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INTRODUCTION

One objective of the SMART I project was to select and install decentralised wastewater treatment technologies in controlled conditions in order to demonstrate their suitability to the Jordanian context.

Within the SMART II project, these technologies are monitored and their performance assessed in order to optimise them for implementation in real decentralised conditions.

The objective of this report is to analyse the performance of the eco-technologies installed at the Fuhais research and demonstration site. The performance of the systems is analysed in terms of compliance with the Jordanian standards for the reuse of treated wastewater (JS 893/2006). This report will emphasise how ecotechnologies can be used to provide an additional water resource for agricultural applications.

1 SITE DESCRIPTION

1.1 LAYOUT

Figure 1 shows the location of the two eco-technologies at the site. The raw wastewater is pumped out of the site collector and sent to the different technologies as required. The wastewater receives primary treatment in a septic tank before treatment by the eco-technologies. Treated effluent is then sent to an irrigation tank, where it is applied to agricultural fields at the site.

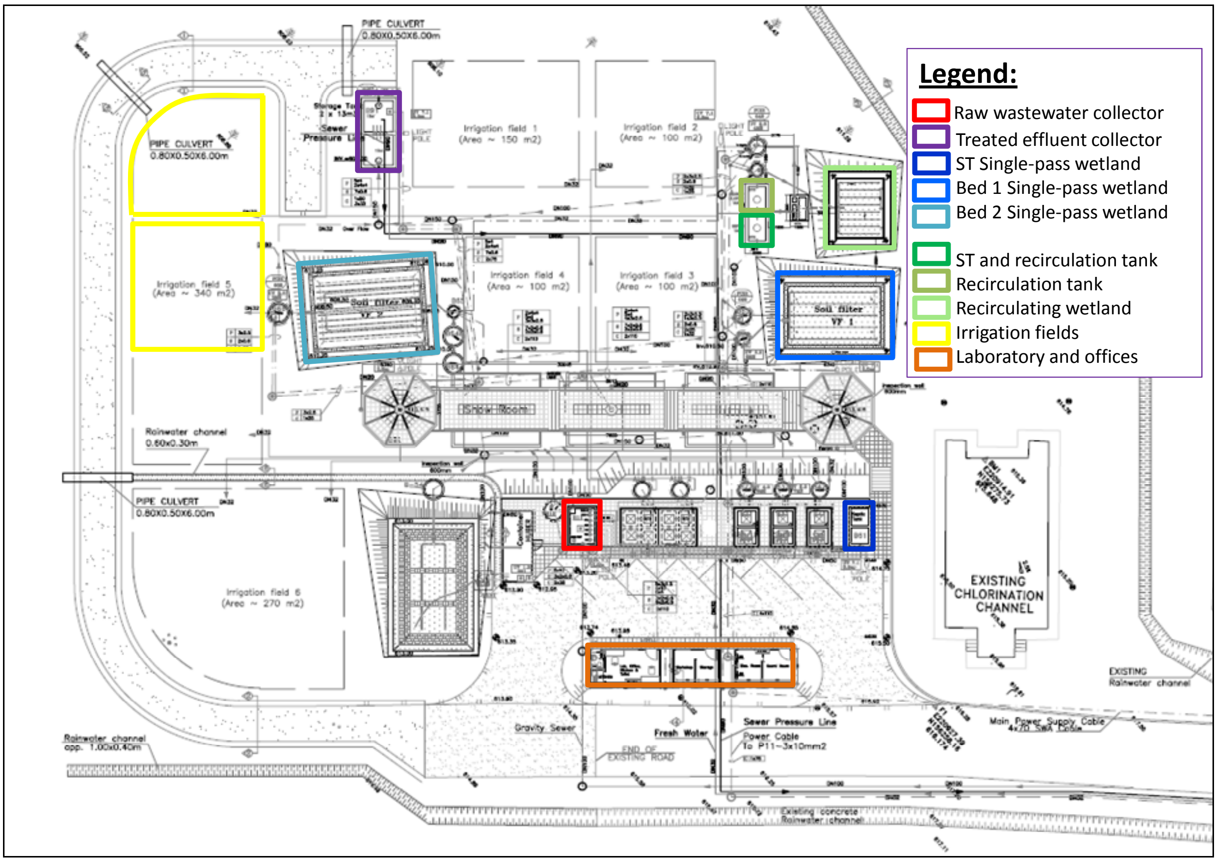

Figure 1: Site location of the two eco-technologies and other facilities.

As visible in Figure 1, the site is also equipped with its own lab and office facilities. The office facilities also include a control room from where the operational parameters of the treatment systems can be both controlled and modified.

1.2 RAW WASTEWATER AND TREATED EFFLUENT

Raw wastewater supply:

The site is supplied in raw wastewater by a transfer pipe connected to the collection tank of the municipal wastewater treatment plant of Fuhais. This allows the site to be supplied with actual wastewater. The collection chamber of the municipal wastewater treatment plant is located after a grit and screen chamber. This allows the wastewater to be free of sand/rocks and of big materials (plastics, branches, etc.) that could obstruct the pipes at the research site.

The collection chamber is fitted with floats that regulate the level of raw wastewater. When the low level is reached, a float triggers the pump that fills the chamber with raw wastewater. When the chamber is full, a high-level float stops the pumps. This gives access to as much raw wastewater as required.

Treated effluent disposal:

As the site is dedicated to research and demonstration of decentralised wastewater treatment technologies, it is not allowed to release treated effluent into the natural environment. If not used for irrigation, the treated effluent from all the technologies is collected in a pump sump and sent back to the municipal wastewater treatment plant of Fuhais for conventional treatment. The pump capacity has been sized to be able to accommodate all treated effluent produced at the site, in normal operational conditions as well as under higher hydraulic loads.

1.3 TECHNOLOGY DESCRIPTION

Eco-technology refers to treatment systems whose design is based on ecological principles. The fundamental aim of these technologies is to reproduce natural processes in order to minimize the use of additional energy, mechanical or chemical inputs. Eco-technologies are robust systems, provide good treatment performance, require only simple maintenance and have low operating costs. They can be designed to satisfy a wide range of effluent quality requirements (from domestic wastewater to landfill leachate and acid mine drainage). Hence, they are ideal for decentralized and remote applications.

For better comparison of treatment efficiency, two different types of vertical flow treatment wetlands were installed at the Fuhais test site (see Figure 2) by the Environmental and Biotechnology Centre (UBZ) of the UFZ. They are: 1) a multi-stage single-pass vertical flow treatment wetland and 2) a recirculating vertical flow treatment wetland.

Figure 2: Photo of the treatment wetlands installed at the Fuhais site.

1.3.1 TWO-STAGE SINGLE PASS VERTICAL FLOW TREATMENT WETLAND

The two-stage single-pass vertical flow wetland was designed to produce high quality effluent in a passive way (no electricity or pumps would be required on a sloped site). It is designed to treat 3,400 L/day (equivalent to about 42.5 Person Equivalents (PE) at a water consumption rate of 80 litres per person per day). The system consists of a septic tank for primary treatment, a vertical flow bed for secondary treatment and nitrification, an organic reactor for denitrification, and a second vertical flow filter for pathogen removal and further polishing. Between loading events, the filter media remains unsaturated and therefore promotes aerobic treatments such as organic matter decomposition and nitrification. Attached growth microorganisms compete against and attack pathogenic organisms. Physical filtering, absorption and adsorption treatment processes also occur. Figure 3 shows the schematic flow diagram of the two-stage single-pass vertical flow ecotechnology.

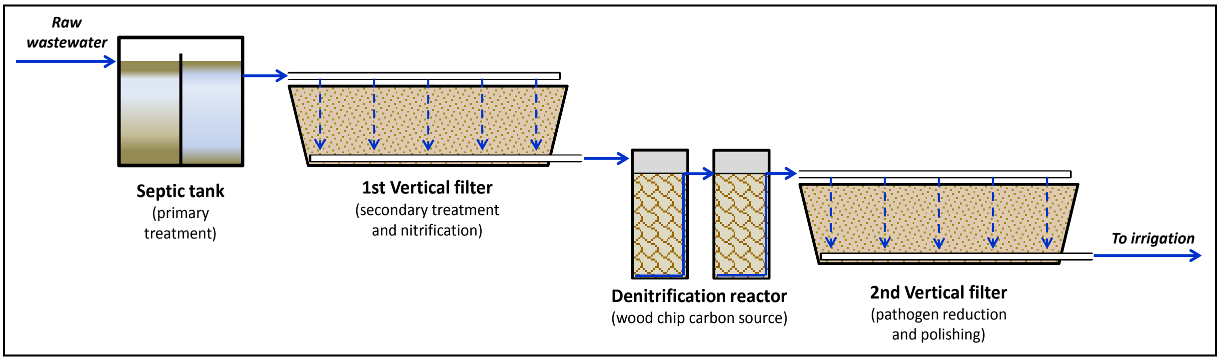

Figure 3: Flow diagram of the two-stage single pass treatment wetland.

Figure 4 shows a view of the single pass vertical flow wetland.

Figure 4: Photo of the single pass treatment wetland at the Fuhais site

The vertical filters consist in 0.8 to 1 m deep beds filled with 2-4 mm zeotuff gravel. 0.2 m of coarser materials are located at the bottom of the bed to facilitate the drainage of the effluent between loadings. The wastewater is loaded at the surface of the beds in small pulses. Wastewater trickles down until it reaches a series of drainage pipes that collect the effluent and send it to the next treatment step (denitrification tank or irrigation tank). The drainage pipes are connected to ventilation risers to enhance oxygen transfer at the bottom of the bed. At Fuhais, the second vertical bed has been planted while the first bed was left unplanted. A PLC system located inside the control room is used to regulate the loading frequency and the volume of each dose. A schematic profile of the second vertical filter is presented in Figure 5.

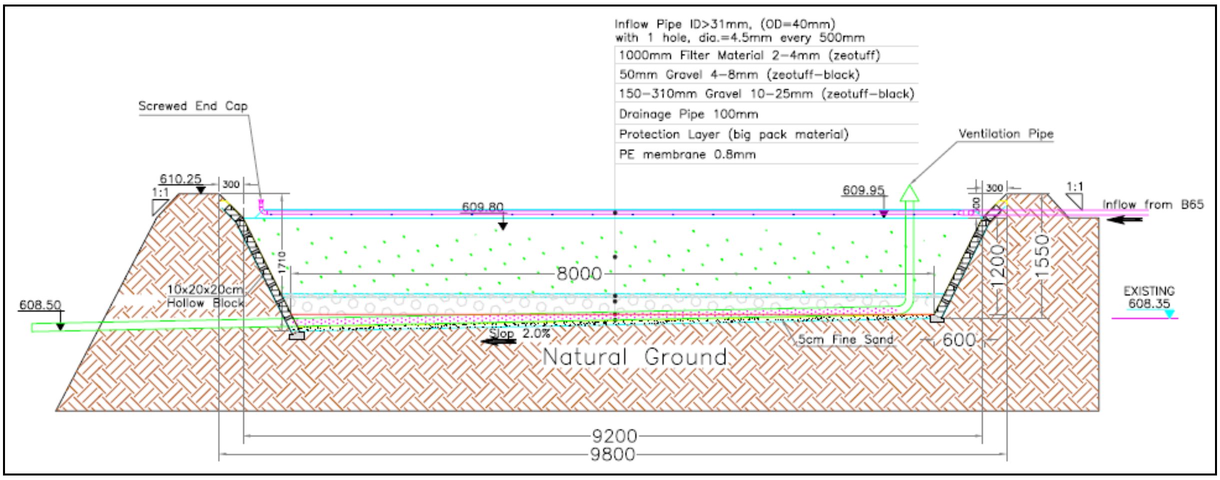

Figure 5: Profile of the unplanted bed of the single-pass ecotechnology system.

1.3.2 RECIRCULATING VERTICAL FLOW TREATMENT WETLAND

Recirculating vertical flow wetlands are intensified ecotechnologies designed to produce high quality effluent within a relatively small footprint. It consists of a septic tank for primary treatment followed by a recirculation tank for denitrification. The effluent is then pumped from the recirculation tank to the vertical flow bed for secondary treatment and nitrification. The bed is filled with 4-8 mm zeotuff gravel as filter media. As for the single-pass system, the wastewater is loaded at the surface of the bed in small pulses. The wastewater trickles down until it reaches a series of drainage pipes that collect the effluent and send it to a flow-splitting device from where a portion of the effluent is returned to the recirculation tank while the rest leaves the system and can be reused for irrigation. The system is designed to treat about 2,000 L/day (equivalent to about 25 PE (at 80 L/PE/d)). A PLC system located inside the control room is used to regulate the loading frequency and the volume of each dose. The flow diagram of the recirculating vertical filter system is shown in Figure 6.

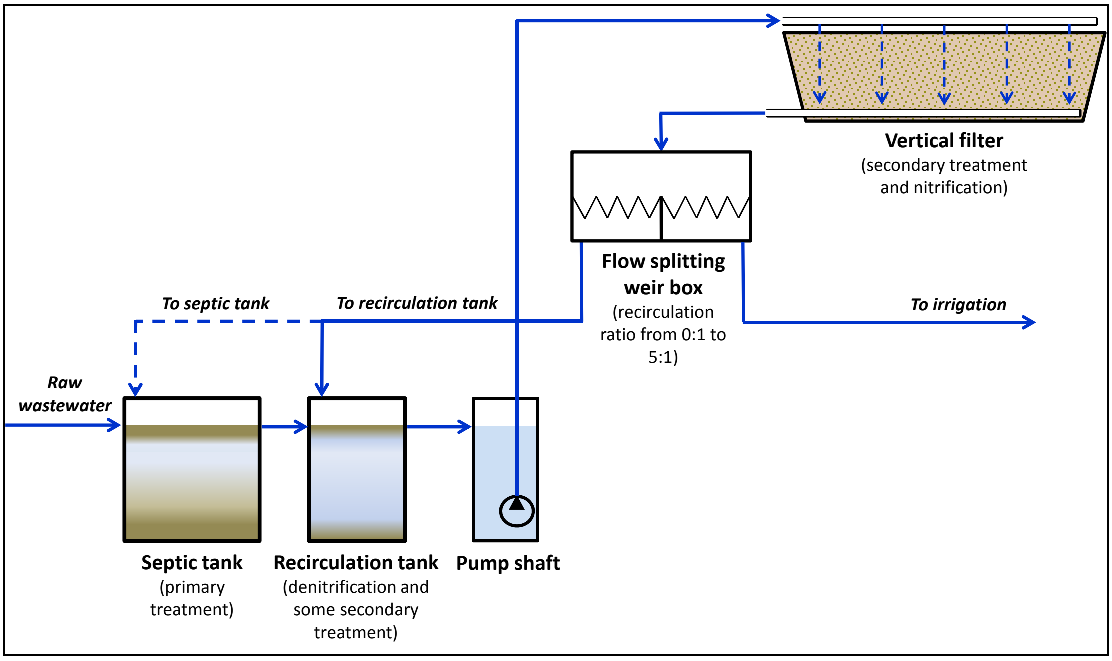

Figure 6: Flow diagram of the recirculating treatment wetland.

Between loading events, the filter media remains unsaturated and therefore promotes aerobic processes such as organic matter decomposition and nitrification (conversion of ammonium into nitrate). Attached growth microorganisms compete against and attack pathogenic organisms. Physical filtering, absorption and adsorption treatment processes also happen. A portion (50 – 85 %) of the effluent leaving the vertical flow bed is returned to the recirculation tank where it mixes with the septic tank effluent, which is anaerobic and rich in organic matter. This provides the required conditions for denitrification and subsequent removal of total nitrogen. Recirculation also improves performance stability by buffering peak flows and diluting shock loads of contaminants. Figure 7 shows the installed recirculating vertical filter and flow splitter weir box device at the Fuhais demonstration site in Jordan.

Figure 7: Photo of the recirculating treatment wetland at the Fuhais site.

2 MONITORING OF THE SYSTEMS

All the wastewater treatment technologies at Fuhais are monitored on the same baseline in order to allow for comparison of the system's performance. Another purpose of the monitoring is to assess the performance of the systems in regard to the Jordanian Standards for the reuse of treated wastewater (JS 893/2006). These standards are presented in the Table 1 below:

Table 1: Jordanian Standards for Irrigation water (JS 893/2006).

Allowable limits per end use		**Irrigation**			Groundwater recharge	Discharge to wadis, streams or water bodies
Parameter	Unit	Cooked Vegetables, Parks, Playgrounds and Sides of Roads within city limits	Fruit Trees, Sides of Roads outside city limits, and landscape	Field Crops, Industrial Crops and Forest Trees		
Class of water		**A**	**B**	**C**		
Biological Oxygen Demand	mg/L	30	200	300	15	60*
Chemical Oxygen Demand	mg/L	100	500	500	50	150**
Dissolved Oxygen	mg/L	>2	-	-	>2	>1
Total suspended solids	mg/L	50	150	150	50	60**
pH	unit	6-9	6-9	6-9	6 – 9	6-9
Turbidity	NTU	10	-	-	2	-
Nitrate	mg/L	30	45	45	30	45
Ammonium	mg/L	-	-	-	5.0	
Total Nitrogen	mg/l	45	70	70	45	70
Escherichia Coli	MPN or cfu/100 mL	100	1000	-	<2.2	1000
Intestinal Helminth Eggs	Egg/L	< or = 1	< or = 1	< or = 1	< or =1	< or =1
Fats Oils Grease	mg/L	-	-	-	8.0	8.0

* For biological WWTP or WWTP with polishing ponds BOD_5 is considered as the filtered BOD.
** For biological WWTP or WWTP with polishing ponds the allowable limit is twice this number.

2.1 PARAMETERS ANALYSED

As mentioned previously, one aim of the research and demonstration site at Fuhais is to compare the produced effluent with the Jordanian Standards for the reuse of treated wastewater. In this regard, the parameters cited in the standards are the focus of the study. These parameters include: COD, BOD_5, DO, TSS, turbidity, pH, TN, NO_3-N and *E. coli*. However, for research purposes, some other parameters are also monitored: field parameters (such as water temperature, redox potential and electrical conductivity), lab water temperature, NH_4-N and NO_2-N. Table 2 presents the different parameters and the analytical methods used.

Table 2: Parameters monitored at the Fuhais research and demonstration site.

	Parameter	Measuring unit	Method	Place of analysis
Field analysis	pH	SU	Probe	Fuhais
	Dissolved Oxygen	mg/L	Probe	Fuhais
	Field Water Temp.	°C	Probe	Fuhais
	Redox Potential	mV	Probe	Fuhais
	Electrical Conductivity	µS/cm	Probe	Fuhais
Lab analysis	Lab Water Temp.	°C	Probe	Fuhais
	COD	mg/L	Test kit	Fuhais
	BOD_5	mg/L	Winkler	BAU
	TSS	mg/L	Filter	BAU
	Turbidity	NTU	Turbidimeter	BAU
	TN	mg/L	Test kit	Fuhais
	NH_4-N	mg/L	Test kit	Fuhais
	NO_3-N	mg/L	Test kit	Fuhais
	NO_2-N	mg/L	Test kit	Fuhais
	E. coli.	MPN/100mL	IDEXX	BAU

Helminth Eggs are not part of the regular monitoring program due to the fact that the lab at the partner university (Al Balqa Applied University) is not equipped to carry out the analysis and that it is not possible to monitor this parameter at the onsite laboratory at Fuhais. Periodic monitoring for Helminth Eggs will be arranged through WAJ (Water Authority of Jordan) laboratories in autumn 2012.

It is unclear in the Jordanian Standards whether the BOD_5 refers to the $CBOD_5$ or to the BOD_5 ($CBOD_5$ + $NBOD_5$). Monitoring is thus currently done for BOD_5 but will be shifted to $CBOD_5$ in autumn 2012 when new analytical methods are implemented.

Additionally, it is unclear in the Jordanian Standards if NO_3 refers to NO_3 (as ion) or to NO_3-N (as nitrogen). Conventional practice is to report water quality data “as nitrogen”, therefore, the data in this report is also reported “as nitrogen” (NO_3-N).

TP and PO_4-P were monitored from 1/2011 – 1/2012. After the baseline performance for TP and PO_4-P were established, monitoring was ceased because phosphorus is not included in the Jordanian reuse standards. Moreover, the systems have not been designed to remove phosphorus. Starting in

2012, the focus of the laboratory analysis was shifted towards a better characterization of TN and *E. coli* removal, which are pertinent to the Jordanian Standards for Reuse of Treated Wastewater.

2.2 SAMPLING POINTS AND SCHEDULE

Due to manpower limitations, both at the Fuhais site for sampling and maintenance and in the labs from January 2011 – May 2012, the monitoring program has been organised to monitor each technology on a fortnightly basis.

However, due to the start of a PhD program on ecotechnologies at the site, in March 2012, monitoring of the two ecotechnologies was changed to a weekly basis. Table 3 gives the sampling labels according to their location and the details of the sampling schedule.

Table 3: Sampling labels and location.

Sample label	Technology	Location
RAW	n/a	Raw Wastewater
ECO1-A	Recirculating Filter	Septic Tank Out
ECO1-B	Recirculating Filter	Recirculation Tank / Filter Influent
ECO1-C	Recirculating Filter	Filter Effluent
ECO2-A	Two-Stage Filter	Septic Tank Out / Filter 1 Influent
ECO2-B	Two-Stage Filter	Filter 1 Effluent
ECO2-C	Two-Stage Filter	Denitrifying Tank Mid-Point
ECO2-D	Two-Stage Filter	Filter 2 Influent
ECO2-E	Two-Stage Filter	Filter 2 Effluent

3 ANALYSIS OF THE TREATMENT PERFORMANCE

This chapter presents the performance results between January 2011 and May 2012 for both ecotechnologies installed at Fuhais. The results are analysed to assess the interest of the ecotechnologies in the decentralised context in Jordan and to examine the compliance to the Jordanian Standards for treated wastewater reuse (JS 893/2006).

3.1 SINGLE-PASS VERTICAL FLOW TREATMENT WETLAND

The chart below (Figure 8) shows the performance of the single-pass vertical flow treatment wetland (ECO-2) compared to the raw wastewater influent and to the Class A and B of the Jordanian Standards for treated wastewater reuse (JS 893/2006). The data presented are mean values, with the exception of *E. coli*, which is presented as $\log_{10}$ geometric mean values. It should be noted that due to analytical issues, the *E. coli* data presented is only from the January 2012 – May 2012 period.

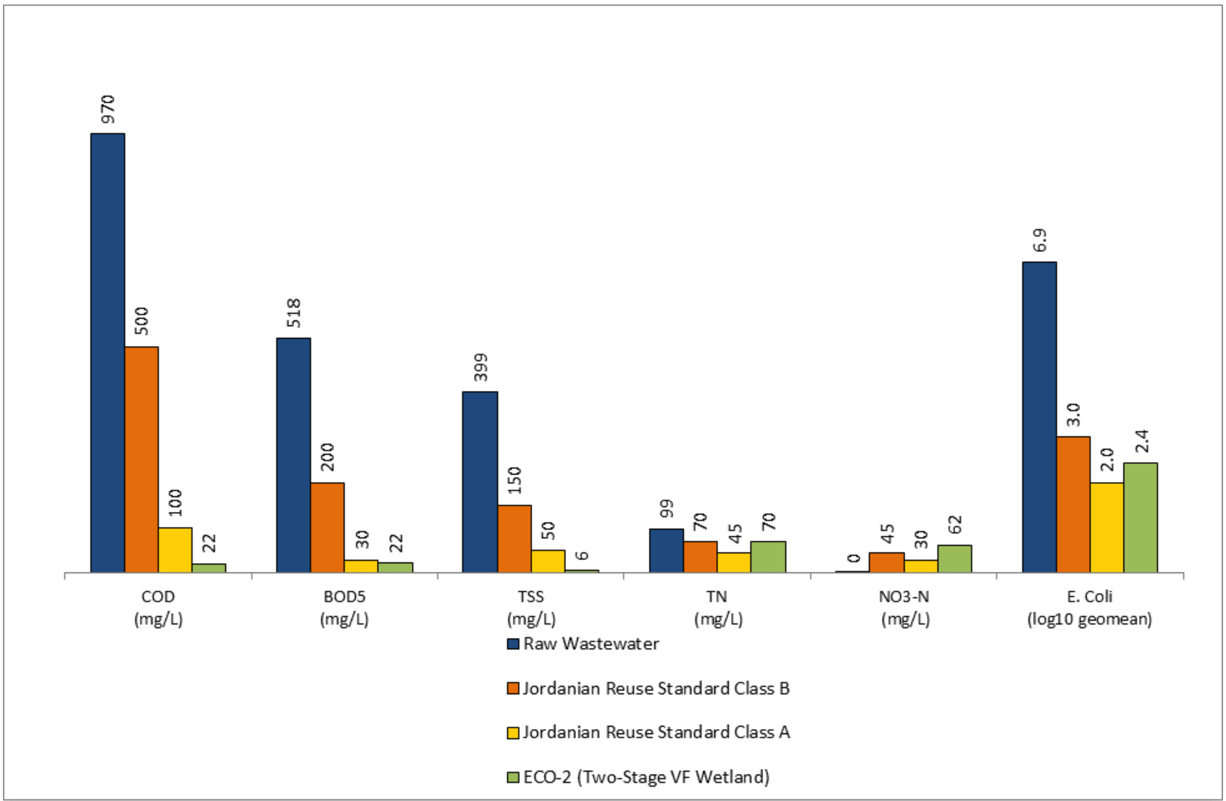

Figure 8: Average performance of ECO-2 compared to the Jordanian Standards.

The Figure 8 illustrates the Table 4 below where the mean values are associated to their standard deviation.

Table 4: Average performance of ECO-2 and standard deviation for the main parameters measured.

Ecotechnologies (Mean concentrations)	COD (mg/L)	BOD5 (mg/L)	TSS (mg/L)	TN (mg/L)	NO3-N (mg/L)	E. Coli (geomean)	E. Coli ($\log_{10}$ geomean)
Raw Wastewater	970	518	399	99	0	7,347,000	6.9
Jordanian Reuse Standard Class A	100	30	50	45	30	100	2.0
Jordanian Reuse Standard Class B	500	200	150	70	45	1,000	3.0
ECO-2 (Two-Stage VF Wetland)	22	22	6	70	62	243	2.4
Standard Deviations							
RAW Standard Deviation	404	74	260	28	0	5,065,000	6.7
Eco-2 Standard Deviation	4	12	6	18	16	246	2.4

The first thing to observe is that the raw wastewaters parameters are very variable as can be seen by the high standard deviation. The irregular wastewater feeding schedule of the research site can probably explain the high variation in raw wastewater quality. Additionally the wastewater composition is influenced by the fact that the wastewater comes from the municipality of Fuhais and has both domestic and commercial (shops, restaurants and a few industries) components.

However, on the other hand, independently of the parameter, Eco-2 offers very stable treatment performance as can be seen in the low values of the standard deviation.

For COD, BOD_5, and TSS, the two-stage vertical flow ecotechnology system meets the Jordanian Class A reuse standards, as can be seen in Figure 8. The methodology used for BOD_5 analysis measures the total BOD_5 (carbonaceous plus nitrogenous components), resulting in potentially elevated BOD_5 results due to the presence of nitrifying bacteria in the effluent. The very low standard deviation values show that the COD, BOD and TSS removal are constantly high.

As can be seen in the graph, the levels of Total Nitrogen (TN = 70 mg/L) and nitrates (NO_3-N = 62 mg/L) remain high. The high concentration of nitrates and low concentration of BOD_5 illustrate the high level of aerobic treatment provided by the vertical flow system (transformation of NH_4-N into NO_3-N and reduction of BOD_5). This characteristic was expected from the beginning and is why the denitrification reactors had been installed. However as shown by the low levels of denitrification, the original carbon source of the reactors has been exhausted. As no sustainable source of carbon has been identified in the study area, the carbon source was not replaced, limiting the removal of nitrogen.

Figure 8 shows also that the two-stage vertical flow ecotechnology proves to be an effective passive disinfection technology. The geomean *E. coli* effluent concentration is 243 CFU/100 mL (2.4 $\log_{10}$) while the Class A of the Jordanian Standard is 100 CFU/100 mL (2.0 $\log_{10}$) and the Class B is 1,000 CFU/100 mL (3.0 $\log_{10}$). This means that the reduction is of about 4.5 $\log_{10}$, a very good performance for a passive system. The low standard deviation (246 CFU/100 mL) illustrates the stability of the system.

3.2 RECIRCULATING VERTICAL FLOW TREATMENT WETLAND

The chart below (Figure 9) shows the performance of the recirculating vertical flow wetland (ECO-1) compared to the raw wastewater influent and to the Class A and B of the Jordanian Standards for treated wastewater reuse (JS 893/2006). The data presented are mean values, with the exception of *E. coli*, which is presented as $\log_{10}$ geometric mean values. It should be noted that due to analytical issues, the *E. coli* data presented is only from the January 2012 – May 2012 period.

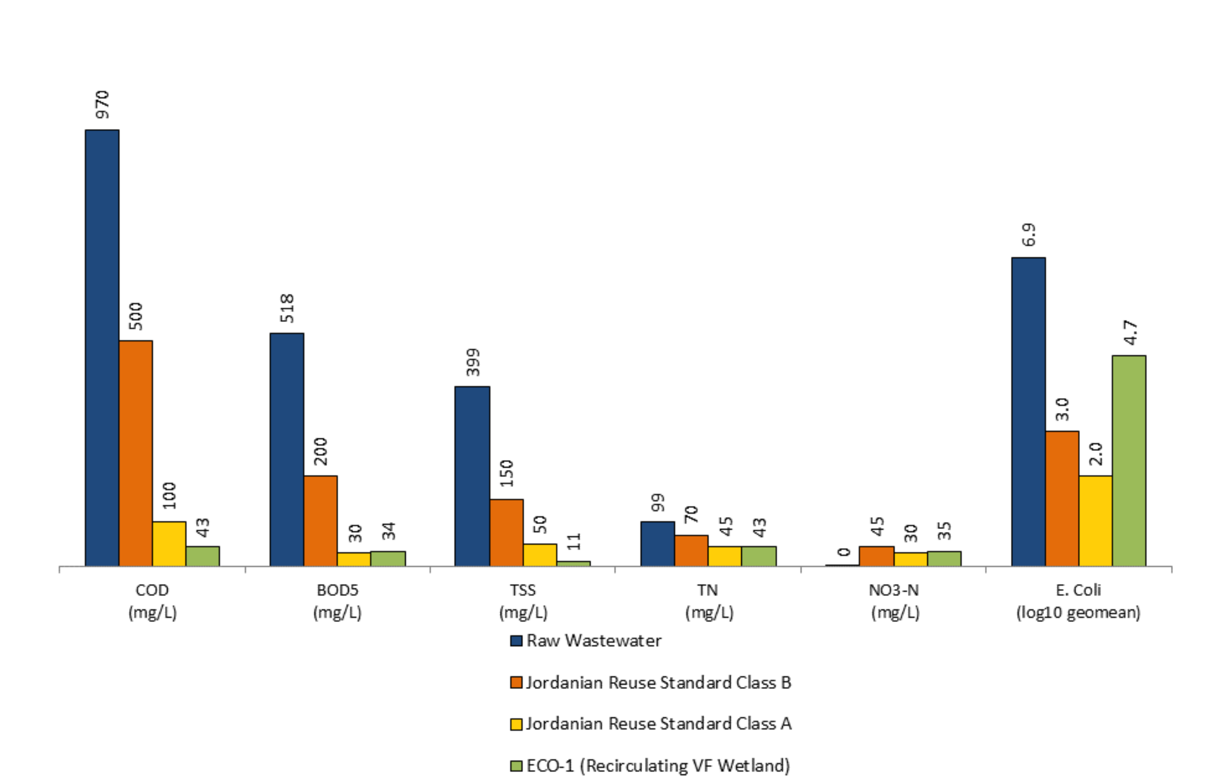

Figure 9: Performance of Eco-1 compared to the Jordanian Standards.

The Figure 9 illustrates the Table 5 below where the mean values are associated to their standard deviation.

Table 5: Average performance of ECO-1 and standard deviation for the main parameters measured.

Ecotechnologies (Mean concentrations)	COD (mg/L)	BOD5 (mg/L)	TSS (mg/L)	TN (mg/L)	NO3-N (mg/L)	E. Coli (geomean)	E. Coli ($\log_{10}$ geomean)
Raw Wastewater	970	518	399	99	0	7,347,000	6.9
Jordanian Reuse Standard Class A	100	30	50	45	30	100	2.0
Jordanian Reuse Standard Class B	500	200	150	70	45	1,000	3.0
ECO-1 (Two-Stage VF Wetland)	43	34	11	43	35	48,500	4.7
Standard Deviations							
RAW Standard Deviation	404	74	260	28	0	5,065,000	6.7
Eco-1 Standard Deviation	15	13	11	12	11	38,022	4.6

The first thing is to observe again that the raw wastewaters parameters are very variable as can be seen by the high standard deviation. The irregular wastewater feeding schedule of the research site can probably explain the high variation in raw wastewater quality. Additionally the wastewater composition is influenced by the fact that the wastewater comes from the municipality of Fuhais and has both domestic and commercial (shops, restaurants and a few industries) components.

However, on the other hand, independently of the parameter, Eco-1 offers very stable treatment performance for most of the parameters (except *E. coli*) as can be seen in the low values of the standard deviation.

Over the 17 months of monitoring, the treatment system has been meeting the Class A and B standards for COD (43 mg/L). It also has been meeting Class B standards for BOD_5 but slightly missing the Class A (34 mg/L instead of 30). Again, the methodology used for BOD_5 analysis measures the total BOD_5 (carbonaceous plus nitrogenous BOD_5), resulting in elevated BOD_5 results due to the presence of nitrifying bacteria in the effluent. Thus, the performance of Eco-1 in terms of COD and BOD_5 reduction is very stable (low standard deviation) and thus highly satisfying.

As expected, Eco-1 also offers very high and stable TSS removal (11 mg/L at the outlet and a standard deviation of 11 mg/L) that exceed the requirements of the standards for Class A and B treated effluent.

As can be seen in Figure 9 and Table 5, the average TN level at the outlet of Eco-1 is 43 mg/L which comply with both Class B and A of the Jordanian Standards with a high stability compared to the variations in raw wastewater. The nitrates level (35 mg/L) complies with the Class B of the Jordanian Standards (45 mg/L) but slightly exceed Class A (30 mg/L). These results identify a higher performance of the aerobic treatment (nitrification) than for the anaerobic treatment (denitrification). When correlated to the high performance of Eco-1 in terms of BOD_5 removal, it can be assumed that the concentration of BOD_5 is not sufficient to provide enough carbon for a total denitrification and/or that the quantity of denitrifying bacteria is not sufficient to process the recirculated effluent (not enough contact surface to grow the bacteria).

The chart also shows that the ECO-1 system proves to be of limited performance in terms of pathogen removal as the geomean *E. coli* count is about 4.7 log10 while Class A is 2 log10 and Class B 3 log10. This was expected as the mixing of the recirculated effluent with the primary treated effluent in the recirculation process is a source of a recontamination with pathogens. The filter media used for Eco-1 is also coarser than the media used for Eco-2. This provides the required higher infiltration rate but lowers the contact time (treatment time) between the biofilm and the effluent and can explain the fact that some E coli bacteria are flowing untreated through the system. This lower performance in E. coli removal was somehow expected as this type of system optimises nitrogen removal.

4 DISCUSSION

The main features of the WHO (1989) guidelines for wastewater reuse consider that wastewater is a resource to be used, but safely. The aim of the guidelines is to protect people in exposed populations (consumers, farm workers, etc.) against excess infection. Faecal coliforms and intestinal nematode eggs were chosen as the indicators of pathogen contamination of the wastewater to be used in agriculture. The WHO guidelines from 1989 (Table 6) are in the process of being revised using new data from epidemiological studies and quantitative microbial risk assessments (Carr, 2005) but are currently still in use.

Table 6: Recommended microbiological quality guidelines for wastewater use in agriculture [a], WHO (1989)

Category	Reuse condition	Exposed group	Intestinal nematodes [b] (arithmetic mean no. of eggs per litre [c])	Faecal coliforms (geometric mean no. per 100 mL [c])	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks [d]	Workers, consumers, public	1	1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees [e]	Workers	1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent Helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

a) In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account, and the guidelines modified accordingly.
b) Ascaris and Trichuris species and hookworms.
c) During the irrigation period.
d) A more stringent guideline (<200 faecal coliforms per 100 mL) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
e) In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

It is interesting to observe that the WHO guidelines are not as strict as their Jordanian equivalent (Table 1). The 1989 revision of the WHO guidelines resulted in a recommended *E. Coli* limit of 1,000 CFU per 100 mL. This decision was based on the consensus view that the actual risk associated with the reuse of treated water for irrigation was much lower than previously thought. The World Health Organization stated that the previous standards were unjustifiably restrictive, particularly concerning pathogenic organisms.

In Jordan, decentralised wastewater treatment and reuse is an opportunity to optimise the use of water and provide new water resources to an arid country. However, the existing Jordanian standards for the reuse of treated wastewater make it very difficult to implement small and decentralized wastewater treatment technologies. The difficulty stems from the fact that the required performance of a treatment system depends not on its size (e.g., how many people are served) but on the expected reuse of the treated effluent (independent of the reuse technology applied).

In addition to the requirements concerning pathogen removal, the Jordanian Standards require nutrient removal. This is an important point that WHO does not consider as some nutrients (Nitrogen and Phosphorus especially) are highly valuable in agriculture (in rural and suburban areas). Although making sense in the centralised context (mainly for mass balance reasons), these standards are highly challenging for decentralised systems and cannot be reached in a cost effective manner.

As a result, it is difficult to identify a single technology that can meet every requirement of the Jordanian Class A standard for reuse of treated wastewater. The treatment requirements for individual households should not be identical to those of larger neighbourhoods or communities. Stricter water quality regulations can be applied as the size of the serviced community increases. It is thus difficult to envision full-scale implementation of the decentralised scenario in Jordan if new reuse standards that fit the specific local context are not formulated. These concerns have been raised by various stakeholders of the wastewater management sector in Jordan (private companies, development organizations and ministries) and are subject to discussions that are expected to bring changes to the current regulations. It would thus not be surprising if new standards adapted to the decentralised context were produced in the short- to medium term. These revised standards should allow successful implementation of ecotechnologies and other decentralized wastewater treatment system to improve the current situation in Jordan.

5 CONCLUSION

Both of the ecotechnologies installed at Fuhais have proven to be robust and stable in operation. The results of the monitoring also show that treatment wetlands are perfectly able to meet the higher standard limits for some parameters but offer more limited performance for some others (nitrogen or pathogen removal). The single-pass vertical filter (Eco-2) is able to reach high BOD, COD, TSS and *E. coli* removal but offers more limited performance in terms of nitrogen removal (TN and NO_3-N). Conversely, the recirculating vertical filter (Eco-1) is able to reach high BOD, COD, TSS and TN removal but has more limited performance in terms of *E. coli* removal.

Therefore the use of ecotechnologies in Jordan has been proved feasible. On one hand, ecotechnologies unconditionally offer high treatment performance and a high improvement compared to the existing situation (infiltration of untreated wastewater). On the other hand, it is clear that as installed at Fuhais the ecotechnologies are not meeting the Jordanian standards for all the parameters and should be implemented in different situation (limited potential exposure to pathogens for Eco-1 and tolerance to higher levels of nitrogen for Eco-2). Further research is currently done at Fuhais to optimise the systems and meet the higher standards for all the parameters. Meanwhile, the use of these systems could be implemented on a broader scale if the appropriate level of precautions in design and operation are respected.