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Realizing integrated wastewater/greywater management in Jordanian public schools

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Abstract: *This article highlights a case study in enabling Jordanian schools to become active agents of adaptation against water scarcity. It aims to demonstrate integrated water resources management at schools with adequate functional sustainability. This case study seeks to answer the question, are Jordanian public schools able to functionally sustain improved water and sanitation? The methodology consists of a twofold process: 1) adapting locally built, innovative, and functionally sustainable technologies; and 2) ensuring local development and local management. It finds that greywater/wastewater treatment, alongside improved reuse facilities and services, can be sustained and functional as long as it achieves effective school water demand, is powered with renewable energy, and is accompanied by a clear coordination, operation, and maintenance framework. Such intervention can reduce freshwater use and energy costs to approximately 30 per cent and 90 per cent respectively.*

Keywords: water and sanitation, water treatment, functional sustainability, schools, Jordan

Introduction

Water scarcity in Jordan

As one of the driest countries in the world, water scarcity affects every aspect of Jordanian life, impeding economic growth and development. Climate change exacerbates existing water problems by reducing water availability and depleting aquifers, according to the Jordanian Ministry of Water and Irrigation (MWI) (2016b). In Jordan, the per capita availability of annual renewable water resources is less than 100 m^3, which is below the absolute water scarcity level of 500 m^3 (MWI, 2017). The MWI plans and operates water networks to deliver 120 litres per capita per day in cities (about 83 per cent of the population), and 80 litres per capita per day in rural areas. Because the distribution focuses on densely populated areas, rural areas only receive water once every 12 days (MWI, 2016b). Therefore, rural reuse of alternative water resources, such as treated wastewater/greywater, is crucial for lowering demands on freshwater resources.

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WASH in Jordanian schools

Jordan is a middle-income country characterized by a strong presence of government schools nationwide (Ministry of Education (MoE) et al., 2016). However, only one in three schools has adequate health services (WHO/UNICEF, 2018), among which, 38 per cent are classified as having severe deficiencies affecting water, sanitation, and hygiene (WASH) conditions due to the influx of Syrian refugees, which brought 130,000 additional students to public schools. The northern governorate of Mafraq has one of the largest numbers of schools in need of reform, with a reported 300 schools (UNICEF, 2020a). This fact, combined with Jordan's high levels of water scarcity, poses a major concern. The WHO/UNICEF (2018) report showed that 10 per cent of Jordanian schools rely on water tankers, either as a primary source of drinking water or to supplement public supply.

Decentralized wastewater management and greywater treatment systems in Jordan

Capitalizing on the Jordanian National Water Strategy 2016–2025, decentralized wastewater management (DWWM) is a valuable technology to explore in order to contribute to water resources. A recent report (UNICEF and WHO, 2019) highlighted that only 77 per cent of the Jordanian population has access to safely managed wastewater services (MWI, 2016b). As defined in the Jordanian DWWM policy, a decentralized wastewater treatment plant (DWWTP) has a design capacity of less than 5,000 population equivalents or a daily hydraulic capacity of less than 500 m^3. For DWWTPs, there are several different techniques available that can suit the local context in terms of quality, safety, cost-effectiveness, and operation and maintenance (O&M). DWWM can allow freshwater savings of up to 64 million cubic metres per year, protect groundwater, and improve the living conditions of communities that cannot be served by central systems due to technical and financial constraints (MWI, 2016a). By 2019, 85 DWWTPs have been implemented in various contexts including hotels, tourism sites, factories, households, and public/private institutions. These DWWTPs contribute 4 per cent treated wastewater to the annual water budget in Jordan (Breulmann et al., 2019). DWWTPs can be increased by targeting a wider scope of institutions, particularly public schools.

Functional sustainability of water and sanitation

There is a growing need to move from focusing solely on rapidly expanding water and sanitation infrastructure to also focusing on attaining long-term enhanced O&M. Carter et al. (1999) defined a function-oriented sustainability for water and sanitation as 'constancy in water supply and sanitation services – which may be achieved through evolving and adaptive delivery mechanisms'. Montgomery et al. (2009) identified the three key components of water and sanitation sustainability in the rural context: 1) effective community demand; 2) local funding and cost recovery; and 3) dynamic O&M. The importance of dynamic O&M has been mainly disregarded by implementers. Montgomery et al. further identified the enabling factors of each of the three components. For dynamic O&M, the enabling factors are clear management responsibilities, accessible spare parts/technical expertise, monitoring and evaluation (M&E), and ongoing outreach and support.

Combining water treatment and reuse with the enabling factors for functional sustainability in Jordanian schools can help maximize freshwater use efficiencies, while enabling a healthy learning environment. This article presents a case study of successful implementation of decentralized wastewater/greywater treatment and reuse at a compound of rural public schools located in the town of Rihab, Mafraq Governorate, North Jordan, integrating community-choice technologies, cost recovery, and adaptive O&M.

Methods

Adherence to ethical standards and procedures

This case study was accomplished in adherence to all standards and ethical procedures of UNICEF according to the programme document signed between UNICEF and Methods for Irrigation and Agriculture (MIRRA). One of the most important procedures was respecting the privacy, customs, and traditions of the involved communities through ongoing participatory planning.

Study area

Rihab is a small town characterized by depleting water resources and accelerated population growth due to the refugee influx since 2012. The population is 23,874 (Department of Statistics, 2019). The area is characterized by underground drainage systems with sinkholes that allow quick and deep percolation of runoff and pollutants, increasing the likelihood of groundwater contamination. The town has wide agricultural activities and relies on cesspits for wastewater disposal (MWI and BGR, 2019). Hence, the area has an effective community demand for improved water and sanitation. The case study targeted a compound of a girls' secondary vocational school, two elementary schools for boys, a mosque, and a public park (Figure 1) which together have around 6,000 m^2 of agricultural land, over 700 students, and 100 teachers. Jordan has 23 agricultural vocational high schools, one of which is the subject of this study (French Agency for Development, 2019).

Methodology for water and sanitation

The case study methodology relied on a two-fold approach: 1) adapting locally built, innovative, and functionally sustainable technologies; and 2) ensuring local development and management.

Adapting locally built, innovative, and functionally sustainable technologies. Water and sanitation systems were designed and implemented in such a way that all spare parts and technical maintenance are available locally at acceptable prices.

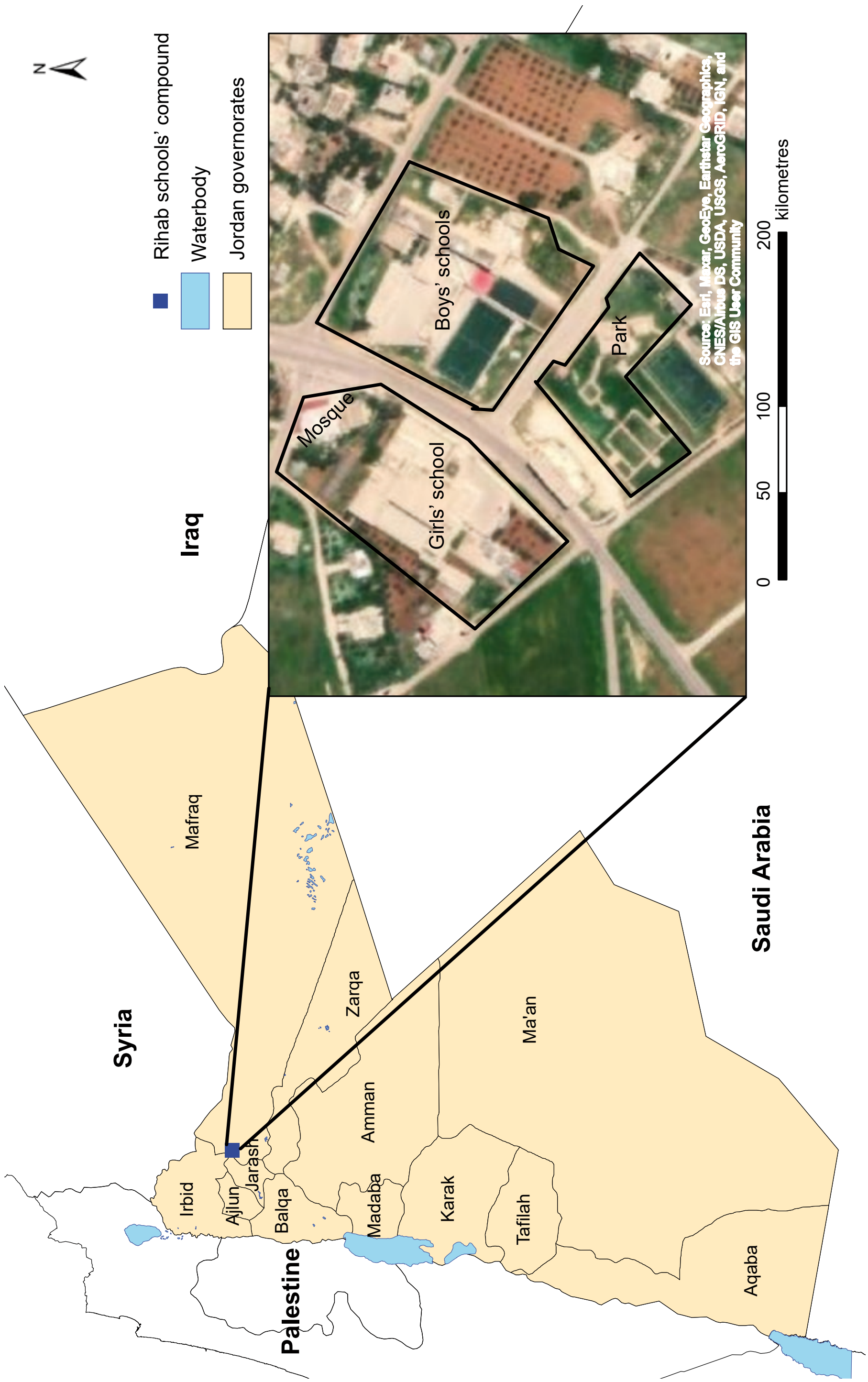

Figure 1 The case study schools' compound, Rihab, Mafraq, Jordan
Source: Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

The implemented greywater treatment system is based on trickling filter technology as shown in Figure 2. The treated greywater is then disinfected and reused for toilet flushing. A back-up water system was installed in case the treated greywater is not enough, which comprises a freshwater storage tank and pump. An automatic control panel operates and controls all of the pumps and air blowers. The cistern flushing toilet basins were renovated to use 3 to 4 litres of water per flush, compared to 10 to 20 litres previously.

A modified septic tank (MST) approach was used to treat wastewater according to the working diagram in Figure 3. The MST is a simple biological treatment process consisting of a dual anaerobic/aerobic biological reactor, and powered by a small air pump. The MST's main features are its compact design, odourless treated water, low investment cost, minimum power consumption, low sludge production, minimal O&M, and intermittent-flow tolerance. The O&M needs include refilling the chlorine once a year, draining the sludge once every three years, and spraying insecticide at the inflow tank openings when water sampling. The average annual recurring O&M costs are less than US$70, for chlorine and desludging primarily, which are paid from the school's own budget. Two MST DWWTPs were installed underground, one for the girls' school and the mosque, and one for the boys' schools. The treated wastewater is used to irrigate stone fruit, olive, forage, and ornamental trees.

Commercially available photovoltaic (PV) solar systems were installed on the rooftops of schools. A PV system consists of solar panels, an inverter, and other electrical and mechanical components that generate electricity (Foster et al., 2009). The solar systems cover all the schools' compound energy needs. The only operation needed is operating the automatic wet cleaning system for panels once every two months for one hour. The wet cleaning system consists of a water tank, a network of plastic pipes extended around the panels, and a mobile washing pump.

Local development and management

In order to contribute to adequate management and development of water and sanitation in schools, the project aimed for the locals to gain greater control and influence over the interventions. The main tools used were:

Inclusive participatory planning. The idea, methods, and technology choice have been articulated after focus group discussions with up to 10 local citizens per discussion. Altogether, we developed and marketed social acceptance of the interventions, and common interests were identified.

Establishing means of efficient coordination. Higher-level linkages and coordination were formed with the MoE to officially approve and facilitate the implementation, handover, and management framework. As a consequence, the MoE committed to taking custody of and sustaining the systems.

Local ownership and coalition-based work. A workgroup of school teachers, education directorate officials, MoE staff, the local municipality, and local citizens council was established in order to implement, manage, and sustain the interventions.

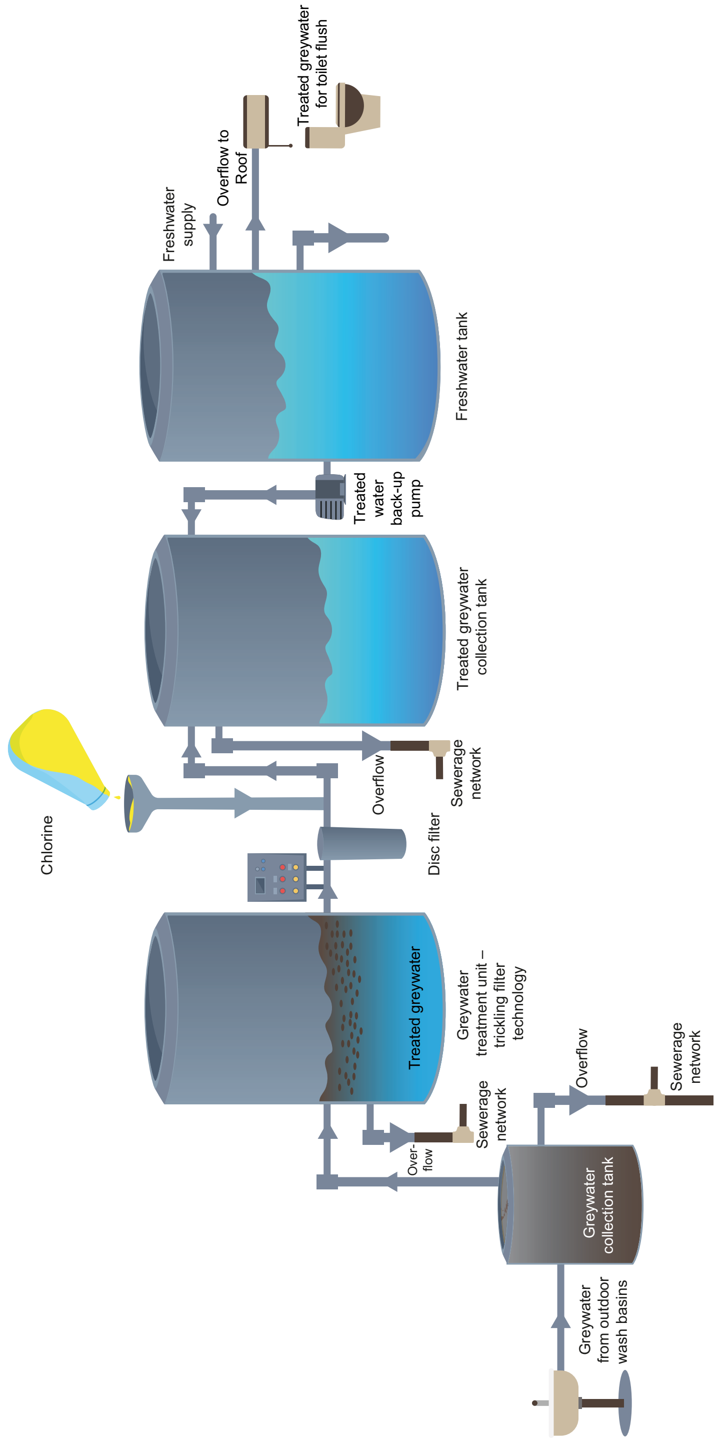

Figure 2 Working diagram of the greywater treatment applied at the schools

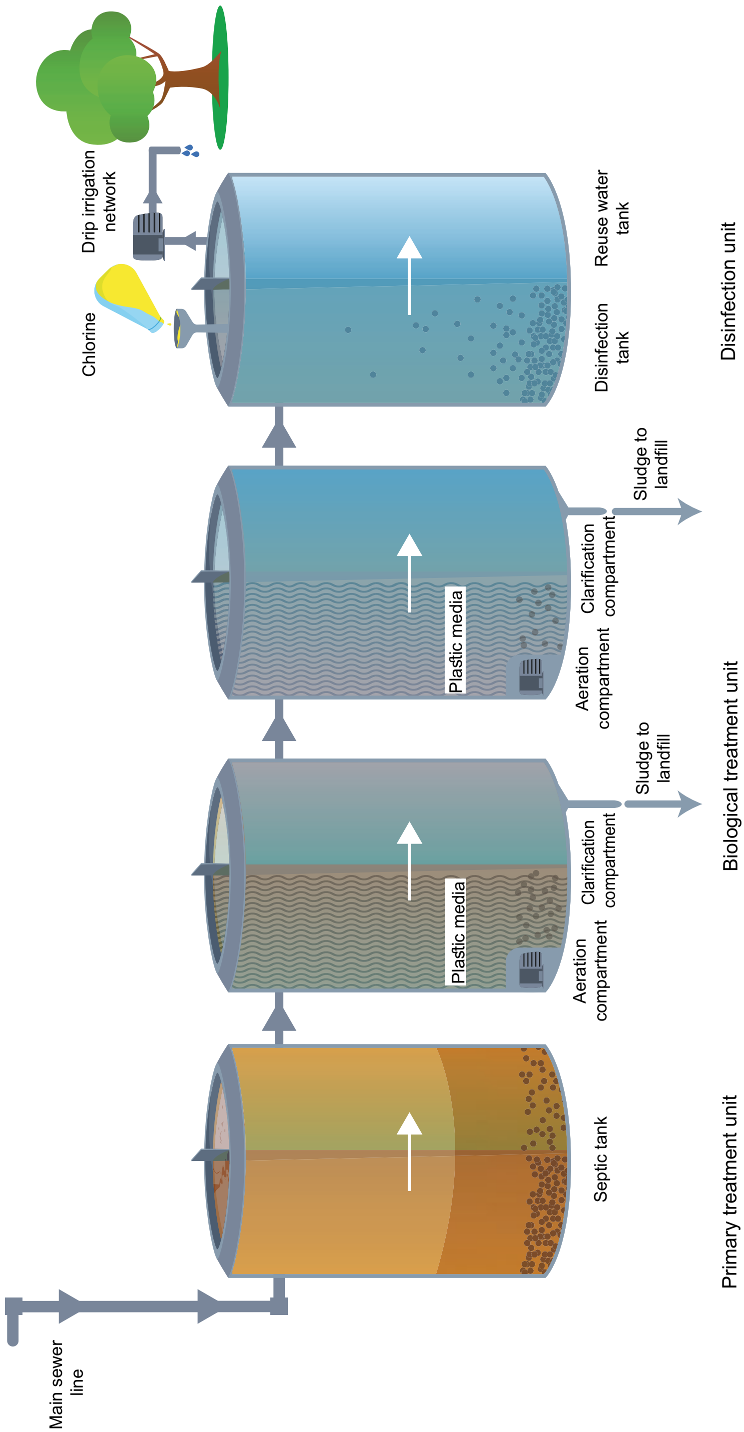

Figure 3 Working diagram of the MST DWWTP applied at the schools

Figure 4 Systems and O&M training applied at the schools

The workgroup ensured a proper phase-out period of one year, involving knowledge transfer, building capacities, assigning responsibilities, and jointly preparing user manuals.

Feedback and complaint mechanism. All beneficiaries had the right to hold the providers and donor accountable through a designated Complaints Response Mechanism (CRM) in a secure and confidential way. The beneficiaries have been trained on the CRM to get a response in a timely manner.

Monitoring and evaluation

The treatment and reuse systems were monitored in terms of quantity, quality, and efficiency in accordance with the Jordanian standards JS893, 2006, for wastewater reuse and JS 1776, 2013 for greywater reuse (JSMO, 2006, 2013). Influent and effluent quantities were tracked through automated sensors and control panels that are installed permanently. Samples were collected from the influent and effluent using a grab sampling method. The monitoring was carried out in three stages, the first two stages aimed at understanding the existing conditions in terms of certain water-quality parameters. The third stage assessed the treatment system under varying flow conditions including consecutive working days and weekends.

The following quality parameters were investigated: 1) chemical oxygen demand (COD) and/or biochemical oxygen demand (BOD), which are indicative measures of the amount of oxygen that can be taken up by reactions of bacteria, used to readily measure the amount of organic matter; 2) total suspended solids (TSS), which is the dry weight of suspended particles that do not dissolve in water; 3) turbidity, which is a measure of the loss of water transparency due to suspended particles, expressed in nephelometric turbidity unit (NTU); 4) nitrate (NO_3–N), ammonium (NH_4–N), and total nitrogen (TN), which indicate the nitrogen presence that can cause algae blooms, as excessive algae growth can cause clogging and reduce dissolved oxygen, resulting in treatment failure (Metcalf & Eddy, 2014).

Results

Improved water and sanitation

The initiative ran from June 2018 to December 2020, of which 6 months were for planning, 12 months for implementation, and 12 months for phase-out and M&E. It integrated technologies that successfully allowed students to gain access to adequate water and sanitation services and enhanced integrated water resources management (MIRRA, 2021). The technologies have allowed high volumes of freshwater savings. The greywater treatment system alone saves over 2 m^3 per week while the two DWWTPs save, on average, 4 m^3 per day. Aggregated freshwater savings account for almost 1,000 m^3 per year.

The results in Tables 1 and 2 show that the tested water quality parameters are within the Jordanian standards, excluding the TN and TSS on some occasions, due to insufficient dissolved oxygen. Such deviation from standards was eliminated by informing the local operators to increase the air blower's operation.

Table 1 Water quality results for the greywater treatment systems

Parameter	*Unit*	*Test results before treatment*	*Test results after treatment*	*Test method*	*Jordanian standards for greywater reuse NO.JS1776.2013*	*Matching the standards*
			Rihab Elementary Schools for Boys			
COD	mg/l	33	10	Photometric cell	≤20	✔
TSS	mg/l	10	≤10	2 μm filtration dried @103–105°C	≤10	✔
Turbidity	NTU	4.47	0.00	Turbidity meter	≤5	✔
			Rihab Secondary School for Girls			
COD	mg/l	120	20	Photometric cell	≤20	✔
TSS	mg/l	40	20	2 μm filtration dried @103–105°C	≤10	✘
Turbidity	NTU	22	0.00	Turbidity meter	≤5	✔

Table 2 Water quality test results for the DWWT systems at the schools

Parameter	*Unit*	*Test results before treatment*	*Test results after treatment*	*Test method*	*Jordanian standards for wastewater reuse NO.JS893.2006*	*Matching the standards*
			Rihab Elementary School for Boys			
COD	mg/l	1,314	13	Photometric cell	100	✔
TSS	mg/l	150	<10	2 µm filtration dried @103–105°C	50	✔
NO_3–N	mg/l	>25	>25	Photometric cell	30	✔
NH_4–N	mg/l	80	2.1	Photometric cell	–	✔
TN	mg/l	185	104	Photometric cell	45	✘
			Rihab Secondary School for Girls			
COD	mg/l	176	<10	Photometric cell	100	✔
TSS	mg/l	30	<10	2 µm filtration dried @103–105°C	50	✔
NO_3–N	mg/l	6.4	7.1	Photometric cell	30	✔
NH_4–N	mg/l	14.1	0.3	Photometric cell	–	✔
TN	mg/l	29	10	Photometric cell	45	✔

The parameters numerical measures for influent and effluent testing results were calculated, as seen in Table 3. The results are exhibited in Figure 5 in relation to the maximum allowable limits of Jordanian Standards.

An economically sustainable case

The combination of energy and water cost savings contributes to cost recovery and economic sustainability on-site. A cost-benefit analysis was conducted by mobilizing data on investment costs and comparing current and previous water and energy costs in order to deduce the accounting benefits. The investment costs are grouped in Table 4. Regular O&M costs, less than $100 per year, have not been considered as they are insignificant. The costs saved per year for water and energy are $70 and $15,000, respectively. Applying the payback period (PBP) formula, PBP = initial cost of investment/annual savings made/cash inflows, indicated that the cost-benefit analysis becomes positive after 10 years.

Table 3 Statistical measures of water quality testing results for DWWT of the third stage

Parameter, i (influent) and e (effluent)	*Mean (X), mg/l*	*Standard deviation (S), mg/l*	*Coefficient of variation (C.V), mg/l*
BOD_i	25.4	18.2	0.64
COD_i	79.3	48.8	0.62
TN_i	35.8	14.8	0.41
$\frac{BOD_i}{COD_i}$	0.42	0.19	0.46
BOD_e	7.1	3.8	0.53
COD_e	20.2	7.4	0.36
TN_e	12.3	0.64	0.05

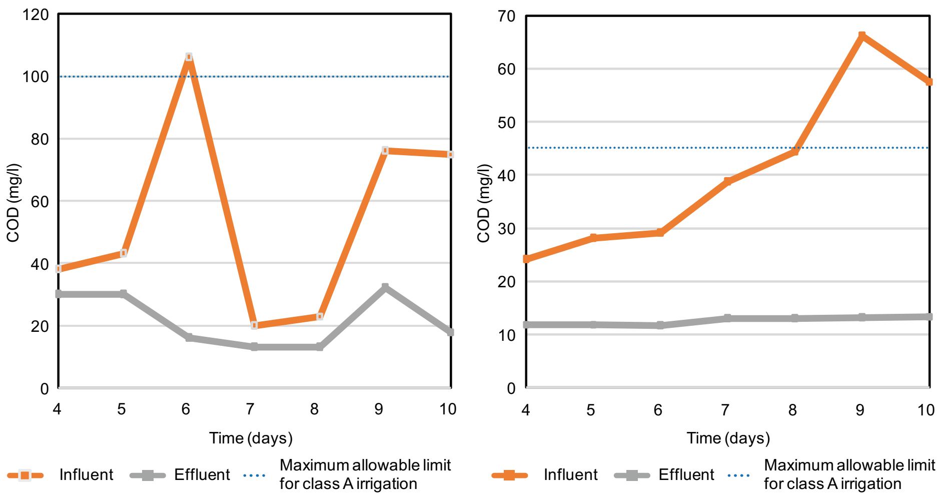

Figure 5 Examining the COD (left) and TN (right) results against the maximum allowable limits in JS 893/2006

Table 4 Investment costs of the interventions installed as part of this initiative

System type	*Cost ($)*
DWWTPs	83,330
Greywater systems	11,300
Solar system	32,486
Irrigation system	16,949
Total	144,068

The cost of investment is relatively high, relative to the Jordanian context. Given that this study is the first of its kind, the strictest measures have been taken to achieve a very safe design and implementation. However, this cost can be halved because it was discovered through the pilot that the quality of the raw grey and black water is not as bad as expected, so the system was over-designed. In such cases the cost recovery period could be shortened significantly.

Sustained local development and management

This case study did not bring something completely foreign to the community since many locals already practise greywater reuse in their homes as they direct greywater to irrigate the trees outside, sometimes treating it using a simple filter. We introduced a common concept that has been scaled-up to an institutional level and a broader framework, incorporating simple and modern water treatment and reuse technologies. The case study outcomes are consistent with the needs of the schools and host community as they practise agricultural activities with increasing water requirements and struggle with high electricity costs. Following intensive consultations, a management framework (Figure 6) was identified. Technical capacity needed for the schools' and MoE staff was documented and applied in terms of cleaning filters, operating the system using the control panels, and replacing chlorine and spare parts (pumps, air blowers, filters, and valves) that are available locally at an affordable price. Nonetheless, the key risk is that major maintenance will be needed due to unexpected sabotage or failure; in such case the MoE has to contract a specialized entity.

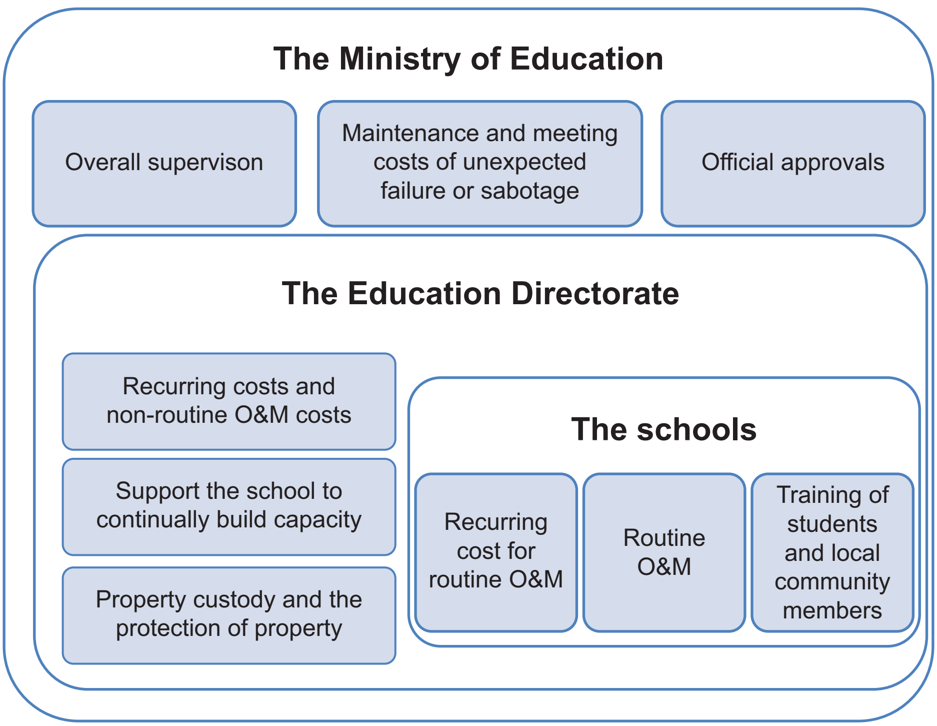

Figure 6 Management framework of the systems at the schools

DWWM in schools: analysis and lessons learned

DWWM in schools is still under investigation and this case study may be considered as one of the first serious experiences in Jordan. The analysis concludes that schools do have the characteristics needed to successfully run such systems, which in turn would prove to be of great educational and environmental value. Vocational schools are very capable due to the availability of budget, staff with the necessary capabilities, and an adequate level of awareness. Nevertheless, it is recommended to integrate protection against sabotage, for example placing systems on roofs, underground, or inside secure rooms. Simple monitoring by the schools is encouraged, for example by phone messages, water quality testing, and/or in-place data recording that can enhance O&M.

The top-down approach is optimal in Jordan, specifically for government schools, where the authorities must transfer their willingness and approval to implement a specific intervention. However, it is essential to encourage public institutions to present their desire for development projects. This increases the opportunities for successful and sustainable interventions.

It was demonstrated and understood that a successful initiative at schools is one that develops and expands what schools already practise. Schools that practise agriculture, vocational education, field work and so on welcome such interventions. Students can become the messengers of sustainable water management within their communities. Students transfer their knowledge and learned practices to their family members and apply it themselves, creating a positive impact on the water sector.

Nevertheless, some challenges remain. Legally, no framework organizes DWWM monitoring in institutions in Jordan. Due to the small scale of these systems, the monitoring is usually done by the providers, throughout the system's expected lifetime, but it is recommended that relevant authorities take part. On a technical level, the systems are managed by the buildings staff of the MoE in the capital city of Amman, which might lead to long shutdown until repair in case of sudden failure that needs specialized attention (Breulmann et al., 2019). Both these issues of sudden failure and external monitoring require a binding legal framework in Jordan.

Conclusion

This case study successfully implemented improved integrated wastewater/greywater management at three rural schools in Jordan. This was achieved through adapting community-choice, locally built, innovative, and functionally sustainable technologies. The implemented systems successfully contributed to saving water and energy. This demonstrates the success of schools as vectors of measures in the face of water scarcity in rural communities. Despite the remaining obstacles, which require further research and monitoring, this initiative adds a positive perspective regarding the Jordanian public schools' ability to functionally sustain improved water and sanitation.

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