

Brief:

Nature-based Zero Liquid Discharge (ZLD) Systems

Addressing Pakistan's water crisis
through Nature-Based Solutions



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Purpose

Pakistan is facing a growing water security crisis driven by rapid urbanisation, population growth, groundwater depletion, climate variability, and limited wastewater treatment. Per capita water availability has declined from around 5,000 m³ in the 1950s to less than 1,000 m³ today, placing the country in conditions of water scarcity. The uncontrolled discharge of untreated wastewater continues to contaminate surface and groundwater sources, increasing public health risks and environmental degradation.

This briefing introduces Nature-Based Zero Liquid Discharge (ZLD) systems as a practical, climate-resilient approach that integrates rainwater harvesting, ecological wastewater treatment, groundwater recharge, and local reuse. By safely treating and reusing water on-site, these systems minimise liquid discharge while strengthening water security and service reliability.

What is Nature-Based ZLD?

Nature-Based ZLD combines:

- Rainwater harvesting
- Groundwater recharge
- Decentralised wastewater treatment through constructed wetlands and Anaerobic Baffled Reactors Filtration (ABRF) and safe reuse

The rainwater is collected, stored, and recharged into groundwater aquifers. Instead of sending wastewater into drains or sewers, water is treated through natural processes and reused locally for irrigation and horticulture activities. This reduces pollution, lowers freshwater demand, and strengthens local water cycles using low-energy, low-maintenance infrastructure.

Climate and WASH relevance

Nature-Based ZLD systems directly support Pakistan's climate adaptation and public health priorities. By capturing rainfall, treating wastewater locally, and replenishing groundwater, they reduce flood risk, improve water availability during dry periods, and protect communities from exposure to contaminated water.

For public institutions such as schools, universities, and health facilities, ZLD improves service reliability, reduces infection risks, and ensures safe water and sanitation even during climate shocks. This makes ZLD not only an environmental solution, but a critical component of resilient WASH and health systems.

WaterAid Pakistan Demonstration Sites

To test feasibility and generate local evidence, WaterAid Pakistan piloted integrated NbS-based ZLD systems in both urban and rural institutional settings. These sites demonstrate technical viability, environmental impact, and policy relevance.



Biotechnology Department, University of Karachi (Urban academic campus)

System components

Rooftop rainwater harvesting, Anaerobic Baffled Reactor (ABR), constructed wetlands, sand filtration, storage tanks, and recharge wells.

Design capacity

Approximately 6,700 gallons per day (Treatment of wastewater)

Results and learning

- Treated wastewater meets Sindh Environmental Quality Standards (Water samples tested at Laboratory)
- Significant reductions in organic load, suspended solids, and pollutants.
- Approximately 400,000 gallons of water recovered annually for irrigation and groundwater recharge.
- Reduced pressure on municipal supply and drainage systems
- Full capture of rooftop runoff supports groundwater recharge and helps reduce localised urban flooding.



Left: Zero liquid discharge (ZLD) project site at the University of Karachi, Sindh Province, Pakistan. January 2026.

What this shows

Large institutions can become net contributors to local water security through integrated, nature-based treatment and reuse.



Rural Health Centre 53-M, Lodhran (Rural health facility)

System components

Rainwater harvesting, Anaerobic Baffled Reactor (ABR), constructed wetlands, sand filtration, and recharge well.

Design capacity

Approximately 1,900 gallons per day (Treatment of wastewater)

Results and learning

- Approximately 42,000 gallons of rainwater captured and recharged annually from rooftops.
- Direct contribution to aquifer replenishment in a water-stressed rural setting
- Demonstrates feasibility of decentralised wastewater treatment and reuse for small public facilities.

What this shows

Health facilities and public buildings in water-scarce areas can improve local resilience through simple, low-cost ZLD systems.



Above: Zero liquid discharge (ZLD) project site at the Rural Health Centre 53-M, Lodhran, Punjab Province, Pakistan. February 2025.

Methodology

Rainwater harvesting potential was estimated based on rooftop catchment area and average annual rainfall of the respective locations, applying appropriate runoff coefficients according to roof surface type to account for system losses.

Wastewater treatment capacities were designed based on estimated daily wastewater generation and facility usage. Treated effluent quality was verified through laboratory testing and assessed against National Environmental Quality Standards (NEQS) to ensure suitability for reuse and groundwater recharge.

Why ZLD Matters for Policy and Planning

- **Water Security:** Reduces dependence on external or declining water sources by recovering and reusing water locally.
- **Public Health Protection:** Prevents untreated wastewater discharge and reduces contamination risks.
- **Climate Adaptation & Resilience:** Enhances flood management, supports groundwater recharge, and builds drought resilience.
- **Cost-Effective & Low-Energy:** Requires lower capital and operational costs compared to conventional treatment plants.

Scalability & Replicability

The ZLD models demonstrated by WaterAid are:

- **Modular:** adaptable to different demand levels
- **Adaptable:** suitable across rainfall zones and site conditions
- **Replicable:** practical for public institutions and developments They are particularly relevant for;
 - Public institutions (schools, universities, hospitals)
 - Housing schemes
 - Industrial and commercial premises
 - New urban developments

Recommendations

Government & Regulators

- Mandate **rainwater harvesting, wastewater treatment, and recharge systems** in:
 - Public buildings
 - New housing schemes
 - Commercial and institutional developments
- Integrate **ZLD/NbS** into:
 - Building codes
 - Environmental approvals
 - Climate adaptation strategies
- Provide **financial incentives, grants, and subsidies** for ZLD adoption.

Local Governments & Utilities

- Shift from centralized wastewater disposal to **decentralized NbS systems**.
- Promote ZLD as a solution for **urban flooding and groundwater depletion**.

Development Partners & Donors

- Support **pilot-to-policy transition** of NbS-based ZLD models.
- Invest in **scaling and replication** across climate-vulnerable regions.

Conclusion: From Pilots to Practical Solutions

Nature-Based Zero Liquid Discharge systems demonstrate that water security, pollution control, and climate resilience can be addressed together through decentralised, affordable, and sustainable approaches.

Evidence from WaterAid Pakistan's demonstration sites shows that institutions can shift from being water users to water stewards by capturing rainwater, treating wastewater, reusing water locally, and replenishing groundwater.

Building on field experience and sector knowledge, WaterAid Pakistan has worked to consolidate practical designs, operational learning, and implementation guidance to support government departments, utilities, and partners to replicate and scale these approaches.

Zero Liquid Discharge is no longer a pilot concept. It is a proven, climate-resilient solution that can be mainstreamed as part of Pakistan's core water infrastructure.



WaterAid/ Muhammad Usama

Above: Aquifer recharge site constructed by WaterAid in Kachnar Park, Sector I-8, Islamabad, Pakistan. December 2024.



Zero Liquid Discharge (ZLD) for Climate-Resilient Health Facilities

Rural Health Centre 53M, Lodhran

To reduce water loss and improve sustainable water use in healthcare settings, a Zero Liquid Discharge (ZLD) system was installed at Rural Health Centre 53M with support from WaterAid.

Led by engineer Muhammad Ejaz from the Buildings Department, the system treats and reuses wastewater on-site, lowering freshwater demand and creating a practical model now being promoted for replication across other public facilities.

“Wastewater isn’t waste, it’s a resource we can reuse to secure water for our facilities and communities.”

- Muhammad Ejaz, Sub-Divisional Officer, Buildings Department, Lodhran



Campus Zero Liquid Discharge (ZLD) Model

University of Karachi

Facing rising heat and water shortages, Karachi University introduced a small ZLD system with support from WaterAid to treat and reuse wastewater for irrigating crops and green spaces.

Guided by Dr Faheem and supported by agriculture students, the campus now conserves water on-site while serving as a hands-on learning lab for climate-resilient agriculture.

“When we start reusing water instead of wasting it, we build real resilience for the future.”

- Dr Faheem, Chairman, Department of Agriculture & Agribusiness Management, University of Karachi

Student-Led Rainwater Harvesting

University of Karachi

Students designed and built a simple rainwater harvesting pit to capture monsoon water and reuse it during dry periods.

Through these practical efforts, alongside plantation drives using indigenous trees, young people demonstrated how small, low-cost actions can conserve water, strengthen green cover, and contribute to local climate solutions.

“We don’t have to wait for big changes, small steps at our level can protect our city.”

- Mahnoor Alam: Graduate, Agriculture & Agribusiness Management, University of Karachi

