WASH Field Note FN/42/2024

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Decentralized Wastewater Treatment System (DEWATS) in Wazir Bagh, Peshawar, KPK, Pakistan

SUMMARY

The Decentralized Wastewater Treatment System (DEWATS) in Peshawar is a pilot project developed to address the dual challenges of wastewater treatment and its reuse for irrigating urban green spaces in Khyber Pakhtunkhwa (KPK), Pakistan. The project, supported by UNICEF and implemented by the Water and Sanitation Services Peshawar (WSSP), sought to minimize the use of pumped ground water for irrigation of public parks and urban green spaces, and mitigate the environmental and public health risks posed by the release of untreated wastewater in a region already grappling with severe water scarcity.

By treating and reusing wastewater to irrigate Wazirbagh park, an eighteenth-century Mughal era historic public park, the project not only revitalized a vital public space, but also reduced pressure on the depleting groundwater resources and reduced annual electricity expenditure by millions of rupees as well. The project also demonstrated the feasibility of decentralized, sustainable water management solutions in urban contexts. This report provides a detailed account of the DEWATS system's design, implementation, outcomes, learnings, and highlighting its potential for replication in similar settings. across Pakistan and beyond.

Introduction

Pakistan's water crisis is one of the most pressing challenges the country faces today. With a population exceeding 220 million, the country's water demand has surged, while its water supply has dwindled due to over-extraction, pollution, and climate change. Pakistan is now classified as water-scarce, with per capita water availability dropping below 1,000 cubic meters per year — a critical threshold below which water scarcity begins to impede socio-economic development and human health.
Agriculture, which consumes over 90% of Pakistan's water resources, is particularly vulnerable to this crisis. The Indus River basin, the lifeline of Pakistan's agriculture, is increasingly strained by reduced glacial meltwater and erratic monsoon patterns. Urban areas are also severely affected, with big cities like Karachi, Lahore, and Peshawar facing acute shortages that lead to social unrest and economic disruptions.

Khyber Pakhtunkhwa (KPK) province, home to over 40.8 million people (MICS 2023), mirrors the broader water challenges faced by Pakistan, with unique regional characteristics. The province's capital, Peshawar, has historically depended on its groundwater and limited surface water resources to meet its needs. However, rapid urbanization, population growth, and industrial expansion have outpaced the development of water infrastructure, leading to significant deficits in both water supply and wastewater management.

One of the most critical issues in Peshawar is the state of its wastewater treatment facilities. Over the past decades, three wastewater treatment plants were constructed in the city, aimed at treating the substantial volumes of domestic and industrial wastewater generated daily. However, due to various factors, including lack of maintenance, inadequate funding, and operational challenges, none of these plants are currently functional. This has resulted in the direct discharge of untreated wastewater into rivers and canals, exacerbating water pollution and posing severe risks to public health and the environment.

In response to these challenges, UNICEF, in collaboration with WSSP, launched the DEWATS project in Peshawar. Decentralized Wastewater Treatment Systems (DEWATS) are an innovative approach to wastewater management, particularly suited to contexts where centralized treatment facilities are either unavailable or non-functional. DEWATS systems are designed to be modular, cost-effective, and capable of treating wastewater close to its source, thereby reducing the environmental impact and enabling the reuse of treated water for various purposes, including irrigation and landscaping.

The DEWATS approach is grounded in the principles of sustainability, simplicity, and adaptability. Unlike conventional centralized treatment plants, which require significant capital investment and complex operational management, DEWATS systems are designed to be low-operational-cost and low maintenance. They can employ a combination of physical, biological, and chemical processes to treat wastewater, with each component tailored to the specific characteristics of the wastewater and the treatment goals. Figure 1 compares the two wastewater treatment systems.

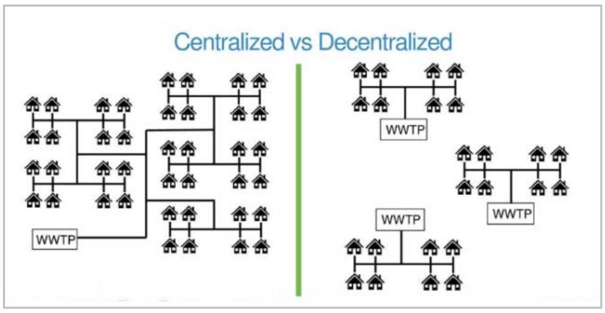


Figure 1. Centralized vs Decentralized WWTP

The Peshawar DEWATS project was developed by Bremen Overseas Research and Development Association (BORDA), with the specific goal of treating wastewater generated by 75 households and utilizing the treated effluent to irrigate Wazirbagh park—a historic and culturally significant green space in the heart of the city. The park, which had suffered from neglect and water shortages, was identified as an ideal site for demonstrating the potential of DEWATS technology in an urban environment.

The DEWATS system is powered by a solar system installed on the roofs. Two sets of solar-powered submersible pumps are installed. The first one pumps wastewater into the settler tank from a lower hydraulic level. The second pumps the treated wastewater into the park through a network of pipes that have been laid throughout the park, with sprinklers attached to efficiently distribute the water across the gardens and the four grounds within Wazir Bagh. The park was dependent on two tube-wells that were not functional during the time of proposal and even if the tube-wells had been functional, they were relatively costly compared to the DEWATS system.

Institutional arrangements

WSSP is mandated to provide water supply, solid waste and sewerage management services to Peshawar city. The WSSP has taken over the responsibility for monitoring of effluent quality and maintenance of the DEWATS system. The Tehsil Municipal Authority (TMA) Peshawar is a local government institution in Peshawar, Pakistan, responsible for providing and managing municipal services within the tehsil's jurisdiction. TMA is responsible for the irrigation system of the park with the treated wastewater.

In order to prevent the DEWATS of falling into a state of disfunctionality, significant efforts have been made by UNICEF to mitigate risks. First,the design and scale of a DEWATS make proper operations more feasible by resource-constraint organistations. Secondly, capacity of both organisations was assessed, and where needed, capacity building exercises where undertaken. These included the management and maintenance of solar-powered pumps. Furthermore, accountability at both organisations was fostered by ensuring regular engagement between WSSP and TMA. Both parties are aware that the project's success depends on maintaining this collaboration long-term, supported by ongoing capacity-building and resource allocation.

Furthermore, because the DEWATS system considerably reduced electricity cost by making the two tubewells that were used to irrigate the park obsolete, savings where introduced which could be allocated to the DEWATS System.

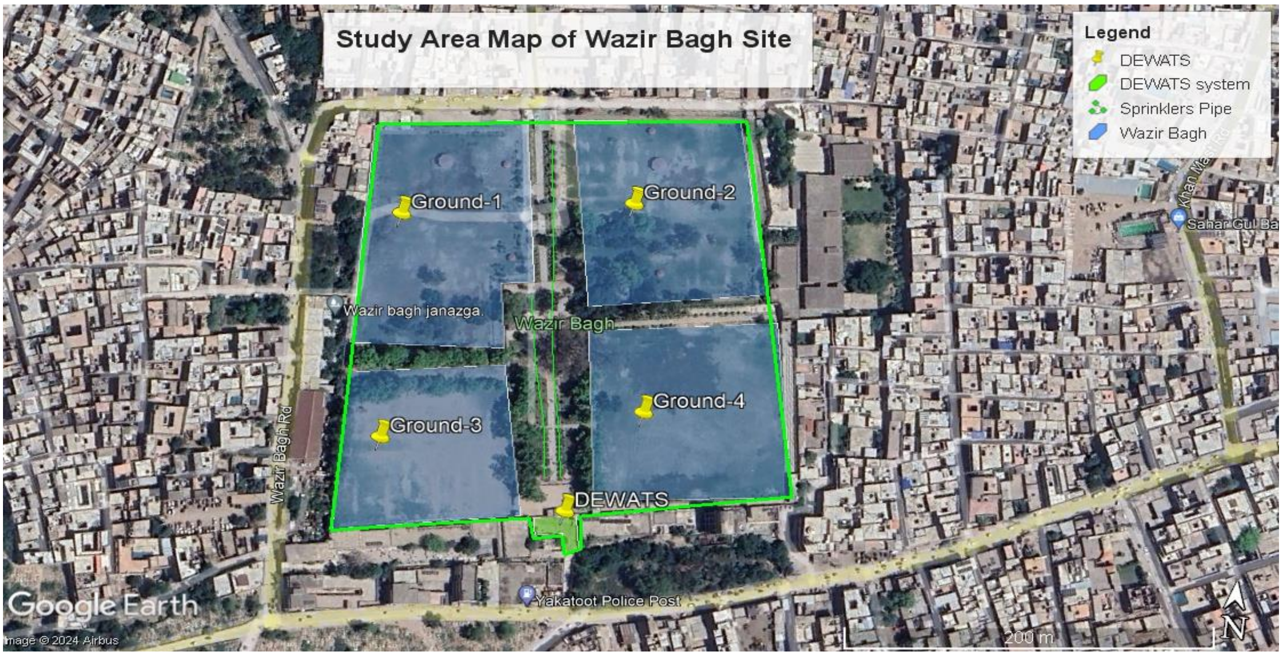
Description of Intervention

Study Area

The study area for the DEWATS System is at Wazir Bagh, located in Peshawar city, the capital of Khyber Pakhtunkhwa (KPK) province in Pakistan. The study site is situated at coordinates 33°59'42.64"N and 71°34'29.31"E, with an elevation of 344 meters above mean sea level (MSL). A DEWATS was installed at the south-end of Wazir Bagh, making it the key focus of the study.

Figure 2 provides a satellite image of Wazir Bagh, highlighting the area where the treatment plant was constructed.

Figure 2. Study Area Map



Components of Wazir Bagh DEWATS

The DEWATS system installed in Peshawar consists of several key components, each playing a critical role in the overall treatment process. Figure 3 shows a schematic representatation of the different treatment steps of the DEWATS system.

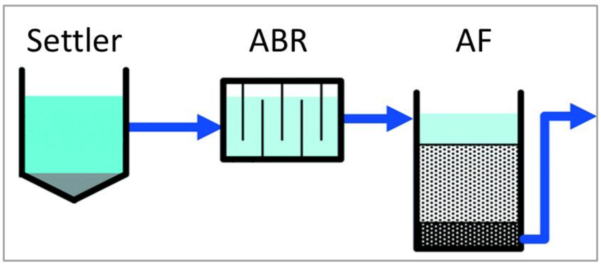


Figure 3: Schematic representation of the treatment process in the DEWATS system

Settler tank :

The Settler Tank is the initial treatment stage, where raw wastewater enters the system. The primary function of this tank is to allow for the settling of heavy solids (sludge) to the bottom, thereby reducing the organic load on subsequent treatment stages. It is designed to maximize the retention time, allowing for effective sedimentation. The settled sludge is periodically removed and can be further treated or used as fertilizer. It achieves an average reduction of 42% in Biochemical Oxygen Demand (BOD) and 40% in Chemical Oxygen Demand (COD), providing a crucial first step in the treatment process.

Anaerobic Baffled Reactor (ABR):

The baffled reactor consists of a series of chambers in which the wastewater flows upstream. Suspended and dissolved solids in the pre-settled wastewater undergo anaerobic degradation by bringing them into close contact with a surplus of active microbial mass. “Hungry” micro-organisms digest the dispersed or dissolved organic matter within a short retention time. The sludge settles down at the bottom of each chamber and the influent wastewater is forced to flow through this sludge blanket. Progressive decomposition occurs in the successive chambers.

The compartmentalized design allows for a sequential treatment process, with each compartment serving as a separate anaerobic reactor. This configuration increases the contact time between the wastewater and the anaerobic bacteria, leading to more efficient breakdown of organic material. The ABR achieves a further reduction of 50% in BOD and 48% in COD, significantly improving the quality of the wastewater before it enters the final treatment stage.

Anaerobic Filter (AF):

The anaerobic filter, also known as fixed-bed or fixed-film reactor, includes the treatment of non-settleable and dissolved solids. Most of the anaerobic micro-organisms in this treatment step are immobile; they attach themselves to the gravel particles which are used as a filter material in this reactor. This surface area allows the micro-organisms to create a biofilm, which enhances degradation of more recalcitrant contaminants by forcing the fresh wastewater to flow through this biofilm, intensive contact with active micro-organisms is established.

The filter is designed to operate under low-flow conditions, ensuring that the wastewater passes slowly through the gravel media, allowing for maximum contact with the biofilms. The design

KEY POINTS

- ***The DEWATS system processes 48 m3/day of wastewater.***
- ***Settler tank, ABR, and Anaerobic filter each seperately achieve more than 40% reduction in BOD and COD (Table 1).***
- ***The DEWATS system reduces BOD by 76% and COD by 82%, bringing both parameters within the acceptable NEQs (Table 2).***
- ***A total of 72 samples were tested for BOD and COD from both influent and effluent.***

also includes provisions for easy cleaning and maintenance of the filter media.

Design Components:

The DEWATS in Wazir Bagh is designed according to BORDA guidelines, featuring a combination of components including a settler, Anaerobic Baffled Reactor (ABR), and Anaerobic Filter (AF). The system is designed to process 48 m^3/day, serving 75 households, each with an average of 7 persons, resulting in a total population of 525. The design is based on a water consumption rate of 110 liters per capita per day (lpcd). Additionally, vents have been installed to emit the biogas generated by the DEWATS, ensuring safe and efficient operation. Table 1 provides detailed input parameters used to design the components of the DEWATS, tailored to meet the specific needs of the community.

Table 1. Designed efficiency of each component of DEWATS.

Treatment Component	BOD (mg/l)		COD (mg/l)		Efficiency %BOD/COD
	In	Out	In	Out	
Settler Tank (4.0 x 2.0 x 2.5m)	300	173	600	360	42/40
ABR (4 No 8.0 x 1.0 x 2.5m)	173	85	360	188	50/48
Anaerobic Filter (2 No 8.0 x 2.5 x 2.5)	85	37	188	87	56/54
Total	300	37	600	87	88/86

Efficiency Evaluation and Monitoring

Sample Collection

In order to evaluate the efficiency and monitor the system's performance, a total of 72 samples were collected from both the influent and effluent. The sample collection and transportation was carried out in accordance with the guidelines provided by the American Public Health Association (APHA). Over the course of a year, variations in temperature and pH were noted and its impact on the efficiency of the system was tested. Pictures of the sample collection are shown in Figure 4.

Figure 4. Sample Collection

Sample Testing

Laboratory testing was conducted at the National Institute of Urban Infrastructure Planning (NIUIP) Lab, where key parameters such as Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), pH, temperature, and Total Suspended Solids (TSS) were measured for both the influent and effluent, following APHA standards. These tests provided critical data to assess the performance and effectiveness of the DEWATS system. Figure 5 shows pictures of the lab testing.

Results

The results have been analyzed for Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, temperature, and Total Suspended Solids (TSS) for both the influent and effluent samples. Table 2 presents a detailed summary of these results, including the average values for each parameter. The effluent results were then compared with the permissible limits set by the National Environmental Quality Standards (NEQs).

Figure 5. Sample Testing

The DEWATS system demonstrated impressive efficiency, achieving a 76% reduction in Biochemical Oxygen Demand (BOD) and an 82% reduction in Chemical Oxygen Demand (COD), effectively bringing both within the acceptable limits set by the National Environmental Quality Standards (NEQs). The system reduced the BOD from an average of 103 mg/L in the untreated water to just 24 mg/L in the treated effluent, comfortably meeting the required standards. Similarly, the COD dropped from 460 mg/L to 72 mg/L, showcasing the system's capability in removing chemical pollutants.

When it comes to Total Suspended Solids (TSS), the system achieved a 67% reduction, lowering TSS levels from 682 mg/L in the influent to 197 mg/L in the effluent, which is within the permissible NEQ range. The treatment process also maintained the water's pH levels within a neutral range, with a slight shift from 7.4 in the influent to 7.8 in the effluent. Additionally, the water temperature saw a minimal increase from 18.5°C to 21°C post-treatment, staying within the recommended range.

Based on this comparison, it was determined that the treated water meets the necessary criteria for safe use in gardening purposes. This indicates that the DEWATS system is effectively reducing pollutants to levels within the acceptable range for safe use in irrigation.

Table 2. Measured removal efficiencies compared to NEQs

Key Parameters	In (Avg)	Out (Avg)	Efficiency (%)	NEQs
BOD (mg/l)	103	24	76	80
COD (mg/l)	460	72	82	150
TSS (mg/l)	682	197	67	200
pH	7.4	7.8	-	6.5-7.5
Temperature (˚C)	18.5	21	-	20-25

Outcomes

The DEWATS project in Peshawar has delivered several tangible outcomes described below, that underscore the value of decentralized wastewater treatment solutions:

Environmental Impact

The system has successfully reduced the environmental footprint of wastewater discharge in the local area. By treating the wastewater and reusing it as green space irrigation water, the project has lowered the pollution load released in local rivers and canals, preventing contamination, and highlighting the system's potential to improve the overall water quality in the region. Furthermore, it decreased the amount of groundwater extracted from the underground aquifers, ensuring that the potable water remains available for drinking purposes.

Sustainability

The reliable availability of treated effluent has revitalized Wazirbagh park, ensuring its sustainability as a green space for the local community. The park now receives a consistent supply of water, which has enabled the restoration of its lawns, trees, and flower beds, enhancing the quality of life for residents.

Reduction in WSSP's Operational Costs

Prior to the project, WSSP operated two deep boreholes at this site to provide irrigation water for the park's green spaces and vegetation, resulting in significant monthly operational costs. With the availability of treated water from the DEWATS system, these expenses have been considerably reduced. This cost-saving measure has also allowed WSSP to repurpose the onsite tube wells for the urban water supply, contributing to the availability of additional drinking water.

Community Awareness and Engagement

The project has also served as a platform for raising community awareness about the importance of wastewater treatment and water conservation. Local residents and park visitors used to rely on the clean groundwater from the previously used tube wells for drinking and abolution purposes. It was with the help of social mobilizers that the locals have been engaged and educated on the different quality of the DEWATS effluent and its appropriate uses. It was through these actions that the need for a clean water source at the park becoame apparent, which resulted in the rehabilitation of the non-functional tube wells besides the DEWATS system.

Potential for Replication

The success of the DEWATS project in Peshawar has generated interest in replicating similar systems in other urban areas of Pakistan. The project has demonstrated that decentralized wastewater treatment is a viable and scalable solution, particularly in regions where centralized infrastructure is lacking or non-functional.

Lessons Learned

One of the key learnings from operating the DEWATS system is the need for routine and preventive maintenance, particularly in managing the solar-powered pump. Since the system relies on solar energy, it is essential to switch off the pump when there is insufficient sunlight to prevent unnecessary wear and tear or potential damage. Properly managing the operation of the pump ensures that the system functions efficiently and prolongs the lifespan of the equipment. The pump has been damaged a couple of times due to mismanagement.

Most importantly, in a country that faces the challenge of coordination among multiple entities working in wastewater management, it may be wise to foster good communication and collaboration when responsibilities are split among different organizations. In the case of Wazirbagh DEWATS system, even after the completion of the project, efforts were made to put the two organizations TMA and WSSP on same page and take ownership of the system.

Another important aspect is that the Wazirbagh park had two tube wells that were not functional at the time of the project proposal. Thanks to the social mobilizers who ensured participation and feedback from the community, it became apparent that these tube wells were needed to be made functional, as otherwise the potentially contaminated treated wastewater would be used for drinking water purposes. By listening to the needs of the local communities, who were used to accessing clean groundwater for drinking and domestic purposes at the park, a situation was prevented where people consumed water not-fit-for-purpose.

With the successful implementation of the DEWATS system, it now stands as a flagship project, showcasing the need for robust, low-maintenance treatment solutions in order to secure safely managed sanitation in Pakistan and to reach SDG goal 6.3.

Way forward

As a next step, the government of Pakistan administered Kashmir has taken up a feasibility study of the system for Muzafarabad city and they are planning for the construction in the coming period. Other provinces are also exploring options of installing this succesfull intervention. UNICEF is staying involved and drafting a strategy for upscaling the impact of this technology.

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