Sustainable Sanitation

Practice

EcoSan Club

Issue 11, 04/2012

- Agricultural wastewater reuse in Sicily
- Sustainable water resources management in the Oasis of Figuig, Marocco
- Community participation and local regulations for sustainable sanitation and water reuse in Anza village, Palestine

Water reuse

partner of:
sustainable sanitation alliance

Impressum

published by / ***Medieninhaber, Herausgeber und Verleger***

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Schopenhauerstr. 15/8
A-1180 Vienna
Austria
www.ecosan.at

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Sustainable Sanitation Practice (SSP) aims to make available high quality information on practical experiences with sustainable sanitation systems. For SSP a sanitation system is sustainable when it is not only economically viable, socially acceptable and technically and institutionally appropriate, but it should also protect the environment and the natural resources. SSP is therefore fully in line with SuSanA, the Sustainable Sanitation Alliance (www.susana.org). • SSP targets people that are interested in sustainable sanitation systems and the practical approach to it. • Articles are published after blind review only. • Sustainable Sanitation Practice is published quarterly. It is available for free on www.ecosan.at/ssp.

Sustainable Sanitation Practice (SSP) hat zum Ziel praxisrelevante Information in hoher Qualität im Zusammenhang mit „sustainable sanitation“ bereit zu stellen. „sustainable“ also nachhaltig ist ein Sanitärsystem für SSP wenn es wirtschaftlich machbar, soziokulturell akzeptiert, technisch als auch institutionell angemessen ist und die Umwelt und deren Ressourcen schützt. Diese Ansicht harmoniert mit SuSanA, the Sustainable Sanitation Alliance (www.susana.org). • SSP richtet sich an Personen, die sich für die praktische Umsetzung von „sustainable sanitation“ interessieren. • Artikel werden nur nach einer Begutachtung veröffentlicht. • Sustainable Sanitation Practice erschient vierteljährlich, kostenlos unter: www.ecosan.at/ssp.

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Cover Photo / ***Titelbild***

Constructed wetlands and fields irrigated with treated wastewater in San Michele di Ganzaria, Sicily.

Editorial

With rapidly growing demand for food and energy on the one hand and continuing urbanisation on the other hand, stress on water resources is steadily increasing. Therefore, reuse and recycling of water will inevitable play a leading part when it comes to sustainable development. Already today most of the world's freshwater recourses are used in agriculture, mostly for food production.

To meet the challenges extremely efficient water use is necessary to achieve overall improvements in water productivity. Multi-use systems will therefore be crucial in integrated water management. Different examples show how water can be reused and recycled and thus increasing water efficiency in urban, peri-urban and rural areas.
Issue 11 of Sustainable Sanitation Practice (SSP) on „Water reuse“ shows 3 examples for the use of treated wastewater for irrigation in agriculture:

- The first paper presents results from a long-term study carried out in Sicily, Italy.
- The second paper presents activities on water management in the Oasis of Figuig, Morocco.
- The third paper presents practical experiences from a feasibility study on technology selection for wastewater treatment and effluent reuse schemes in Anza village, Palestine.

The thematic topic of SSP's next issue will be „Treatment wetlands“ (issue 12, July 2012). Information on further issues planned will be available from the journal homepage (www.ecosan.at/ssp). As always we would like to encourage readers and potential contributors for further issues to suggest possible contributions and topics of high interest to the SSP editorial office (ssp@ecosan.at). Also, we would like to invite you to contact the editorial office if you volunteer to act as a reviewer for the journal.

SSP is available online from the journal homepage at the EcoSan Club website (www.ecosan.at/SSP) for free. We also invite you to visit SSP and EcoSan Club on facebook (www.facebook.com/SustainableSanitationPractice and www.facebook.com/EcoSanClubAustria, respectively).

With best regards,
Günter Langergraber, Markus Lechner, Elke Müllegger
EcoSan Club Austria (www.ecosan.at/ssp)

Content

Agricultural wastewater reuse in Sicily

This paper describes a long–term study on constructed wetland treatment and wastewater reuse for irrigation in Sicily.

Authors: S. Barbagallo, G. L. Cirelli, S. Consoli, F. Licciardello, A. Marzo, M. Milani, A. Toscano

Abstract

In Mediterranean countries, water shortage is becoming a problem of high concern affecting the local economy, mostly based on agriculture. In addition, often the problem is not only the scarcity of water in terms of average per capita, but the high cost to make water available at the right place, at the right time with the required quality. In these cases, an integrated approach for water resources management including wastewater is required. The management should also include wastewater reclamation and reuse, especially for agricultural irrigation. This study evaluates and compares the efficiency of two full-scale Horizontal SubSurface Flow Constructed Wetlands (H-SSF CWs), located in Southern Italy (Sicily), both in terms of water quality improvement (removal percentage) and achievement of Italian wastewater discharge and irrigation reuse limits. Moreover, the impact on tomato crops of drip and sub-drip irrigation with treated municipal wastewater, as well as effects of wastewater reuse on main production features, microbial soil and products contamination were investigated. The analysis of the reuse scenario confirms that, under controlled conditions, low-quality wastewater can be used to increase tomato crops production in water-scarce Mediterranean environments.

Introduction

The economical sustainability of the agricultural sector in Sicily (Southern Italy) has to cope with the availability and management of water resources for irrigation. Crop water requirements are, generally, unfulfilled for relevant percentages and the need to use alternative water sources, like urban treated wastewater (TWW), is urgent. Moreover, reusing these discharged effluents can significantly reduce or completely remove the impact of these effluents from receiving environments.

The monitoring campaign carried out in Sicily (Barbagallo et al., 2012) evidenced the potential presence of 523 urban wastewater treatment plants (WWTPs), of which 259 actually in operation, 89 not in operation, 32 abandoned, 47 under construction and 96 just planned by the public administration. Figure 1 depicts the 523 urban WWTPs in the Sicilian territory by evidencing their operation. In particular, 49% of WWTPs in operation treat wastewater (WW) coming from urban areas with person equivalent (P.E.) (e.g. evaluated on the basis of the organic load) between 2,000 and 10,000, while more than 60% of the planned WWTPs will serve urban communities smaller than 2,000 PE.

The WW volume produced by WWTPs in Sicily amount to $155 \cdot 10^6$ m^3 (plants in operation) and $48 \cdot 10^6$ m^3 (plant under construction). The total volume available in the short term is therefore about 27% of the irrigation needs of the island, estimated at about $750 \cdot 10^6$ m^3/year, taking into account areas served by both collective irrigation

Technical data:

The Constructed Wetlands treatment plant for wastewater reuse:

- system is designed for about 2200 inhabitants
- flow rate: 4 L/s
- surface area: about 4,000 m^2
- irrigation area from 200 to 1,550 m^2
- cultivar of tomato plant "Incas" and "Missouri"
- total amount of irrigation volume from 5,500 to 6,000 m^3/ha during each year of the trial.

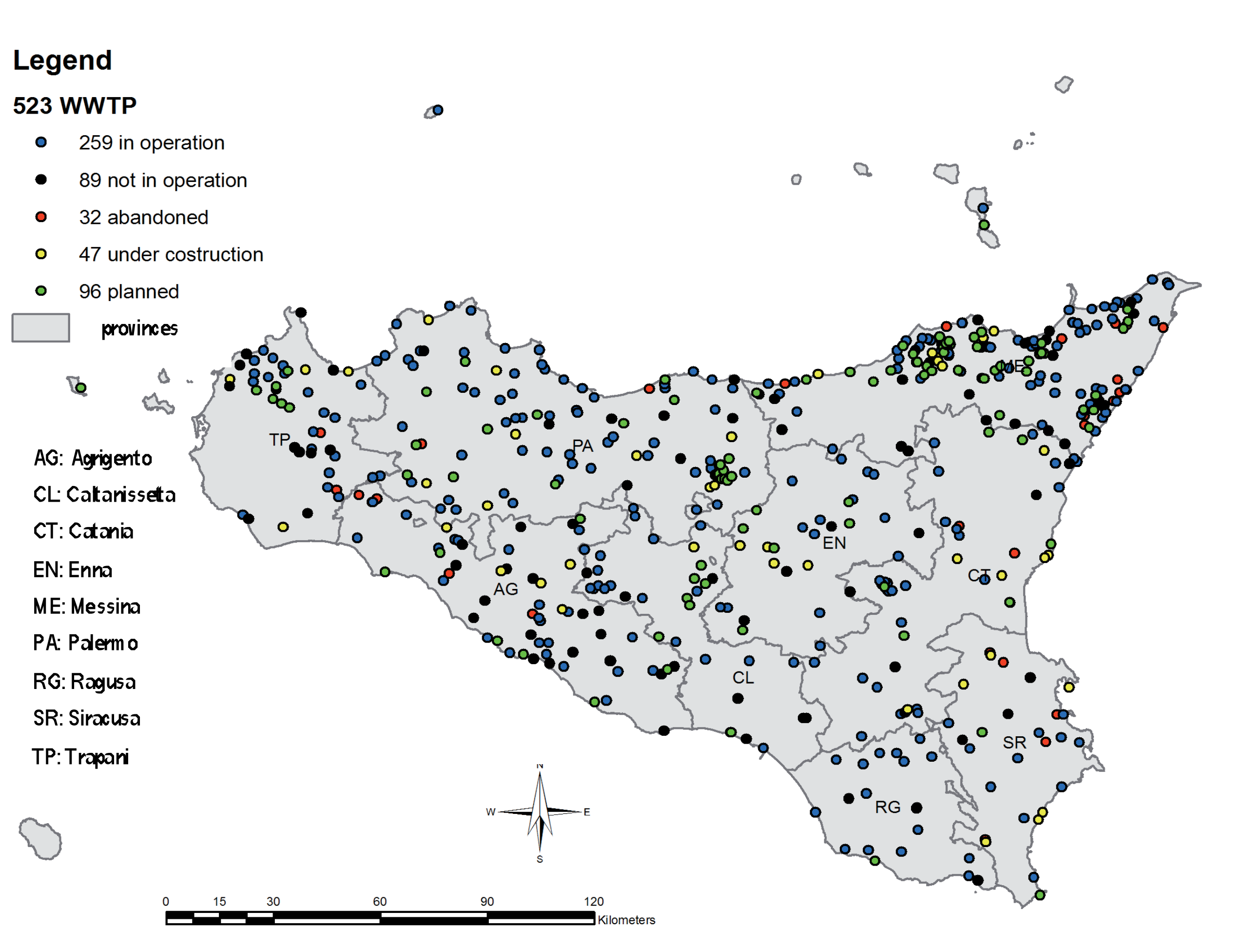


Figure 1. Location of the 523 urban WWTPs in the 9 Sicilian provinces

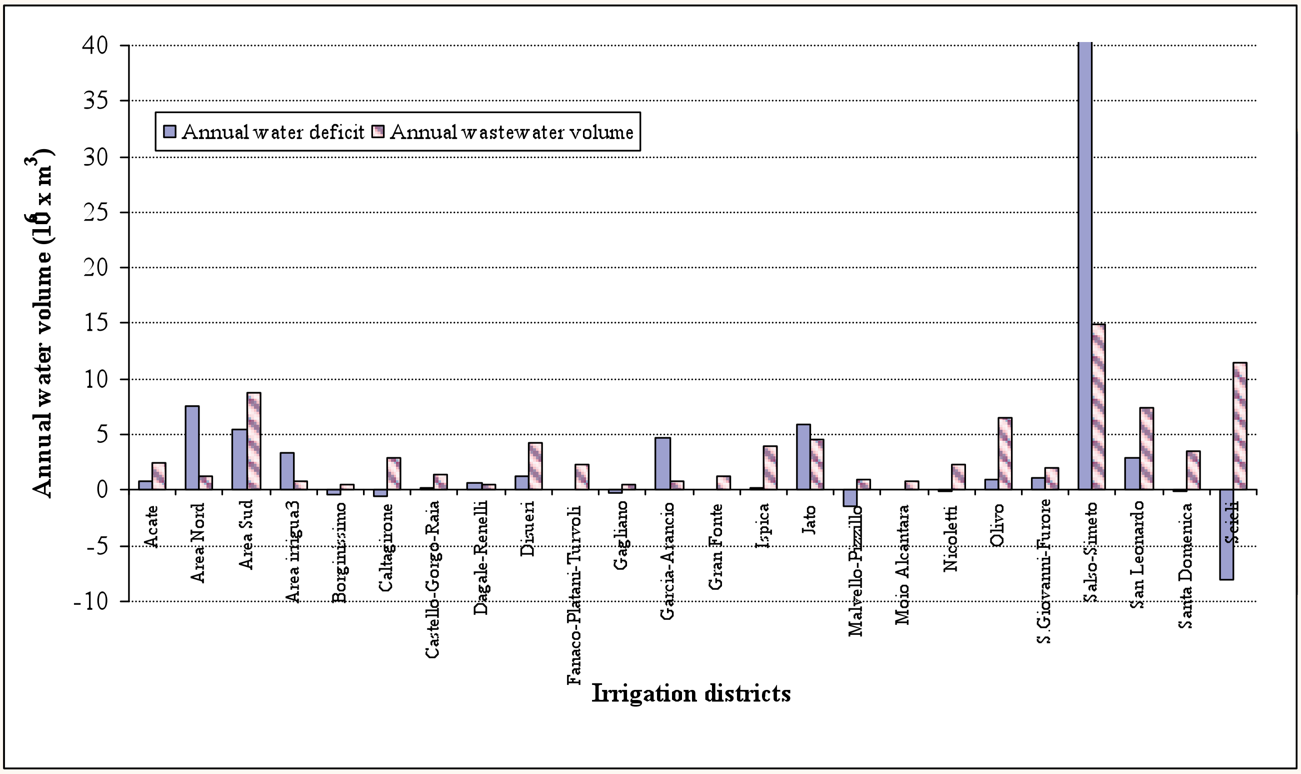


Figure 2. Annual water deficit and wastewater volume for each irrigation district

systems operated by public Consortia and private water sources.

But, a hampering factor to the development of TWW reuse is related to the total cost (construction, operation and maintenance) requested for reclamation, in addition to the cost for water distribution and the monitoring of the whole reuse system since WWTPs are often far from the irrigation area. On the basis of selection criteria (based on altitude, available flow rate, distance) and by the use of Geographical Information System (GIS), in Barbagallo et al. (2012) the area where it is economically viable to plan and design the infrastructures needed for the reuse of TWW have been identified. As a result, 24 of 37 irrigation areas operated by Consortia were eligible to receive TWW from 59 WWTPs (in operation or under construction). In particular, through the use of TWW ($87{\cdot}10^6$ m^3/year) 10 districts could cover the deficit and gain a surplus of water resources, 8 districts having no deficit could increase water availability, 6 districts could partially be able to meet water needs (Figure 2).

Although the reuse of WW is potentially beneficial, it raises soil contamination and public health concerns. As a consequence, these practices have to be regulated according to WW reuse norm limits that, in some countries, have become increasingly stringent. For example, the Italian law regarding the quality of water to be reused in agriculture (Decree No. 185, 12/06/2003, Ministry for Environment) has extremely tight limits, especially for microbiological parameters (Escherichia coli and Salmonella) (Barbagallo et al., 2011). Consequently, the adoption of tertiary treatments downstream of conventional WWTPs may be required to comply with legal limits. The adoption of natural systems, such as constructed wetlands, a natural WW treatment system, combined with conventional treatment plants, seem to be a suitable solution to improve water quality and it could be a cheap alternative for urban WW treatment especially in small and medium communities where low maintenance and operation needs are essential (Puigagut et al., 2007).

This paper describes the removal performance of two horizontal subsurface flow (H-SSF) constructed wetlands (CWs) designed to treat the secondary effluent of municipal wastewater with different operation lives: 8 and 3 years. Moreover, the paper reports the results of six years of research on irrigating tomato crops with the effluent coming from the tertiary-constructed wetland treatment.

Material and methods

Constructed wetland treatment plant

The research was carried out in a full-scale constructed wetland treatment plant located in San Michele di Ganzaria (Eastern Sicily), a rural community of about 5,000 inhabitants, 90 km South-West of Catania. The area is characterized by a Mediterranean semi-arid climate, with a mean annual rainfall of 600 mm and a mean daily temperature of 18°C in the observation period. The experimental plant consists of two horizontal subsurface flow (H-SSF) constructed wetlands (CWs) working in parallel that have an almost equal surface area (about 2,000 m^2) but with different operation life: H-SSF1 in operation since 2001 and H-SSF2 since 2006 (Cirelli et al., 2007). The constructed wetland treatment plant is used for tertiary treatment part of the effluent (about 4 L/s) of a conventional wastewater treatment plant (trickling filter) (Figure 3). Both wetlands are 0.6 m deep, were filled with 8-10 mm gravel and were planted with Phragmites australis.

Water quality analyses

At the inlet and outlet of H-SSF1 (from 2001) and H-SSF2 (from 2007) the following physicochemical parameters were evaluated to December 2008 (about twice a month for H-SFF1 and weekly for H-SSF2) according to APHA (1998) methods: total suspended solids (TSS) at 105°C, BOD5, COD, total phosphorus (TP) and total nitrogen (TN). Microbiological parameters, such as E. coli and Salmonella were also evaluated. E. coli was counted according to APHA (1998) methods and Salmonella was examined according to Barbagallo et al. (2003).

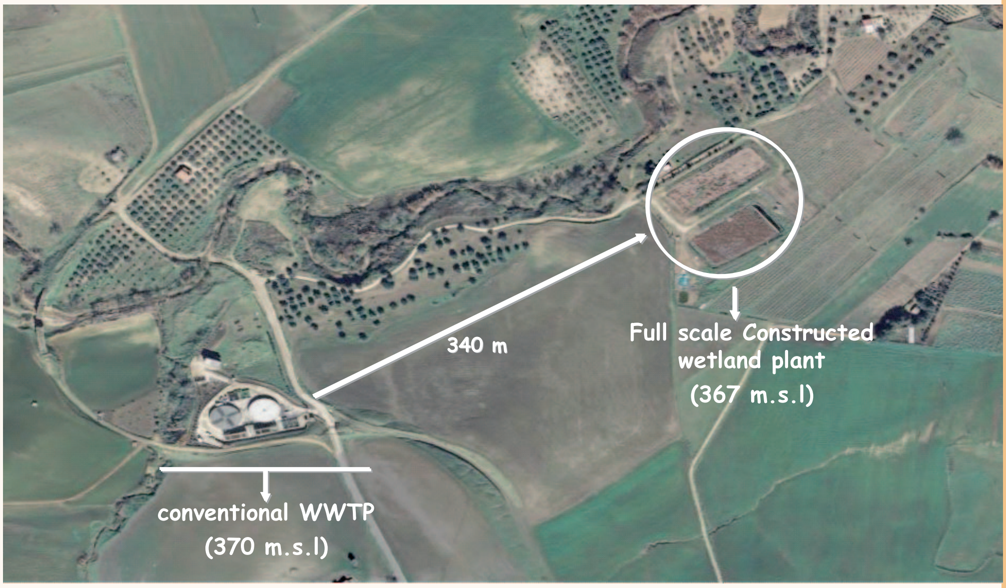


Figure 3. Experimental plants location

WW sampling has been done in different days for the two beds. For the physicochemical parameters, the evaluation of treatment performance was based on the removal efficiency percentage. For microbiological parameters log reductions were calculated.

Irrigation systems

A system using the effluent coming from the tertiary-constructed wetland treatment to irrigate tomato crops was build in the area during the irrigation seasons 2004-2009 (Figure 4).

The experimental field was moved during the years. In particular, the soil was sandy-loam during the first 4 years of the experiment (2004-2007) and clay (USDA textural soil classification) during the following period (2008-2009).

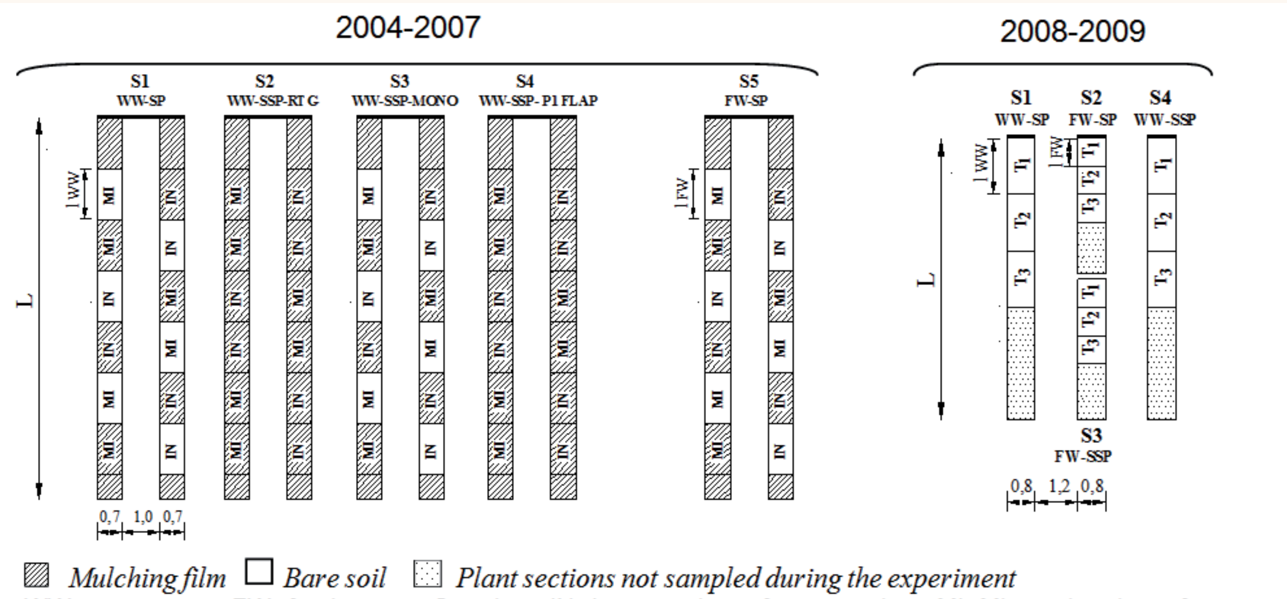
Monitoring period 2004-2007. In 2004, the site was equipped with two parallel testing systems, each one of four plots supplied by WW (plots S1…S4 were replicated two times; in Figure 4 just one testing system is reported). Four different drip lateral types were evaluated. A control system, supplied with fresh water (FW) was also installed. Two cultivar of tomato plant “Incas” and “Missouri” were transplanted into the open field. Irrigation scheduling was based on a simplified soil water balance method, by recording climatic data and evaporation rates through a Class A pan evaporimeter.

The total amount of irrigation volume measured by volumetric meters was of about 6,000 m^3/ha during each year of the trial.

Monitoring period 2008-2009. Figure 4 reports the experimental system design during 2008-2009 monitoring periods. In the scheme, two plots (S1 and S4) were supplied by WW and two (S2 and S3) by FW. All plots were equipped with surface (SP) or subsurface (SSP) polyethylene laterals. The chosen drip laterals were the same (P1 and MONO) showing the highest performance during the 2004 monitoring program. Irrigation scheduling was based on the advection-aridity model as function of evapotranspiration rates (Parlange and Katul, 1992), rainfall, soil water content (evaluated by time domain reflectometry method). The total amount of irrigation volume measured by volumetric meters was of about 5,500 m^3 during each year of trial. More information can be found in Cirelli et al. (2012).

Soil contamination analysis. During 2004-2006 monitoring period, soil contamination analyses were carried out to assess E.Coli, Enterococcus Faecalis (EF) and Salmonella concentrations within soil columns (from 0.1 to 0.4 m of depth) collected close to emitters (Aiello et al., 2012).

Crop yield features and microbiological contamination. The effect on crop production features due to water qualities (treated WW and FW), drip lines (SP and SSP) and soil coverage (just during 2004) and their interactions were evaluated during the trials. Marketable yield (MY), marketable fruits number (MN), fruit mean weight (MW) and unmarketable fruits number (UMN) were determined and processed. Analyses of variance (2-ways ANOVA) identified the effects of main factors and their interactions. Treatment means were compared



WW: wastewater; FW: fresh water; Sx: plots; IN: Incas variety of tomato plant; MI: Missouri variety of tomato plant; T1…T3: tomato crop replicates in 2008-2009; SP: surface pipe; SSP: subsurface pipe; SSP-RTG: P1 Rootguard subsurface light pipe; SSP-MONO: Mono subsurface rigid pipe; SSP-P1 FLAP: P1 Flap subsurface light pipe; l_{WW}: length of WW sections (6 m in 2004-2007 and 2009; 8 m in 2008); l_{FW}: length of FW sections (6 m in 2004-2009; 4 m in 2008 and 3 m in 2009); L: total length (45 m in 2004-2007; 40 m in 2008 and 31 m in 2009)

Figure 4. Experimental irrigation system at S. Michele di Ganzaria (Sicily, Italy) during 2004

by the least significance test, considering * for P<0.05, ** for 0.01<P≤0.05 and *** for 0.001<P≤0.01. The methodology followed to assess the microbiological contamination is described in Aiello et al. (2012).

Results

Constructed wetland performances

As the water flew through the constructed wetlands, an improvement on wastewater quality was achieved since a decrease in concentrations for all physicochemical and microbiological parameters was observed (Table 1 and Table 2). A generally better performance for H-SSF1 in BOD5 and COD was observed for the overall operation. The mean organic matter removal was about 60% in H-SSF1 and 40% in H-SSF2. This could be explained by alga growth and decomposition occurring in the free water surface area at the end of the H-SSF2 (the last 3 meters of the bed functions as a free water surface with an area of about 190 m^2) which increases organic concentration in the effluent. Another possible explanation is that starting from the start-up of 2007. The mean influent concentrations detected were generally lower than in previous years, giving overall lower removal efficiency for the two beds. Except for few deviations, both systems produce a final effluent with TSS concentration less than 20 mg/L regardless of input level (up to 120 mg/L for H-SSF1 and 113 mg/L for H-SSF2). This performance was very stable over their entire operational periods (8 years for H-SSF1 and 3 for H-SSF2) and does not show any decrease. The mean TSS removal in H-SSF2 (67% ±20) was lower than that obtained in H-SSF1, but it is to note that lower was the mean TSS concentration detected at the H-SSF2 influent. There is very little or no difference in the results for H-SSF1 and H-SSF2 for E. coli reduction. Similar E. coli treatment trends of both wetlands were observed with a mean reduction more than 2.5 log units. In particular, E. coli, were reduced to a mean value of 2.7 Ulog (± 0.8) (incoming range 4.5-5.3 Ulog) in the effluent of H-SSF1 and a mean value of 2.6 Ulog (± 0.8) in H-SSF2 (incoming range 5.3-5.4 Ulog). Despite plant uptake of nitrogen and phosphorus generally being non significant for their removal, a positive effect of the plants was observed. In the first year of H-SSF2 operation, its average removal efficiency of nutrients (60% to 46% for TN and TP) was higher than that in the H-SSF1 bed in 2001 (29% to 31% for TN and TP) (Table 1 and Table 2). These differences in removal efficiency during the start-up of the plants, is probably related to the sampling period. Samples were collected at the beginning of plant growth in H-SSF1, while the sampling survey began when the plants were already fully developed in H-SSF2.

Table 1. Mean influent (±SD) and effluent (±SD) wastewater concentrations and mean (±SD) pollutant removal efficiencies (R) throughout the monitoring period in H-SSF1

		TSS		BOD_5		COD		TN		TP		*E. coli**	
2001	in (mg/L)	66	(18)	35	(10)	76	(21)	26	(3)	6	(<1)	5.3	(0.4)
	out (mg/L)	12	(4)	11	(4)	18	(4)	18	(4)	4	(1)	3.1	(0.8)
	R (%)	81	(6)	68	(11)	75	(5)	29	(11)	31	(10)	2.2	(0.5)
2002	in (mg/L)	95	(17)	44	(16)	92	(22)	21	(4)	7	(3)	5.1	(0.4)
	out (mg/L)	11	(3)	13	(4)	19	(4)	10	(7)	5	(1)	3.1	(0.9)
	R (%)	88	(4)	68	(13)	78	(6)	56	(22)	32	(23)	2.1	(0.8)
2003	in (mg/L)	82	(15)	42	(8)	84	(14)	23	(5)	7	(2)	5.1	(0.3)
	out (mg/L)	12	(3)	11	(3)	17	(5)	12	(5)	4	(1)	3.0	(0.7)
	R (%)	85	(4)	72	(8)	79	(5)	50	(16)	37	(15)	2.0	(0.5)
2004	in (mg/L)	39	(35)	16	(8)	37	(15)	31	(6)	7	(1)	4.5	(0.7)
	out (mg/L)	5	(2)	8	(2)	16	(4)	25	(8)	6	(<1)	2.0	(0.7)
	R (%)	77	17)	37	(28)	51	(20)	20	(16)	17	(6)	2.5	(0.5)
2005	in (mg/L)	41	(16)	25	(9)	48	(16)	-	-	-	-	4.8	(0.4)
	out (mg/L)	3	(2)	8	(2)	16	(4)	-	-	-	-	1.5	(0.6)
	R (%)	92	(5)	63	(13)	63	(15)	-	-	-	-	3.5	(0.5)
2006	in (mg/L)	69	(8)	54	(13)	87	(18)	-	-	5	(1)	5.0	(0.1)
	out (mg/L)	10	(5)	19	(1)	34	(3)	-	-	3	(1)	2.6	(0.6)
	R (%)	86	(7)	63	(10)	61	(5)	-	-	31	(12)	2.4	(0.5)
2007	in (mg/L)	36	(12)	24	(7)	44	(9)	31	(7)	7	(1)	5.1	(0.4)
	out (mg/L)	14	(6)	16	(5)	29	(10)	25	(10)	6	(<1)	2.4	(0.1)
	R (%)	84	(15)	50	(27)	59	(21)	49	(19)	16	(6)	2.6	(0.4)
2008	in (mg/L)	34	(26)	21	(9)	36	(14)	20	(7)	8	(3)	5.2	(1.1)
	out (mg/L)	13	(7)	15	(7)	27	(14)	9	(4)	7	(2)	2.6	(1.1)
	R (%)	54	(24)	29	(19)	26	(18)	56	(16)	12	(8)	2.4	(0.9)
Overall period	in (mg/L)	62	(31)	32	(15)	64	(28)	23	(6)	7	(2)	5.0	(0.5)
	out (mg/L)	10	(5)	11	(4)	20	(8)	13	(7)	5	(2)	2.7	(0.8)
	R (%)	80	(17)	58	(22)	63	(22)	45	(20)	27	(16)	2.5	(0.8)

* Concentration and removal values in log units

Table 2. Mean influent (±SD) and effluent (±SD) wastewater concentrations and mean (±SD) pollutant removal efficiencies (R) throughout the monitoring period in H-SSF2.

		TSS		BOD_5		COD		TN		TP		*E. coli**	
2007	in (mg/L)	27	(24)	35	(5)	63	(9)	23	(5)	4	(<1)	5.3	(0.7)
	out	7	(3)	18	(7)	37	(13)	9	(3)	2	(1)	2.7	(1.0)
	R (%)	68	(17)	42	(22)	41	(23)	60	(19)	46	(20)	2.6	(0.7)
2008	in (mg/L)	41	(27)	30	(18)	50	(26)	34	(17)	7	(2)	5.4	(1.0)
	out	11	(7)	17	(8)	30	(15)	13	(7)	5	(3)	3.0	(0.8)
	R (%)	67	(23)	41	(16)	37	(19)	58	(15)	35	(31)	2.4	(0.7)
Overall period	in (mg/L)	35	(26)	31	(14)	55	(22)	29	(14)	6	(2)	5.4	(0.7)
	out	9	(6)	17	(8)	33	(15)	11	(6)	4	(3)	2.6	(0.8)
	R (%)	67	(20)	41	(19)	38	(20)	59	(16)	40	(27)	2.6	(0.8)

* Concentration and removal values in log units

Wastewater discharge and reuse limits

It could be deceptive to evaluate constructed wetland performance just according by removal efficiency. Constructed wetlands, and in general all wastewater treatment plants, are designed to meet discharge limits. For this reason, samples expressed as percentages below the Italian wastewater discharge limits into surface waters (D.Lgs. 152/2006) and for agriculture reuse (DM 185/2003) have been calculated (Barbagallo et al., 2011). In both effluents, COD and TSS concentrations were always below the Italian discharge concentration (35 mg/L and 125 mg/L respectively). Furthermore, the two wetlands always reduced COD to acceptable concentrations for irrigation (100 mg/L). Just a few samples (1 out of 80 for H-SSF1 and 5 out of 35 for H-SSF2) didn't comply with the BOD_5 limit of 25 mg/L for discharge into surface water. Both effluent nitrogen concentrations met the legal requirements for irrigation (35 mg/L) while the phosphorus limit (10 mg/L) was only exceeded by 3% (H-SSF1) and 5% (H-SSF2) of the samples. Despite constructed wetlands having shown good removal of microbial indicators (more than 2.5 log units) did not show the ability to produce effluent with E. coli levels matching Italian wastewater reuse standard (50 UFC/100 ml - Maximum value to be detected in 80% samples for natural treatment systems). Only 35% and 27% of samples collected at the outlets of H-SSF1 and H-SSF2, were below the maximum E. coli value limit imposed by the law. This result highlights the need for further treatment to achieve the Italian limits required for irrigation reuse. Following the WHO Guidelines (2006), in the 80% of samples E. coli contamination was in the range of 10^2-10^4 CFU 100 mL^{-1}, corresponding to a median risk rotavirus infection of 10^{-3} pppy, in an unrestricted irrigation and considering additional 2-3 log pathogen reductions by means of post-treatment control measures. So wastewater reclaimed by the constructed wetland system could be used for unrestricted crop irrigation if combined with some health protection measures, such as e.g. respect of withholding periods to allow pathogen die-off after the last wastewater application, in order to obtain the supplementary 2-3 log reduction needed to achieve the health based target of 10^{-6} DALY (Disability-Adjusted Life Years).

Hygienic quality of tomato crops and soil

Table 3 reports the average hygienic quality of tomato crops washing solution evaluated over the years of trial. By analysing the microbiological data it is not easy to determine if such contamination was due to the fruits contact with TWW, to an environmental pollution or to an accidental contamination occurring during sampling. The former possibility could be realistic during 2004 and 2005 years of trial, because we operated in the worst case condition (tomato fruits sampled near the drippers). During 2006-2009 period, the fruits sampled not in contact with soil/plastic mulch showed a very weak E.Coli contamination (60 CFU 100 g^{-1}), which fell within the quality recommendations (≤100 CFU g^{-1} E.Coli for pre-cut fruits and vegetable ready to eat) established by the European Commission (Commission Regulation

Table 3. Average microbiological quality of tomato fruits over the years of trial

Year	Sampling procedure	*E.Coli* (CFU 100 g^{-1})	*EF* (CFU 100 g^{-1})	*Salmonella* (CFU 100 g^{-1})
2004	1	4×10^2	5×10^2	
2005	1	1×10^2	2×10^3	
2006	1	4×10^2	4×10^3	
	2	8	1×10^3	
2007	1	1	1×10^4	Absent
	2	0	2×10^3	
2008	1	6×10^1	5×10^1	
	2	0	0	
2009	1	6×10^1	4×10^2	
	2	0	7	

1: samples of tomato fruits in contact with soil/plastic mulch; 2: samples of tomato fruits not in contact with soil/plastic mulch. E.Coli: Escherichia Coli; EF: Enterococcus Faecalis

2073/2005). EF concentrations were generally not negligible, suggesting that the found contamination could depend on the contact with WW.

During 2004-2006 monitoring period, the analyses on soil samples collected between 0.1-0.4 m from the surface level evidenced a not negligible microbial content. In particular, a mean E.Coli content of about $3×10^3$ CFU 100 g^{-1} was found, with a decrease of about 3 log units along the examined soil profile. EF concentrations were found in all investigated soil columns layers, with a mean of about $1×10^3$ CFU 100 g^{-1}. During 2007-2009 monitoring period, the concentration of E.Coli measured in the soil sampled were very low. No Salmonella contamination was recorded.

Crop yield evaluation

The results of WW reuse for vegetable cultivation were different according to crop and cultivation seasons. Differences on crop production features between the trials may be related with the harvest operation modalities. Between the different tomato varieties analysed in the study, the genotype Missouri was more suitable for reclaimed WW. The marketable total yield (mean of 60 t ha^{-1} during the trials) resulted significantly ($P<0.05$) higher for WW irrigated tomatoes in 4 of the 6 available years (it was not possible to evaluate the parameter in 2008 due to the fact that the Phytophtora affected tomato plants). The unmarketable production (mean of 50 fruits m^{-2}) resulted significantly ($P<0.05$) lower for WW irrigated tomatoes in 3 of the 5 available years.

The adoption of SSP laterals determined a significant improvement of MY (+28%) that was related to the increase in marketable fruits (+18%) and mainly to the decrease in unmarketable fruits (-30%), especially during 2008-2009 period. Finally, on the agronomic point of view, the use of tertiary treated municipal WW is suitable for the cultivation of vegetable crops. The obtained qualitative and yield results were slightly influenced by water quality. However, the different WW quality features during the years of trial require further physical and chemical characterization analyses to optimize the reuse scenario.

Conclusion

The constructed wetlands located in San Michele di Ganzaria (Sicily), have proved to be efficient in removing the main chemical and physical pollutants from the secondary effluent of urban wastewaters treatment plant. The results of this study confirm the high reliability of CWs for tertiary wastewater treatment given that the H-SSF1 treatment capacity remained largely unchanged after eight years of operation.

Despite increasing pressure to make more efficient use of water resources, irrigation of food crops with reclaimed water still remains a contentious issue. The debate is complicated by the fact that reuse scenarios can vary substantially with respect to WW treatment level, irrigated crops, sampling procedures, etc. The presented study, based on a 6-years monitoring program, showed that municipal WW, reclaimed according to a Constructed Wetland system may be successfully used, under specific experimental conditions, to irrigate and grow tomato crops.

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Sustainable water resources management in the Oasis of Figuig, Morocco

In the Oasis of Figuig, Morocco, a sustainable management of the water resources in the Oasis shall be implemented that is focusing in the rational use of water in agriculture and wastewater reuse. This paper presents the activities carried out in the Oasis within the Project "Support to the public policy of water management in Figuig".

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Abstract

The Oasis of Figuig (Morocco) is located in Morocco's far South-east, near the Algerian border. Water resources are scarce in the Oasis and the sanitation is very poor. The community of Figuig requested technical assistance to improve the water management in the Oasis. This paper describes the activities carried out in the Oasis within the frame of a Programme of Support to the public policy of water management in Figuig funded by the ACCD (Agència Catalana de Cooperació al Desenvolupament). The tasks performed by the different teams that contributed to the project have been: the aquifer characterisation, the implementation of a water user's community, the planning and management of wastewater treatment and reuse, and the implementation of sensitisation and capacity building programs. The activities carried out have contributed to the planning and management of the water resources of the Oasis in a sustainable and integrated way. A global water management in the Oasis is absolutely necessary in order to gain sustainability and maintain in good conditions the scarce resources available.

Key facts:

- Water resources in the Oasis of Figuig (Morocco) are scarce and the sanitation is very poor.
- The community of Figuig requested technical assistance from the NGO Món-3 to improve the water management in the Oasis.
- The integral water management tasks included: the aquifer characterisation, the water users community implementation, wastewater treatment and reuse planning and management sensitisation campaigns and capacity building programs and the creation of a water analysis laboratory and a municipal water service.
- The neighbourhood (ksar) of Hammam-Foukani is the only one with a complete sanitation system: a sewerage system and wastewater treatment with waste stabilization ponds (WSPs).
- The sanitary quality of the final effluent met the irrigation water standards for restricted irrigation the entire year according to the WHO recommendations (WHO, 1989) and the draft of the future Moroccan legislation on wastewater reuse. According to this, the final effluent can be used for the irrigation of trees (i.e. date palms).
- At present 1 ha of trees are being planted around the WSP to avoid the infiltration of sand in the ponds during sand storms and to prevent desertification. Part of this plantation is being irrigated with the WSP effluent.
- The Water User's Community with capacity building and sensitisation campaigns has totally changed the perception of the population about the use of treated wastewater: from a dangerous waste to an additional water and fertiliser source.
- The water analysis have also contributed to the acceptance of wastewater reuse practices, as the regular monitoring of the WSP effluent creates confidence in the population about the quality of this new source.

Introduction

Water shortage is currently one of the biggest concerns worldwide. According to the Kyoto summit in 2003, two billion people will not have access to safe drinking water supplies by 2015. The Mediterranean countries belong to the most affected regions by water scarcity (Bdour et al., 2009).

Morocco is characterized by an arid to semi-arid climate with occasional long periods of drought caused by extreme weather conditions. Moreover, water resources are unevenly distributed. Indeed, these resources are evaluated at about 30 billion m^3. Only 11.5 billion m^3 can be used and 93% serve for irrigation of 1.2 million ha. With an increasing urban population, Morocco is at the limit of hydric stress and a deficit of about 500 Mm^3 of fresh-water is expected by 2020 (Thari et al., 2010). Therefore, it is essential to develop new water resources, especially for agriculture. For this reason, an integrated water management, including reclaiming wastewater for agricultural use, is an essential strategy to increase water resources. The integrated water management will offer long term social and technical solutions.

The Oasis of Figuig (Morocco) is located in Morocco's far South-east, near the Algerian border, at an average height of 880m and has an estimated population of 15,000 inhabitants. The climate is Saharan, consisting of cold winters (with a minimum temperature of 3,8 ºC) and hot summers (with a maximum temperature of 43,1 ºC). There are often severe drought periods when the rainfall only reaches 50mm, and occasional heavy rains that cause floods and damages. The main economical activity of the Oasis is date production. The total surface dedicated to date cultivation is about 700ha with an estimated 150,000 palm trees. The municipality of Figuig is divided in seven quarters (ksour).

Water resources are scarce in the Oasis. The main water resource of the community is groundwater, through wells, natural sources and mines (foggaras). This water is used for potable consumption and agricultural irrigation (mainly palm trees) (Figure 1). The main irrigation technique in use is border irrigation, which represents a large waste of water. Over the last years, there has been an increase of the arable land mainly due to the proliferation of new wells built without any control. This situation has lead to an overexploitation of the aquifer resulting on a salinisation of the groundwater resources as well as the soil.

On the other hand, sanitation is very poor. Most houses are only provided with septic tanks or cesspits. Although part of the community has a piped sewerage system this is still not in use since the wastewater treatment plant has not been constructed yet. The main problem associated with poor wastewater management is the contamination of the aquifer. Hammam-Foukani is the only ksar with a complete sanitation system: a sewerage system and a waste stabilization pond (WSP). The WSP was built in 1998 in order to treat and reuse the wastewater for agricultural irrigation purposes. However, the system was not well maintained and the monitoring of the ponds, in order to evaluate the correct performance of the system and the quality of the final effluent was not carried out. Therefore, this non-conventional resource of water was not used.

The community of Figuig requested technical assistance from Món-3 to improve the water management in the Oasis. Since 1999, Món-3 and several research teams from the University of Barcelona (UB) have been collaborating with the municipality of Figuig for the implementation of a sustainable management of the water resources in the Oasis. This paper presents the

Figure 1. Figuig Oasis: water storage and distribution systems

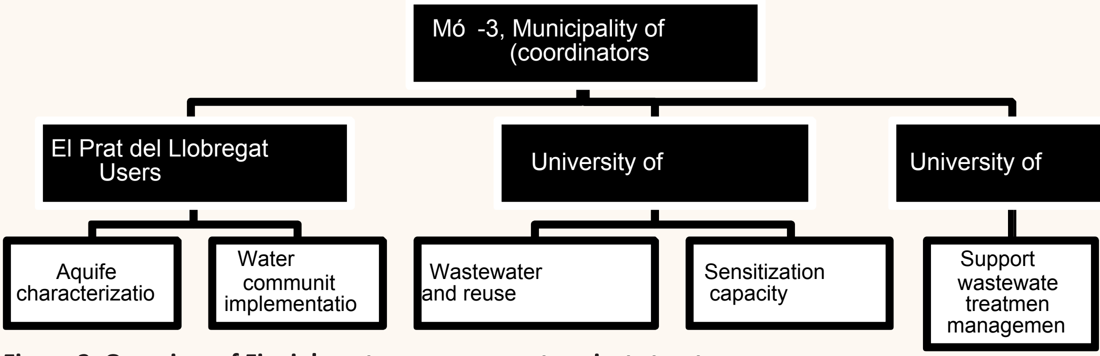

Figure 2. Overview of Figuig's water management project structure.

activities carried out in the Oasis by the Water Resources Group of the University of Barcelona, the University of Oujda and the Irrigation Community Association of El Prat del Llobregat within the frame of a cooperation programme designed by Món-3 and the municipality of Figuig for the public policy of water management.

The project structure and approach

The Programme "Support to the public policy of water management in Figuig" is divided into specific task groups as outlined in Figure 2. The project has a multidisciplinary approach including technical experts of different disciplines: hydrology, chemistry, geology and biology. The project manager (Món-3) oversees all aspects of the project in coordination with the Municipality of Figuig, to ensure all key decisions are transmitted to the community. For the major activities of the project a community consultation has been put in place to ensure that the outcome is in line with the community expectations.

Project tasks

Aquifer characterization

A study was carried out to establish the quality of the ground water; the water budget and the magnitude and direction of hydraulic gradients. These campaigns were carried out with numerous sampling points (Figure 3) taken during 2008 measuring piezometric levels, in-situ parameters (electrical conductivity (EC), pH and temperature) and chemical analysis (HCO_3^-, SO_4^{2-}, Cl^-, NO_3^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+). The analyses were performed according to APHA (2005). The analysis of some chemical species from Piper, Schöeller and Stiff modified diagrams, from the ionic relations and geochemical ratios (r SO_4^{2-}/r Cl^- , r Cl^-/r HCO_3^-), made possible to determine the groundwater flow direction from piezometric data's (Figure 3). The geological characterisation of the area is based on the study made by Bencheriffa and Popp (1990).

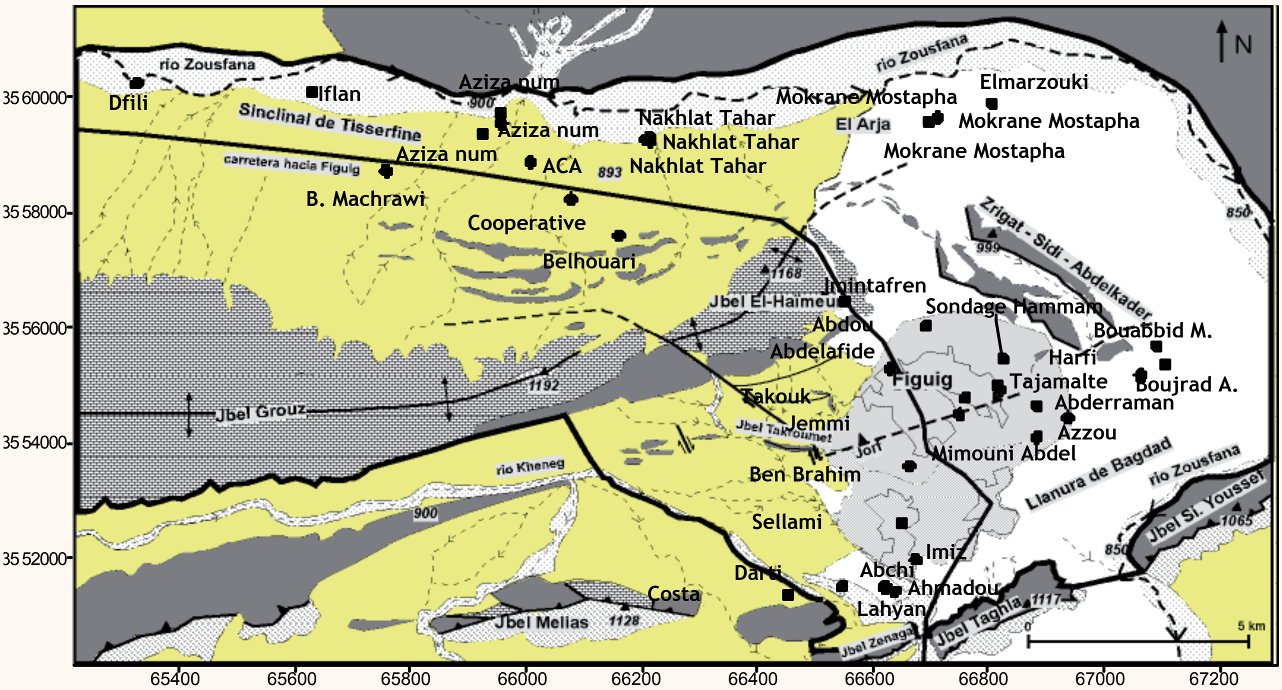

Figure 3. Map of the water sampling points (38) used in the hydro-geological study

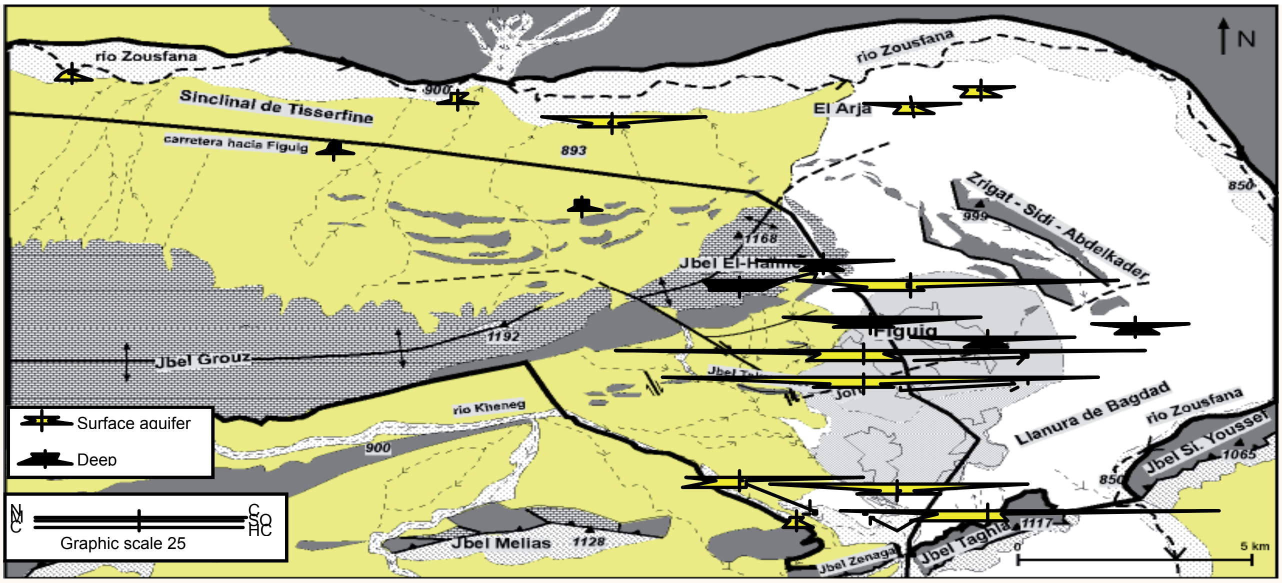

Figure 4. Representation in Stiff modified diagram of data results from the campaigns

The community of Figuig has two aquifers: a superficial and a deep one. Most of the water from the shallow aquifer is intended for agricultural use while the water from the deep aquifer is mainly used to supply the population with drinking water. The groundwater level measurements, the parameters in-situ and the samples analysed from the different wells monitored, determined the flow direction of both aquifers (Figure 4).

Chemical analysis show that the shallow aquifer presents four hydro-chemical families (calcium bicarbonate, sodium chloride influenced by upwelling water, sodium chloride from irrigation water infiltration and intermediate waters), while three families are found in the deep aquifer (calcium bicarbonate, bicarbonate-calcium sulphate and sodium chloride). The high content of nitrates found in some samples of Figuigs aquifers is linked to intensive cultivation (small plots with high density of cultures) and the presence of farms nearby wells and water sources in the surface aquifer. The northern areas of the Oasis have a higher quality of water for agricultural purposes; while in the south water has a poor quality for irrigation. The concentrations of nitrates and chlorides indicate a low quality of water for human consumption according to Moroccan legislation and WHO recommendations.

The water from the occasional heavy rains is mostly wasted and does not feed the aquifer of the oasis, causing floods and serious damages in the village. A storm water management system in the surrounding area of the basin, regulating particularly erosion, runoff and over flows is necessary to avoid floods, to improve the quality of the groundwater (less salinity) and the quantity of water available.

The evaluation of the aquifer characteristics has lead to determine the quantity and quality of the groundwater, so it proves to be a useful tool for the community for managing the water resources of the Oasis. It is also a useful tool for planning the actions to be taken (i.e. wastewater reuse, managed aquifer recharge) in order to assure a long term availability of the water in the Oasis.

Water user’s community implementation

The Oasis of Figuig holds a structure of water use dating back a thousand years. The water administration has been carried out by the locals using an irrigation infrastructure based on flood irrigation. Generally, the structure of each irrigation association is based on a source, a distribution network and several culture lands interspersed within the urban area of the Oasis. The gradual increase of the wells extraction together with the alleged effects of climate change have caused problems of water availability in some of these communities, underlining the fragility of the Oasis.

Based on this analysis, Món-3 began to cooperate in 2006 with the “Comunitat d’usuaris d’aigua del Delta del Llobregat” (CUADLL) in order to create a global community of water users similar to the Water Users Community of the Llobregat (Queralt, 2007). The Figuig Water Users Community is composed by 12 members who were elected by the community and are representative of every ksar. Therefore, it covers all the water uses of the Oasis (including the Municipality’s) in order to reinforce a sustainable management of the Oasis scarce water resources. Following several brainstorming sessions in Barcelona and Figuig the statutes of the water users’ community were approved and it was officially constituted during the International Water Forum held on 5th and 6th of November 2007 in Figuig. Currently, the Water Users Community has implemented a control network of aquifer levels and has installed two pluviometers to

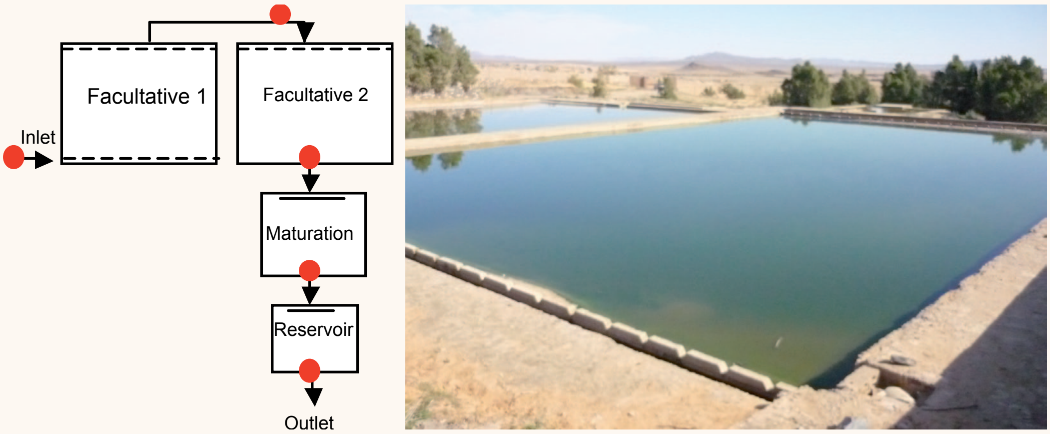

Figure 4. Flow diagram of Hammam Foukani's WSP, sampling points and view of the facultative ponds

control de water budget. The community is also participating in the wastewater reuse planning (inventory of the current cultures and the potential ones, farmers information on the amount of land and type of cultures that could be irrigated with reclaimed water,..). In the near future, a 40 km water transfer from a reservoir will be in operation and the Water User's Community of Figuig will be responsible for managing and distributing this water.

The implementation of a Water Users Community that takes into account and includes all water users facilitates the integrated water management of the Oasis. The creation of Water Users Community has also established a collective conscience and the problem of over exploitation of groundwater is now perceived as a community concern.

Wastewater treatment and reuse planning and management

The Hammam Foukani WWTP started operating in 1998 and has 3 ponds in series (2 facultative and 1 maturation pond) and a reservoir for irrigation (Figure 4). The population served is approximately 1200 PE and it has an average flow of circa 70 m^3/day.

The average overall loading received by the plant is of 142 kg BOD_5/ha/d. The main characteristics of the WSP are shown in Table 1.

Before the monitoring programme implementation, several corrective measures were done in the WSP:

- Desludging of the first facultative pond, as the volume of the pond was reduced more than 1/3 due to sludge and sand accumulation.
- Elimination of macrophytes that had invaded all the ponds.
- Construction of a sand barrier (wall and trees) to avoid the infiltration of sand in the ponds during sand storms.
- Cleaning of the inlet and outlet structures.

After these corrective measures a monitoring programme was conducted. Physicochemical (Electrical conductivity (EC), pH, COD, SS, BOD_5, N-NH_4^+, N-NO_3^-, P-PO_4^{3-}), microbiological (Fecal coliforms (FC) and helminth eggs) and biological parameters (algae characterisation and quantification) were monitored from October 2008 to November 2009 making a total of 8 campaigns (2 campaigns per season). Samples were taken in each unit process of the WWTP. Analyses were performed according to Standard Methods (APHA, 2005). Analyses for helminth eggs were performed also in the extracted sludge of the pond according to Bouhoum & Schwartzbrod (1989). Table 2 presents the WSP average effluent quality and total removal efficiency.

The inlet concentrations are high but characteristic of a wastewater from the small communities in Morocco (El Hamouri et al., 2003; Mustapha, 2009). The WSP

Table 1: Design characteristics of the WSP of Hamman Foukani.

Ponds	Volume (m^3)	Surface (m^2)	Depth (m)	HRT* (days)
Facultative 1	812	650	1,25	10
Facultative 2	812	650	1,25	10
Maturation 1	244	315	1	3
Reservoir	200	100	2	1

*hydraulic retention time

Table 2. Average concentrations and total percentage removal of the WSP for the main physicochemical and microbiological parameters.

Parameters	Inlet	Facultative 1	Facultative 2	Maturation	Reservoir	Total removal
pH	7,4	8,1	8,2	8,4	8,4	-
EC (mS/cm)	3,2	3,3	3,4	3,4	3,4	-
COD (mg/L)	556	320	254	233	225	58 %
BOD_5 (mg/L)	350	290	210	177	175	51 %
SS (mg/L)	289	190	174	155	151	48 %
$N\text{-}NO_3^-$ (mg/L)	*	*	*	*	*	-
$N\text{-}NH_4^+$ (mg/L)	42	29	23	17	17	57 %
$P\text{-}PO_4^{3-}$(mg/L)	11	7	6	5	4	60 %
FC (log)	7,7	6,6	5,7	4,7	4,4	3,3 log
Helminth eggs** (eggs/L)	35	-	-	-	n.d.	-

*$N\text{-}NO_3$ concentrations <0.5 mg/L

**Helminth eggs were analysed at the inlet and outlet of the WSP, n.d. = not detected

performed well taking into account the short HRT (Hydraulic Retention Times) of the original design. The sanitary quality of the final effluent met the irrigation water standards for restricted irrigation the entire year according to the WHO recommendations (WHO, 1989) and the draft of the future Moroccan legislation on wastewater reuse. According to this, the final effluent could be used for the irrigation of trees (i.e. date palms). The average concentration of FC in warm periods was about 3500 CFU/100 mL, which almost reaches the limit for unrestricted irrigation (3000 CFU/100 mL). The WSP was meant to produce an effluent able to be reused for unrestricted irrigation; however the designed HRT were too short to obtain such a good quality.

Organic matter (BOD_5, COD) and SS concentration at the final effluent were high, due to the high organic load that receives the pond and the short HRTs. Fluctuations in the effluent quality were observed according to the season. COD, BOD_5 and SS concentrations were higher during the warmer periods due to the presence of algae, as confirmed by the algae quantification. On the other hand the removal of FC was higher in summer (> 4 Ulog) when the concentrations of algae were important. High ambient temperature, solar radiation and pH due to the growth of algae have been reported to encourage pathogen inactivation and die-off (Davies-Colley et al., 1999).

The EC of the final effluent was about 3,5 mS/cm which is often lower than the groundwater EC used in the oasis for palm trees irrigation. It is necessary to underline that palm trees support water EC higher than 5 mS/cm.

If an unrestricted irrigation is required, the addition of a maturation pond or a complementary treatment (e.g. constructed wetland, sand filter) would improve the FC removal and would contribute to achieve the quality required. Moreover, if a constructed wetland, a sand filter or a rock filter as a complementary treatment is added, the high amount of SS (algal SS) of the WSP effluent would be reduced. In case of drip irrigation implementation, these post treatments would be mandatory.

The sludge extracted from the pond was placed in mounds over the sand beside the WWTP. The sludge samples taken from the surface of the mound presented 0,57 helminth eggs/g DM (dry matter) (Trichuris sp.). The WHO guidelines (WHO, 2006) for sludge reuse in agriculture recommend (<1 helminth egg/g DM). This sludge can be, therefore, used as agricultural amendment. On the contrary, the sludge samples taken much deeper from the mounds presented more than 1 helminth egg/g DM. Therefore if the sludge must be reused in agriculture it is necessary to spread it in thin layers over the sand to guarantee the sanitary quality.

At present 1 ha of trees are being planted around the WSP to avoid the infiltration of sand in the ponds during sand storms and to prevent desertification. Part of this plantation is being irrigated with the WSP effluent. Nowadays, and with the consultation of the Water Users Community of Figuig and the associations of farmers of Hammam Foukani, an agriculture wastewater reuse programme is being designed. The programme will take into account the type of cultures, the amount of land for cultivation, the soil characteristics and the irrigation techniques.

Figure 5. Sensitisation and capacity building interventions

Based on the analysis of the performance of Hammam Foukani's WSP, another study is being carried out regarding the design and location of the future WWTP that will treat the wastewater of all the Ksour of the Oasis in order to generate reclaimed water. The reclaimed wastewater of the future WSP is planned to be used for agriculture and urban irrigation.

Sensitisation campaigns and capacity building programs

Several sensitisation campaigns on efficient water use (water savings), sanitation and wastewater reuse acceptance were conducted from 2007 to 2010. The campaigns addressed farmers associations (6 campaigns), women associations (2 campaigns) and quarter associations (3 campaigns) as well as different schools (2 campaigns). The sensitisation campaigns were performed in collaboration with the University of Oujda in order to provide a local approach to the population. These campaigns were a success with a high number of participants turn up.

Capacity building interventions included two training courses addressed to the members of the local institutions searching to improve the capacity building of the local community on water resources management. These courses covered some theoretical but mainly practical aspects such as operation and maintenance of WSP, laboratory techniques (physicochemical and microbiological parameters), reuse-oriented wastewater management, irrigation good practices and potabilisation issues. These courses enabled the transfer of an up-to date knowledge to technicians and administrative staff as well as other stakeholders with some practical experience in the field. Regarding wastewater reuse acceptation, these sensitisation campaigns and knowledge transfer to different actors, have made change the perception of the population of Figuig regarding the reuse of treated wastewater, as a safe and necessary source of water.

Additionally a large training course on water analyses has been performed from 2010 to 2012 due to the fact that a laboratory of water analyses has been created within the framework of the project.

Water analysis Laboratory and Water Service

Due to the isolated situation of the Figuig oasis, and thus the difficulty on the realisation of water analysis due to the transportation time and costs; a laboratory for water analyses was constructed and equipped in 2010. A building was restored to implement the Municipal Service of Water (that is in nowadays in charge of the water management in Figuig) and the water analysis laboratory. The headquarters of the Water Users Community is also located in the laboratory building. The laboratory is in operation now (Figure 6), and the person in charge of it has been trained in the frame of the project by

Figure 6. Municipal water and sanitation service and water laboratory.

experts from the University of Oujda and Barcelona. The laboratory allows the control of potable water, wastewater, treated water and irrigation water by the community itself. Nowadays a municipal regular monitoring of the pond wastewater quality has been implemented, encouraging the reuse of the wastewater for the irrigation of date palms.

Challenges, recommendations and conclusions

The activities carried out in the frame of the Project "Support to the public policy of water management in Figuig" have contributed to the planning and management of the water resources of the Oasis in a sustainable and integrated way. An integrated water management in the Oasis is absolutely necessary in order to gain sustainability and maintain in good conditions the scarce resources available.

The characterisation of the aquifer is an essential tool to know and predict the quantity and quality of ground water available for the different uses.

The implementation of a Water Users Community including all water users facilitates the integrated water management of the Oasis.

Ponds systems seem to be an adequate technology for the wastewater treatment and reuse in an Oasis context, due to its good performance in these climate conditions and the low operation and maintenance costs. The use of treated wastewater for irrigation (mainly date palms) could be an important non-conventional resource that could solve the water shortage.

At present 1 ha of trees are being planted around the WSP to avoid the infiltration of sand in the ponds during sand storms and to prevent desertification. Part of this plantation is being irrigated with the WSP effluent. Nowadays an agriculture wastewater reuse programme is being designed. The programme will take into account the type of cultures, the amount of land for cultivation, the soil characteristics and the irrigation techniques.

Sensitisation campaigns are necessary for the public awareness on the water quantity and quality problems. Capacity building is essential for an autonomous and correct water resource management by the members of the community.

Before the implementation of the different projects activities the majority of the population of Figuig did not accept the reuse of wastewater as concept, even if talking about treated or reclaimed wastewater. The implementation of the Water User's Community with the capacity building of some members, the sensitisation campaigns and the monitoring of the pond, has totally changed the perception of the population about the treated wastewater: from a dangerous waste to an additional water and fertiliser source.

The creation of the waster service with the laboratory of water analysis has also contributed to the acceptance of wastewater reuse practices for the population, as the regular monitoring of the pond inspires confidence to the population about the quality of this new source.

The multidisciplinary approach of the project has permitted to evaluate integrated up-to-date information in the different fields of the water resources management, in order to provide solutions to all related aspects to the water cycle in a community.

Acknowledgments

The major part of the activities of this study has been done thanks to the project " Support to the Municipality of Figuig's good governance for the development of public policies related to the socioeconomic activation of the Oasis of Figuig – Morocco (PR-2008)" from the ACCD (Agència Catalana de Cooperació al Desenvolupament). The authors would like to thank the Municipality of Figuig and all the associations of the community for their participation and support during the execution of project.

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Community participation and local regulations for sustainable sanitation and water reuse in Anza village, Palestine

This article presents the practical experience gained while conducting the feasibility study on technology selection for wastewater treatment and effluent reuse schemes in Anza village, Palestine.

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Abstract

Free access to water and agricultural land, and sustainable sanitation can reduce food insecurity and enhance economic development in Palestine. This paper presents initial findings of an EU funded project to erect sustainable wastewater treatment and effluent recycling schemes for food security in Anza village. The project aimed at the erection of affordable and environmentally sound sanitation infrastructures considering community consultation and local regulatory rules. The feasibility study showed that low cost treatment options were neither sustainable nor cost effective compared with mechanised biological systems. Results of scoping sessions revealed that major stakeholders (village council members, women and farmers) are willing to accept and pay for environmentally sound and cost effective sanitation facilities. The study recommends the need for coordination between regulatory institutions, funding agencies and community to oversee and coordinate planning activities. Early community participation in the planning process facilitated proper technology selection considering the socio-political, financial and environmental aspects.

Introduction

The growing tendency in reclamation of treated wastewater and reuse of recycled water (treated wastewater) worldwide urges water policy makers in Palestine to integrate water recycling practice as a core element of water resource management. The widespread of water reclamation and reuse for agricultural purposes in Mediterranean countries is driven by water scarcity, water resources protection, environmental security and sustainable sanitation as well as safe and affordable recycled water (Friedler, 1999; Angelakis et al., 1999).

The agricultural sector is a major element for a viable Palestinian economy. Therefore, the availability of freshwater is crucial to achieve food security and sustainable life. Despite the fact, the agriculture is

Key messages to ensure sustainable recycled water use for food security in Palestinian rural communities:

- In Palestine, land scarcity, local environmental issues and stringent effluent quality rules constrain the application of natural and low cost treatment systems;
- Early participation of community and local authorities in the decision making process facilitated proper choice of wastewater treatment technology and use of recycled water;
- Public perception and cultural issues are crucial and need to be evaluated and improved when recycled water use in agricultural irrigation is considered. Thus, public consultations help promote acceptance and pre-detection of future misconceptions.
- Flexibility and availability of a given treatment system, safe and environmentally sound recycled water, public awareness, OM and repair, affordable costs for recycled water should early be considered in the planning process;
- Practical management strategies with clear responsibilities and cost recovery dictate the future sustainability planned wastewater treatment facilities;
- Establishing sustainable sanitation facilities entails technology selection that is financially affordable, socially adequate, technically practical, institutionally suitable and environmentally sound.

the greatest water consumer (65% of the available water) in Palestine, only around 11% of the total Palestinian agricultural land is irrigated. This is mainly due to the Israeli control over the main Palestinian water sources, climate conditions of the region and mismanagement of irrigation water. The political well and commitment, as well as limited access to available water resources and agricultural land exacerbate the urgent needs for effluent reclamation and recycled water use in Palestine (Al-Sa`ed, 2005). In addition, the variable and unbalanced distribution of annual rainfall and seasonal drought periods have endorsed water restrictions in irrigated agricultural lands which use more than 70% of Palestine's available water resources (Nassar et al., 2009).

The provision of environmentally viable and cost effective wastewater treatment facilities in Palestinian rural communities is an overwhelming challenge for decision makers, community leaders and environmental professionals (Al-Sa`ed 2007a). Most rural communities lack adequate sanitation facilities, where domestic sewage is stored in cesspits posing health and environmental hazards through leaking, infiltration and uncontrolled disposal practices. Current installed low-cost onsite treatment systems in rural areas are unsustainable and causing annual environmental degradation, due to overloading, faulty design and implementation, absence of monitoring, maintenance and repair, poor public awareness, lack of administrative and legal control measures (Al-Sa`ed, 2007b, Al-Sa`ed and Mubarak, 2006). Nitrate is one of the most common pollutants in Palestine's ground water and is associated mainly with human activities such as percolation of nitrate-rich water from irrigation, leachate, cesspits and wastewater treatment plants (Almasri, 2008). In the West Bank, several groundwater wells showed nitrate content, which exceeds WHO`s maximum contaminant level (11 mg N/l) for potable uses. In Gaza strip, excessive nitrate concentrations (300-500 mg N/l) in water supplies pose serious public health risks causing 'blue-baby' syndrome and still-birth in both humans and livestock (Shomer, 2011).

The growing demands of Palestinian communities for food and freshwater require use of recycled water in agricultural purposes not only to abate food insecurity but also to protect natural water resources and improve land management. While the volume of wastewater is increasing, the safe disposal can be difficult due to lack of sustainable sanitation services. However, the use of recycled water (reclaimed effluent) for agricultural irrigation is the obvious solution, requiring building capacity and local expertise in the full range of technology involved (Abu Madi et al., 2008). Treated wastewater reuse is covered through a number of regulations and standards which are already established in the Palestine Authority (PSI, 2012). However, since treated wastewater reuse has not been implemented at large scale, enacting these regulations and standards have only been applied to issue permits for urban sanitation and effluent reuse schemes. Enacting these rules and standards for monitoring and control of recycled effluent (discharge and reuse) is still an ongoing debate within different ministries and relevant institutions in Palestine.

This article presents the practical experience gained while conducting the feasibility study on technology selection for wastewater treatment and effluent reuse schemes in Anza village. The focus is made on understanding the perceptions of stakeholders with insights to impacts of recent Palestinian regulations for the reuse of treated wastewater in agricultural irrigation.

Project Aim and Scope

Serving Anza village with a central sewerage network, wastewater treatment and effluent reuse scheme or Anza wastewater treatment facility [Anza WWTF] is part of the 'Food Security Thematic Programme' (FSTP) funded by the European Union [EU]. The project aims at improving the living conditions of the Palestinian inhabitants and economic development of Anza village. In addition to the design works and environmental impact assessment study performed for the Anza WWTF, the project entails safe disposal of the treated wastewater [recycled water] from the planned wastewater plant. The safe disposal of treated wastewater will be made beneficial through a planned reuse of recycled water in agricultural irrigation.

The feasibility study investigated several wastewater treatment alternatives including natural and mechanised treatment technologies. Vertical flow constructed wetlands and sequencing batch reactor (SBR) were analyzed. One major selection criteria was installing a system that has low-capital and affordable annual running costs with less environmental impacts. The recycled water is planned for restricted agricultural irrigation considering soil, climate, crops and socio-economic conditions in the community. A number of meetings and interviews were held with farmers and various stakeholders from the Ministry of Agriculture (MoA), Environmental Quality Authority (EQA), Palestine Water Authority (PWA), Ministry of Health (MoH), Palestinian Standards Institution (PSI) and Anza Village Council to investigate the feasibility of reuse. All of these institutions and Ministries are aware of the importance and need for the reuse of treated wastewater in the West Bank.

Materials and Methods

As mentioned earlier, the project entails design, implementation and operation of sanitation infrastructures including the sewerage networks, wastewater treatment plant (WWTP) and effluent reuse schemes in Anza and Bet Dajan villages. In addition, a baseline environmental and an environmental impact assessment for the wastewater treatment plant were also performed. For the accurate design of the WWTP, grab samples of domestic wastewater obtained from similar rural areas with central sewerage networks were collected and analyzed. Field questionnaires were developed, distributed and analyzed to gain knowledge on perception and understanding of municipal council members, farmers, women and school children. As of space limits, this paper presents the results for Anza village obtained from the environmental baseline report [reference], scoping sessions, personal interviews, lab analysis and feasibility study on proper wastewater treatment technologies.

Results and discussion

Baseline environmental profile

Anza, a Palestinian village situated in Jenin District in the Northern of the West Bank with 2,034 residents (2010), will reach 2,969 in the year 2022 and about 4,471 by 2035. Besides one kindergarten, Anza has two schools; one for boys (260 children) and another for girls (227 children). Furthermore, there is a functional healthcare clinic, a women centre, two agricultural societies, a charitable society and a sport club. Two olive presses work on full capacity during the olive fruits picking season. Since 1995, the village is administered by the village council having 9 members appointed by the Ministry of Local Government.

The total area of the village is estimated at around 5,000 dunums (1 dunum=0.1 ha). Some 1,000 dunums are plain rain fed land. This area is usually cultivated with cereals like wheat, barley, corn, broad-beans, and lentil in addition to olive trees (Figure 1). About 4,000 dunums are mountainous and planted with trees such as olives, figs, and almonds. The plain land within the project area is dry land of low agricultural productivity as it relies totally on fluctuating rainfall seasons. Various vegetable types can be planted as open agriculture or in green houses if sufficient quantity and safe irrigation water is available.

Provision of drinking water supply for Anza village is secured by Jaba' agricultural well. The latter provides the village with about 4,000 to 5,000 m^3 of drinking water per month. Without prior treatment but disinfecting (chlorination), drinking water is elevated to a concrete water, from which further distributed via the network to households. From official records of the village council, the average daily water consumption per capita from the network (48 l) in addition to 41 l from rainwater harvested in household cisterns during winter months. Hence, the daily water consumption for potable uses per capita in total is about 89 l. The un-accounted for water (losses) in the network is estimated around 32%. Drinking water tariff is collected from the households based on monthly water bills at a fixed rate of 1.35 US$/$m^3$.

Before this project, domestic wastewater was stored in individual or collective cesspits, where the domestic septage from cesspits is frequently vacuum-trucked and disposed off uncontrolled on agricultural land and discharged into nearby wadi. Depending on the vacuum truck loading capacity, the average costs for septage evacuation and transport range between 3.85-5.75 US$/$m^3$ septage. It is worth mentioning that these costs exclude the safe treatment and disposal costs of septage.

Figure1: Overview of Anza village with olive trees orchards

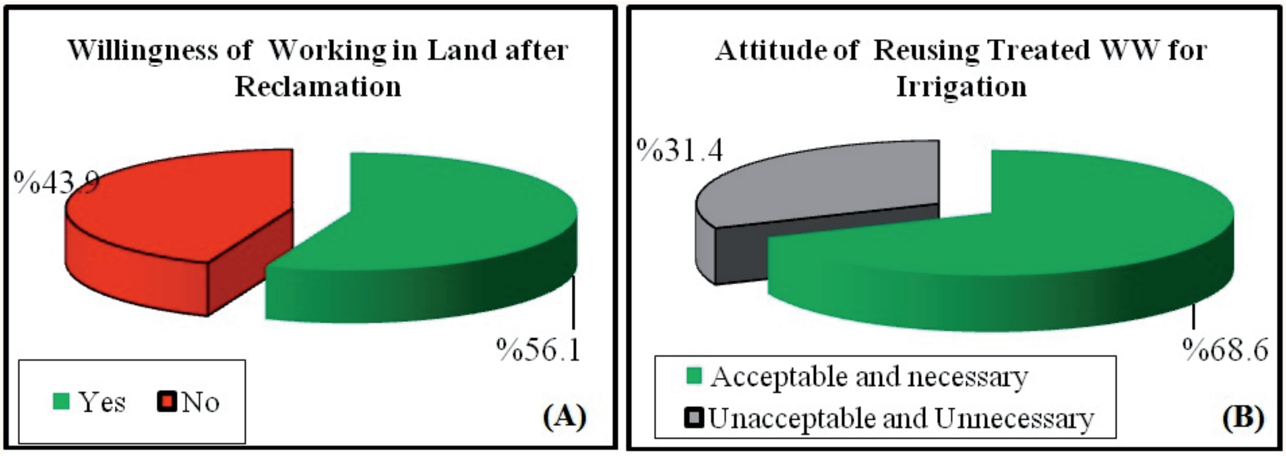

Figure 2: Willingness and attitude of households to use treated water in agricultural irrigation

Field questionnaires on community perceptions

Three questionnaires were distributed to explore the community perceptions related to public awareness, socio-economic situation, knowledge and attitude towards wastewater treatment and recycled water use in agricultural irrigation. Field surveys were performed via three separate questionnaires designed for households (61 questions), school children (22 questions) and farmers (46 questions) in the village. The total surveyed residents in the village included 70 households, 144 children, and 20 farmers. Due to space limitations, the results obtained from the surveys on households and farmers are presented.

Collecting and analysing the data gained from questionnaires distributed on households and farmers revealed the following main results:

Perceptions of households and farmers towards use of reclaimed water in irrigation

Our interviews with the various institutions in the area showed a good awareness regarding the need and importance to utilize treated wastewater in agriculture. The Ministry of Agriculture considers such utilization as very important and it is willing to guide farmers through reuse activities. From the contacts we had with officials in municipalities, with the experience of the systems they manage, it seems that a monthly cost of 15 NIS per household would be acceptable, which is around US$ 4, which would bring the cost per cubic meter of wastewater to US$ 0.35.

92.9% of households supported the idea of constructing a central WWTP in the village while 7.1% rejected. 88.2% of households expressed their willingness to pay money contribution for the construction of the wastewater sewerage network and treatment system and they can pay about US$ 75, whereas 11.8% refused to pay. 74.6% expressed their willingness to pay monthly fees for wastewater services after connecting their houses to sewerage network and they can pay about US$ 4 per month, whereas 25.4% rejected that. 73.8% of households expressed their agreement to reuse the treated wastewater to irrigate their lands, while 26.2% refused that.

Figure 2 shows that about 56.1% of households are willing to work in agriculture if their land is reclaimed and irrigated with recycled water, while 43.9% of respondents voted against. Pro-reuse of recycled water in agricultural irrigation (68.6%) and

Figure 3: Knowledge of farmers about reclaimed water irrigated cops

considered this practice as acceptable and necessary, meanwhile 31.4% represented the view of rejection.

Farmers interviewed in the area were willing to utilize treated wastewater in agriculture, although they had some concerns regarding marketing crops irrigated with treated wastewater. It appeared from the meetings and interviews that the difficulties (religious, psychological, hygienic safety) associated with reuse will be in marketing crops irrigated with treated wastewater. Thus, there is a need for public awareness and training regarding the conditions which make consuming crops irrigated with treated wastewater safe for use. All the questioned farmers underlined the necessity for routine laboratory testing of the treated wastewater to monitor the quality and ensure safety and suitability recycled water for irrigation. Fifty percent of the farmers expressed their knowledge that most of local agricultural products as well as those imported from Israel are being irrigated by treated wastewater while the other 50% denied their knowledge (Figure 3). About 40% of the latter group reported they will refrain consuming such products, if they would have known. However, 90% of the farmers are willing to use treated water for irrigation once an official religious decision (Fatwa) is issued regards suitability and safety.

Looking at previous activities in the West Bank regarding reuse, most of training and awareness programs were directed towards agricultural reuse. However, consumer awareness is essential to improve the marketing potential for crops irrigated with treated wastewater in accordance with standards. Thus, it will be recommended in the early stages to irrigate fodders and almonds which will not face marketing problems. It will be also possible to plant fodder crops in the open flat areas and among existing olive trees in the area within WWTP area. At later stages, other fruits could be planted especially tropical fruits.

Based on Palestine Standards for treated wastewater reuse and climatic conditions in the area, fodder crops, almonds and fruit trees were identified as potential crops to be irrigated with treated wastewater. Fodder crops such as alfalfa will be safely irrigated with treated wastewater and farmers there are familiar with such crop which is demanded by local markets. There are many fruit trees that could also be planted in the area and irrigated by treated wastewater. The fruit trees include:

- Tropical fruits (as citrus, guava, avocado, mangos and kiwi),
- Stone fruits (as almonds, pomegranate, peaches, plums and apricots),
- Other fruits such as grapes, apples, and date palm.

Despite the legal restrictions endorsed by the Ministry of Agriculture (MoA) regarding irrigation of vegetables and olive trees with recycled water, the latter can be utilized in supplementary irrigation of olive orchards. Figure 4 shows the willingness of farmers to cultivate fruit trees (53%) and their acceptance (84%) to eat recycled water irrigated fruits.

The areas identified for irrigation are mainly located along the nearby wadi where the treatment plant would be constructed. The slopes around the wadi will require some land reclamation activities to be used for irrigated agriculture. Thus, in the initial stages of the project, the more flat area of the wadi is proposed for irrigation of industrial crops in greenhouses, while highland with stone fruits. Farmers in Anza village cultivate rain fed areas with olives and field crops. Farmers understand the importance of irrigation and they are interested in reusing treated wastewater for agricultural production to improve their income.

For managing the proposed wastewater treatment and effluent reuse schemes, it will be possible to

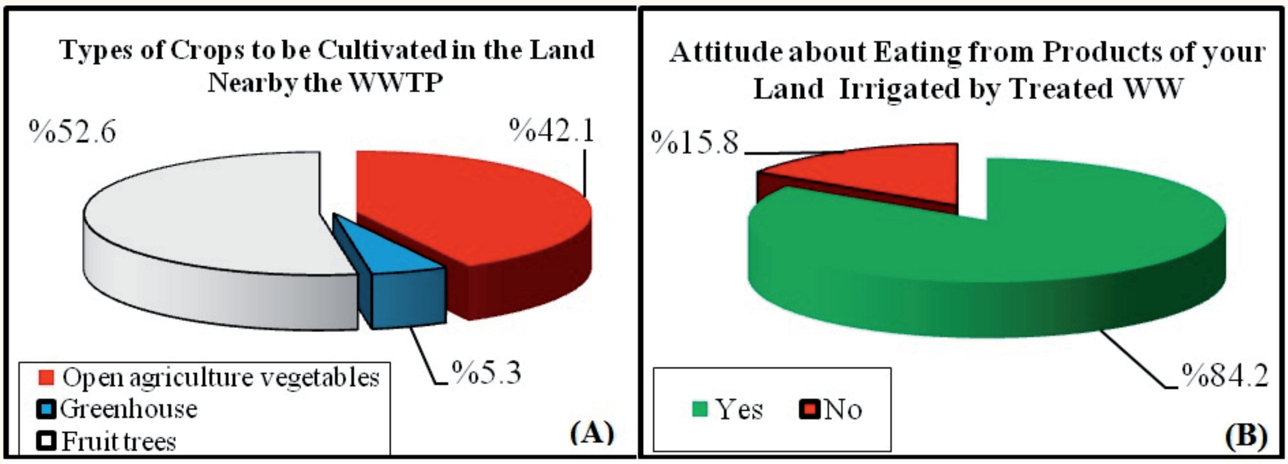

Figure 4: Farmers attitude towards cultivation and consumption of crops irrigated by recycled water

improve the organization and build capacity of the existing farmer associations in Anza village. Other possible management (administrative and legal coordination) form for the WWT facility can be administered and legally organized either through the Village Council or by establishing a new Recycled Water Association (RWA). However, housing the RWA in the village council lead to a better human capacity and organizational structure to manage and operate both the WWTP and the effluent reuse schemes. Alternative management options for the recycled water system should be analyzed before completing the construction of the WWTP.

Technology selection and local applicable regulatory requirements

The legal and institutional frameworks for the management of wastewater and effluent reuse have been expressed in the Palestinian development plans and under focus in the policies and strategies of the Palestinian Water Authority (PWA) and Ministry of Agriculture. Due to political, socio-economic and capacity building issues enacting of such ambitious policies and putting development strategies into practice are still lacking. However, the use of treated wastewater in agricultural purposes in Palestine is accomplished at pilot scale and the Palestinian farmers lack the practical experience in using this resource in a safe and an environmentally sound manner.

Seasonal drought periods, increased water demands in Palestine have forced water-related authorities, local councils and farmers to consider use of treated wastewater as a supplementary water source. As a consequence, there is a growing momentum favouring use of recycled water in agricultural irrigation. However, despite few successful pilot scale recycled water efforts, there has been a simultaneous increase in opposition against widespread of large scale agricultural reuse schemes (Al-Sa`ed, 2007b; Nassar et al., 2009). This is mainly due to public psychological issues and potential impacts of rest pollutants (mainly nutrients and pathogens) in the recycled water on human health and natural environment.

In this study, we argue that proper selection of treatment technologies considering community consultation and local environmental rules for treated effluent is one core element for achieving sustainable wastewater treatment and effluent reuse schemes. A comprehensive one year study was conducted to investigate the proper wastewater treatment system considering process reliability, treatment efficacy, capital and annual running costs, environmental impacts, and effluent quality. The ultimate goal is to reduce food insecurity in Anza village through planned use of recycled water in restricted agricultural irrigation. The treatment applied consists of pre-treatment (screening, grit removal) and biological units (vertical flow constructed wetlands and sequencing batch reactors) followed by disinfecting unit. Initially, detailed design was made for the constructed wetland system based on EU requirements related to installing natural treatment systems due to low energy and running costs.

The consequences of inadequate sanitation facilities in Palestine are awful. Therefore, planning and design of use or non-use oriented sanitation services should aim at the selection of robust wastewater treatment alternatives that reliably protect both public health and the environment. The selection of process technology focussed heavily on the environmental, health and safety aspects of recycled water alternatives. Thus, mechanised treatment alternatives, health and safety issues, public acceptance and costs were among the issues analyzed and evaluated in the feasibility study. In doing so, the planning team has considered the effluent requirements regards recycled water of safe and environmentally sound quality and the recently published technical regulations set for nitrogen contents in treated wastewater (Table 1). Valuing those rules and guidelines with detailed analysis of treatment alternatives revealed that the sequencing batch reactor (SBR), a modified activated sludge system, was the most reliable process technology. Table 2 illustrates the technologies evaluated with potential recycled water use purposes.

More stringent rules and guidelines for treated wastewater are becoming increasingly required. Combined with limited financial and human resources, lack of public awareness, increasing pollution loads, limited access to available land and

Table 1: Palestinian effluent quality guidelines (PSI, 2012)

Parameter	Agricultural reuse (class B)	Stream discharge*
BOD (mg/l)	20	10
TSS (mg/l)	30	10
Total-N (mg/l)	30	10
Total coliforms (CFU/100 ml)	1000	1000

* According to recent Israeli standards for treated wastewater reuse.

Table 2: Technology selection based on potential recycled water use purposes

Recycled Water use Purposes	Mechanised WWTP	Natural WWTP
• Restricted agricultural irrigation (pasture irrigation, stone fruits, industrial crops)	Screening, grit	Screening, grit, UASB
	SBR systems	Vertical flow constructed wetland
• Discharge into nearby stream (during winter season and/or failure of recycled water use	Disinfecting unit (chlorination)	Disinfecting unit (chlorination)
	Centrifuge (sludge dewatering	Sludge drying beds

freshwater sources, public health and environmental protection, periodic seasonal drought periods call for the establishment of sustainable wastewater treatment facilities in Palestinian communities. Inbar (2006) reported on the new Israeli regulations for treated wastewater reuse in agricultural purposes and discharge into streams. Those rules and guidelines are also applied for the approval of Palestinian wastewater facilities according to signed memoranda of understandings. The type of wastewater treatment technology dictates the quality of treated effluent. Restricted or unrestricted use of treated effluent for irrigation of agricultural crops is affected by the soil type, receiving water bodies' quality, irrigation type, crop patterns, and the acceptance of farmers to use and willingness to pay, if any. The choice of wastewater treatment technology should take into consideration qualitative and quantitative selection criteria, where the selection should based solely on financial aspects (low capita cost) but should reflect best practical option, foot print and preserve natural resources. Furthermore, optimized process control strategies should be possible to improve the biological process performance and reach a proper water quality and energy consumption.

Irrespective of the planned use of recycled water, public health risks and the potential environmental damages (soil, plant, water) are issues of paramount importance while analysing wastewater treatment alternatives (Al-Sa`ed 2007a; 2007b). According to Fatta et al., (2004) health considerations tackle fate of pathogenic organisms that are, or could be, present in the treated effluent and the build-up of toxic materials within the soil, and subsequently within plant and animal tissues which might eventually reach the human food chain. The leaching of materials such as nitrates and toxic-soluble chemicals into the groundwater is also a matter for concern. Environmental risks involve the effects of the use of

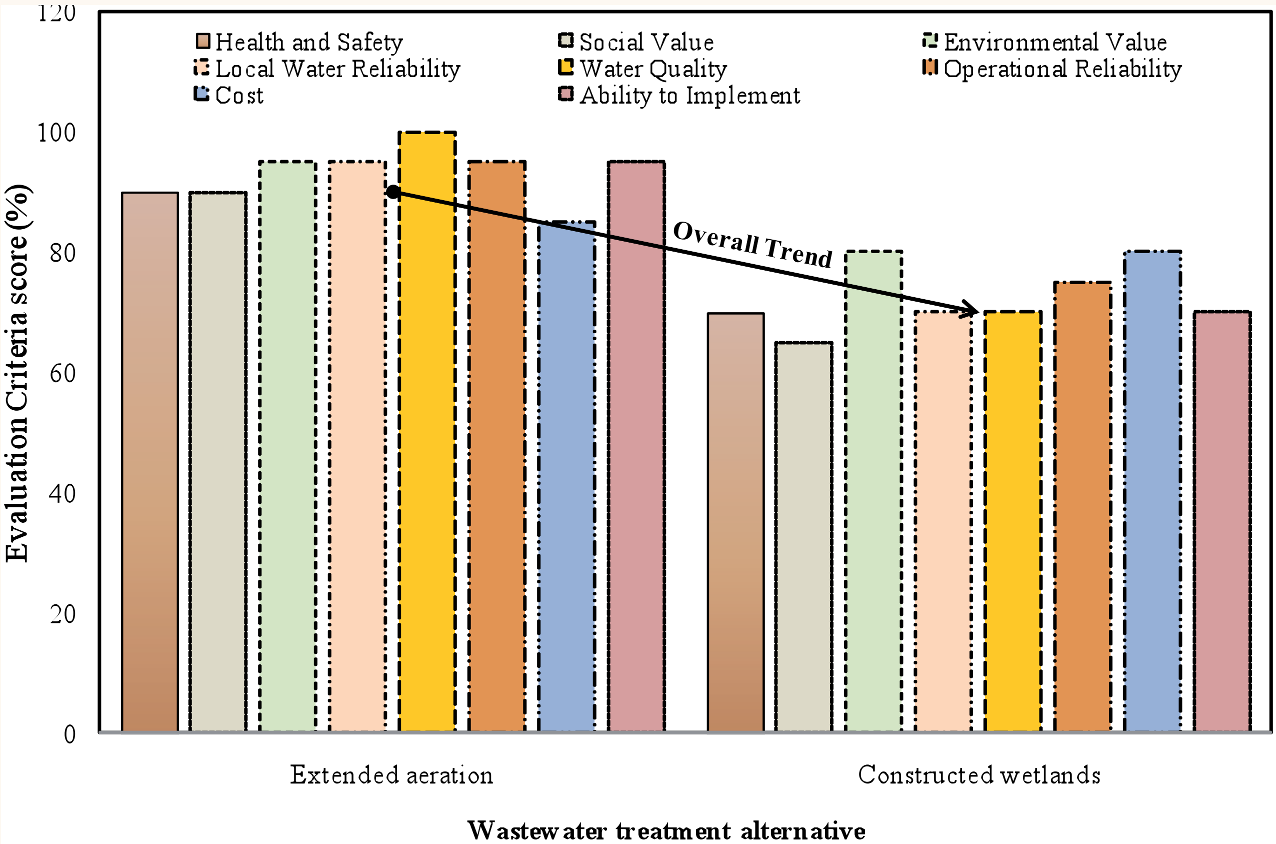

Figure 5: Evaluation criteria for the selection of wastewater treatment systems

high strength nitrogen wastewater containing other dissolved substances (TDS, heavy metals and boron ...etc) which have deleterious effects on both growth and development of plants (Lado and Ben-Hur, 2009). Recently, the Palestinian Standards Institution (PSI, 2012) issued new technical regulations (TR34-2012) implementing the precautionary principle [if, then] under the code of water resources protection. The PSI regulations require that wastewater treatment technologies should comply with an effluent quality for total nitrogen of 30 mg N/l, if the communities are planning to use recycled water in agricultural irrigation.

Considering technical, environmental, socio-cultural and economical aspects of both SBR compared and constructed wetlands revealed an overall positive decision for installing an SBR system (Figure 5). This decision is supported by the reply of respondents towards health and environmental issues, which the households and farmers reflected. The limited access to water and land as well as urgent needs to protect the environment and natural resources were the main factors behind the decision for mechanised treatment systems rather than natural based technologies. This decision enhances the safe use of recycled water as a supplement to irrigation water in Anza village; a core element of achieving an integrated water management plan.

Sustainability of sanitation and agriculture should be considered within an integral natural water-agro-ecosystem. In this ecosystem soil-water-plant-environment-living beings coincide very well, where equilibrium of food chains and their related water-energy balances are balanced (UNEP, 2011). Ecological sanitation efforts should adopt innovative and environmentally sound wastewater treatment technologies, not only to ensure sustainable agriculture but also improve agricultural productivity, improve soil quality and conserve the environment. Sanitation facilities utilizing a zero-liquid discharge as water (resource) conservation technology is the future of water and food independent communities.

Conclusions and recommendations

Based on the results presented and discussed above, the following major conclusions and recommendations can be made:

- The public acceptance is crucial to the sustainability of recycled water use in agricultural purposes in Palestinian communities. The essential role that public consultation may play should be fully recognised at all levels (decision makers, planners and funding agencies). Given the positive response of farmers in Anza to utilize recycled water in agricultural irrigation in Anza village, increasing public sensitisation of adjacent communities on recycled water use and the associated benefits will scale up Anza irrigation schemes.
- Innovative treatment and recycling systems should be employed to maximize an effective use of the recycled water in a zero-liquid discharge approach. It is important to underline the role of recycled water use to the Palestinian water sector since reuse will lower the increasing demand pressure on the available water resources. Finally, an efficient use of recycled water for different purposes will enable Palestinian communities to achieve water self sufficiency, independence and overcome the limited access to available water sources.
- Use of recycled water for arid land irrigation will reduce food insecurity and improve livelihood of farmers through cultivation of high price crops irrigate by treated effluent. Reuse of treated effluent will increase food productivity and efficacy by changing crop patterns into fruit trees, fodder and industrial crops.
- The limited access to water and land as well as urgent needs to protect the environment and natural resources were the main factors behind the decision for mechanised treatment systems rather than natural based technologies. This decision enhances the safe use of recycled water as a supplement to irrigation water in Anza village; a core element of an integrated water management plan.

Aside from the political constrains caused by the Israeli occupation, the problems of limited access to water sources and land scarcity will continue because of increased population growth, high living standards, and rapid urbanization. All this threaten the water supply in general and agriculture in particular and lead to both an increase in water consumption and pollution of land and water resources. Establishing sustainable sanitation facilities integrated with agro-ecological systems in Palestinian rural areas is the road map. Since public awareness campaigns and education are the foundations of sustainable wastewater treatment facilities, technical support, training and engagement of main stakeholders in a fair decision-making process ensure an enabling environment for food insecurity abatement and rural development in Palestine.

Acknowledgements

This paper lies among the activities of the project “Beit Dajan and Anzah villages- North West Bank- Produce more food through sustainable and safe use of reclaimed wastewater in agriculture”, an EU funded project within the Food Security Thematic Programme' (FSTP). Contract No. DCI-FOOD/2010/237-082; duration: 1.1.2011-1.1.2014). The authors are grateful for the EU financial support for the implementation of this project.

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