	Inspect gutters during system inspection, and periodically after	Clean gutters or make changes to ensure the drain quickly between
		Keep gutters clear of debris	rainfall	rain events

Hazard	Hazard event	Treatment	Monitoring	Corrective actions
Chemical				
Roof catchment contamination	Accumulated sediments on roof catchments	Keep roof catchment and gutters clean and install a first flush diverter to minimise entry of nutrients and sediments to tanks	Check first flush diverter operation during system inspection.	Maintain first flush diverter
			Inspect roof and gutters during system inspection.	Clean gutters
		Use 'gutter guard' or tank inlet screening to minimise entry of leaves	Inspect tank sediment levels every 2-3 years	Clean tank, if required
	Contamination with smoke and emissions from flues	For wood heaters, use fuel that is not painted or treated with preservatives, and ensure flues are installed according to the appropriate Australian standards	Check choice of fuel	Discard inappropriate fuel
			Check the installation	
		For other flues, exclude affected sections of roof from rainwater catchment	Inspect roof before installing tank	Address as appropriate
	Overflow and discharges from roof-mounted appliances into catchment	Eliminate or exclude affected sections of roof from catchment	Inspect roof before installing tank	Make alterations, as appropriate
			Check during system inspection	
Contamination from roof and system materials	Chemical leaching from roof or system materials	Remove lead flashing and seal any exposed preserved/treated timber or exclude affected sections of roof from catchment (this is particularly important for schemes with moderate risk of ingestion)	Inspect roof before installing tank	Remove, cover or seal, as appropriate
		Do not collect water from roofs coated or painted with materials that may leach hazardous substances (e.g., lead-based paints or tar-based materials)	Inspect roof before installing tank	Remove, cover or seal, as appropriate
		Use tanks and system components that comply with the relevant Australian standards	Check suitability of components with supplier or retailer	Remove or replace product
Other	Other source of chemical contamination, for example from atmospheric pollution (identified on a case-by-case basis)	As appropriate	As appropriate	As appropriate

Hazard	Hazard event	Treatment	Monitoring	Corrective actions
Distribution and Plumbing				
Microbial and chemical				
	Cross connections between rainwater and other water supplies	Ensure distribution system complies with PIC guidance and relevant Australian standards	Inspect system after installation to ensure compliance	Rectify non-compliant distribution or plumbing work
	Chemical leaching from system materials		Inspect after modifications or maintenance to system to ensure compliance	
	Cross connections between rainwater and other water supplies	Ensure distribution system complies with PIC guidance and relevant Australian standards	Inspect system after installation to ensure compliance	Rectify non-compliant distribution or plumbing work
			Inspect after modifications or maintenance to system to ensure compliance	
End Use				
Microbial and Chemical				
	Unintended use of rainwater (e.g., drinking causing illness)	Make residents and rainwater users aware of appropriate uses through communication tools	Ensure communication tools or packages are available to rainwater users and updated when necessary	Address as appropriate
		Provide signage, where appropriate	Inspect signage presence and condition during system inspection	Repair or replace signage
		Ensure distribution and plumbing system complies with relevant standards	Inspect system after installation to ensure compliance	Rectify non-compliant distribution or plumbing work
			Inspect after modifications or maintenance to system to ensure compliance	
		Ensure backflow prevention protects drinking water supply at any drinking water back-up to rainwater system and complies with Australian standards	Inspect distribution system for cross connections to drinking water supply or connections to inappropriate uses	Rectify any inappropriate connections
			Inspect backflow prevention system, as per manufacturer's advice and Australian standards	Repair or replace as appropriate

Demonstration of household rainwater harvesting systems in Pakistan

Rainwater Harvesting Model: Rawalpindi and Islamabad, Pakistan

Pakistan is a country with high water security issues and thus needs full consideration to manage its water resources. One such resource is the rainwater that becomes the part of wastewater and causes urban flooding every year.

To demonstrate methods to improve water security in Pakistan, WWF-Pakistan has started a project with the help of Australian Aid under the Australia-Pakistan Water Security Initiative with a vision to implement the water sensitive cities approach. Under this project, among many water sensitive initiatives, one is the installation of 575 rainwater harvesting systems that will have the capacity to harvest 48,029 m^3/year and benefit more than 24,000 people.

Since its inception, more than 250 rainwater harvesting systems have been installed and are operational; harvesting rainwater for drier seasons and benefitting more than 1750 individuals resident in the demonstration sites. See figures 7 and 8.

Figue 7: One of the beneficiaries of a rainwater harvesting system installed as part of the APWASI project

Figue 8: Rainwater harvesting systems installed at demonstration sites

Conclusion

Amid the rise in water stress in urban areas across Pakistan, there is a dire need to adopt water sensitive approaches to save and reuse freshwater resources. One such approach is rainwater harvesting which can have a significant impact in alleviating water unavailability in areas that experience sufficient rainfall. In addition, this issue has also highlighted the WWF-Pakistan and Australian-Aid joint initiative to deal with water security in two demonstration sites of Rawalpindi and Islamabad, Pakistan. This initiative is expected to not only address the issues associated with safe water and sanitation but also engage the community to achieve water sustainability.

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