CASE STUDY

WASTEWATER TREATMENT AND REUSE — EL ATTAOUIA, MOROCCO

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INTRODUCTION

Wastewater treatment in rural areas of Morocco is significantly lacking, with uncontrolled discharge the norm. Due to a lack of irrigation options, farmers often use untreated wastewater and subject themselves and consumers to significant health risks. In the case of Morocco, approximately 70 million m³ of untreated wastewater are used each year without any sanitary precautions to irrigate an area of more than 7000 hectares.[1]

The Town of El Attaouia is situated in the region of Haouz, Morocco, 75 km NE of Marrakesh (see Figure 1). The region is arid with irregular precipitation varying from 100-300 mm/yr, making irrigation essential for any intensive agricultural production. Temperatures vary between 10°C in January to 45°C in July. The Town is experiencing rapid population growth, from 11,000 inhabitants in 1994 to 20,000-23,000 in 2010, to a projected population of 38,800 by 2015 producing an ultimate daily wastewater flow of 2,000 m³.[2]

Figure 1. El Attaouia, Morocco

An innovative wastewater treatment technology was established in 2003 to treat the town's wastewater. The system is based on pilot-scale research carried out at the Institut Agronomique et Vétérinaire Hassan II between 1985-2000 and consists of anaerobic reactors followed by a high rate algae pond and maturation basins.[3] The technology was developed to address certain limitations in lagoon systems, which is the most prevalent form of wastewater treatment in Morocco, including:

- A reduction in the surface area occupied by the basins
- A simplification of sludge management
- Recovery of biogas and elimination of odours

The objectives of the full scale project at El Attaouia are to:

- Effectively treat the town's wastewater
- Reuse the treated wastewater for agricultural production
- Demonstrate the technology's capacity at full scale

El Attaouia waste water treatment plant — Phase II construction (2011)

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Institut Agronomique et Vétérinaire Hassan II

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OVERVIEW OF THE WASTEWATER TECHNOLOGY

The wastewater system consists of two stages, with Stage I providing primary and secondary treatment and Stage II providing tertiary treatment. The first stage consists of two up-flow anaerobic digesters in series followed by a settling chamber and sludge drying beds. The second stage consists of a high rate algae pond followed by two maturation basins in series.

Stage I — Primary/Secondary Treatment

The role of Stage I is to remove organic matter and suspended solids from the wastewater and is depicted in Figure 2. Wastewater flows by gravity through two up-flow anaerobic digesters in series having a diameter of 10 m, a depth of 7 m and a volume of 550 m^3 each. The design residence time is 0.62 d per digester. Sludge exiting the second digester is separated in a settling chamber (HRT 1.5-2.5 hrs) and is removed daily by gravity flow to sand drying beds. This is the only sludge management activity. A gravel filter was installed after the settling chamber to filter any remaining solids prior to the wastewater entering the algae channel. Biogas is collected and can be flared to control odours or burned to produce heat or electricity.

Stage II — Tertiary Treatment

The role of Stage II is two-fold: firstly to reduce pathogen counts for agricultural reuse, and secondly to reduce nitrogen and phosphorus loads for sustainable crop production. For unrestricted reuse (i.e. irrigation of produce eaten raw) pathogen standards are typically 10^3 CFU/100mL *E.coli* and <1 helminth egg/litre, which is consistent with Moroccan regulation.[4,5] The high pH fluctuations caused by the photosynthesis/respiration of the algae helps to reduce pathogen numbers in both the high rate algae pond and the maturation basins. Maturation basins also reduce the effluent algae content. The design residence time in the high rate algae pond is 3.3 days and is 1.5 days in each of the maturation basins. The system is not designed to achieve 10^3 CFU/100mL *E.coli* for unrestricted wastewater reuse.

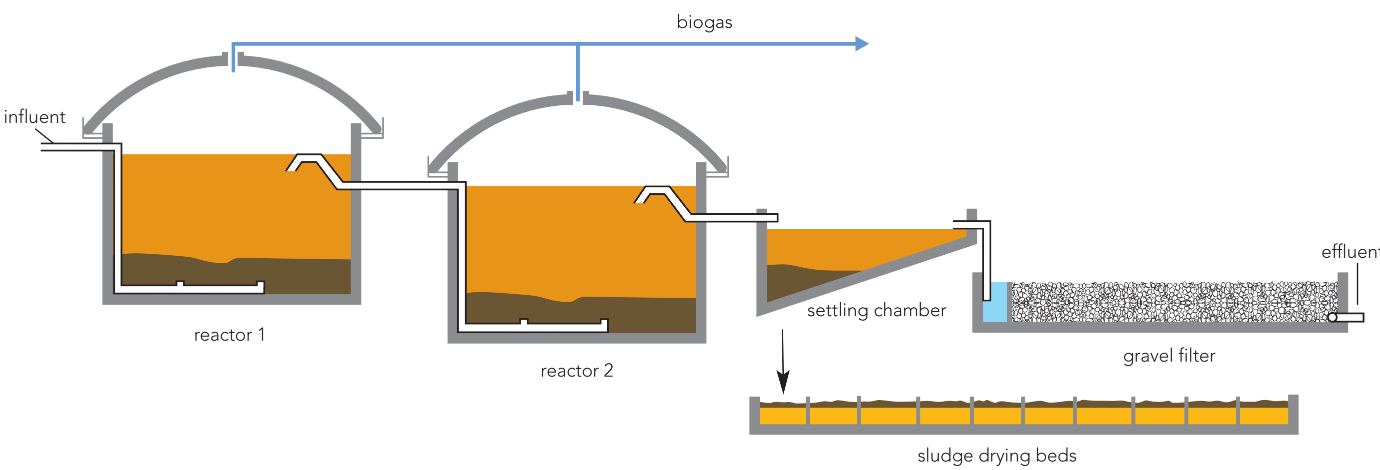


Figure 2. Cross-Section Schematic of Stage I Unit Processes

SYSTEM CONSTRUCTION

The project was completed in two phases. The first phase was completed in 2003 with a design flow of 450 m^3/d; however, by 2006 the WWTP was receiving 880 m^3/d due to strong population growth. A second phase was completed in 2011 to treat an additional 820 m^3/d for a total design flow of 1,270 m^3/d. The dimensions of the WWTP Unit Operations are described in Table 1 with a net specific occupied area (construction only) of 0.70 m^2 per person equivalent (PE).

The capital cost of the system was 400 Moroccan Dirhams/PE or 50 USD/PE. The cost was very low due to the use of local materials and contractors applying a lower standard of construction practices. Following stringent civil engineering rules the same construction would have been at least double the cost.

Table 1. WWTP — Dimensioning of Unit Operations

	UNITS	PHASE I (2003)	PHASE II (2011)
Design Flow	**m^3/d**	**450**	**820**
Anaerobic Reactors			
Number of Reactors	Number	2	2
Diameter	m	10	10
Depth	m	6.5	8.0
Volume (per reactor)	m^3	550	630
Residence Time (per reactor)	d	0.62	0.62
Settling Chamber			
Length x Width	m	8.5 x 2.8	23 x 4.5
Depth	m	2.2	2.2
Operating Depth	m	1.7	1.7
Residence Time	hr	1.5	2.5
Gravel Filter			
Flow	m^3/d		1640
Length x Width	m		24 x 14
Depth	m		0.8
Volume of Gravel	m^3		135
Sludge Drying Beds			
Number of Beds	Number	4	10
Length x Width	m	7.0 x 2.8	8.0 x 3.0
Sand Depth	m	0.7	0.7
High Rate Algae pond			
Length x Width	m	124 x 60	
Depth	m	0.7	
Operating Depth	m	0.45	
Residence Time at 1270 m^3/d	d	3.3	
Maturation Basins			
Number of Basins	Number	2	
Length x Width	m	63 x 25	
Depth	m	1.2	
Operating Depth	m	1.0	
Residence Time (per basin)	d	1.5	

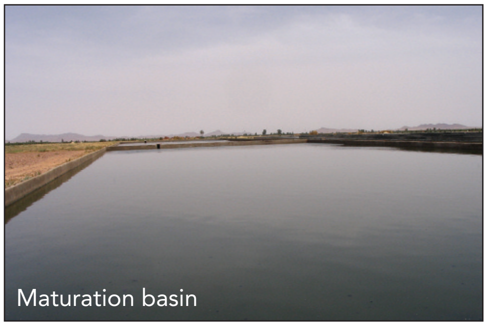
Phase I Unit Processes


Upflow anaerobic digester


Settling chamber


Sludge drying bed


High rate algae pond


Maturation basin

SYSTEM PERFORMANCE

The system performed well for the first three years of operation fulfilling the major effluent quality requirements; however, by 2006 the system was receiving 880 m^3/d, almost twice the design flow of 450 m^3/d. Even with high hydraulic loading rates the system was capable of removing 85% of COD and 80% of TSS (see Table 2). However, the anaerobic digesters where only removing 20% of COD, while they are capable of removing 60% if the residence time is respected. Nitrogen was modestly reduced with 22% reduction in TKN-N, while phosphorus was not removed in the system. Fecal coliform were reduced by 4.4 logs, from 4.6 x 10^8 to 1.8 x 10^4 CFU/100mL and helminth eggs are completely removed from the wastewater.

Inlet to high rate algae pond — system overloaded (2006)

The high hydraulic loading rate resulted in solids migrating to the high rate algae pond, which was causing sedimentation problems in the channel with the algae dying off, anoxic conditions prevailing and odours being produced. Additional anaerobic digesters, an additional settling chamber and a gravel filter were installed as part of the Phase II construction to address these issues. It was determined that the high rate algae pond and maturation basins were sufficiently large to accommodate the ultimate design flow of 1,270 m^3/d.

Table 2. System Performance (2006)

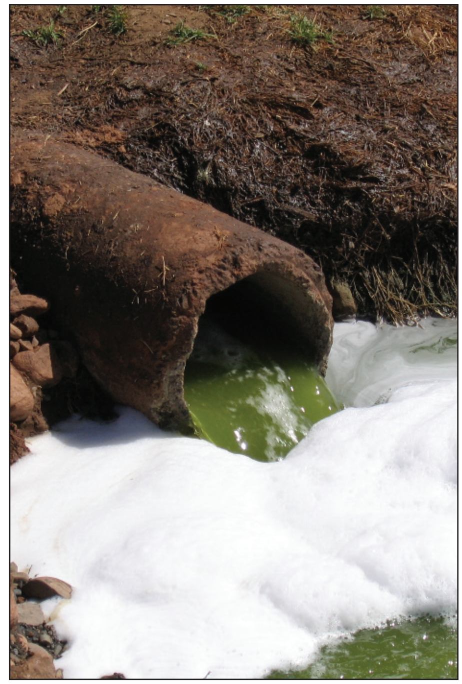
Sampling Point	COD (mg/L)	TSS (mg/L)	TKN-N (mg/L)	PO_4^{3-}-P (mg/L)	Fecal Coliform (CFU/100mL)	Helminth Eggs (Eggs/L)
Influent Wastewater	900	300	72	7.8	4.6 x 10^8	35
Settling Chamber Outlet	720	—		—	—	—
High Rate Algae Pond Outlet	345	380	72	7.1	—	—
Maturation Basin I Outlet	240	-	56	8.3	—	—
Maturation Basin II Outlet	135	60	50	7.6	1.8 x 10^4	0
Reduction	85%	80%	22%	—	4.4 logs	100%

WASTEWATER REUSE

The agricultural land surrounding the wastewater treatment plant does not receive enough water from the irrigation reservoir to meet the water demand, making the treated effluent a valuable resource for local farmers. In order to exploit the treated wastewater an Association of Irrigation Water Users was created and legally constituted in 2003 under the supervision of the Regional Office of Agricultural for the Region of Haouz (ORMVAH). The treated effluent is shared amongst 7 farm families and is used to irrigate 20 ha of agricultural land. The irrigated surface will increase to 60 ha with the completion of Phase II.

Traditional flood irrigation with treated wastewater

El Attaouia WWTP and zone irrigated with treated wastewater



Treated wastewater containing algae

An evaluation of the reuse of treated effluent for agricultural production was conducted during the summer of 2008; six years after the Association of Irrigation Water Users was created.[6] Yield was compared to adjacent farms irrigating with water from an irrigation reservoir and from farms relying solely on rainfall (Table 3). The farmers using the treated effluent to irrigate their fields did not add any inorganic fertilizer.

Table 3. Comparison of Crop Yield with Different Sources of Irrigation Water

Crop	Yield with Source of Irrigation Water (Quintal/ha)		
	Treated Effluent	Reservoir Water + Fertilizer	Rainfall Only
Wheat	53	53	8
Alfalfa	356	285	—

The irrigated fields produced 6.6 times the yield of wheat compared to fields relying solely on rainfall and it is impossible to produce alfalfa in this region without irrigation. The crops irrigated with treated effluent produced similar yields to crops irrigated with reservoir water, only without the addition of inorganic fertilizer. The use of treated effluent is clearly beneficial when compared to rainfall alone and provides similar yields to crops grown with reservoir water, while saving on fertilizer costs.

The electrical conductivity (EC) of the treated effluent is fairly high (2.0 mS/cm) and is at the low end of the salt tolerance rating for moderately sensitive crops such as alfalfa but below the tolerance rating for moderately tolerant crops such as wheat.[7] An EC of greater than 2.5 mS/cm could risk soil salination over the long term.

In addition to using treated wastewater, the farmers collect the dried sludge, which also has high conductivity levels. The sludge is an excellent source of nutrients and organic matter; however, conductivity levels in the soils must be monitored over time.

Mature wheat irrigated with treated wastewater

CONCLUSIONS

Wastewater treatment technologies with low energy demand and low maintenance requirements are necessary for the sustainable wastewater management in poor to middle income countries. Treated effluent is an important potential source of irrigation water for arid and semi-arid regions. The system in El Attaouia, Morocco, provides a good example of wastewater treatment and agricultural reuse in an arid climate which can be replicated in similar rural towns and villages.

Fodder corn harvest from fields irrigated with treated wastewater (2008)

[1] World Health Organization (2008). *Intestinal parasitosis and use of untreated wastewater for agriculture in Settat, Morocco.* Eastern Mediterranean Health Journal 14:6, 1435-1444.

[2] Melkaoui Abdelhadi (2006). Performances et dimensionnement du réacteur anaérobie à flux ascendant à deux etapes (RAFADE). De la station pilote de l'IAV à la celle de la Ville d'El Attaouia. Mémoire de fin d'Etudes IAV Hassan II, Rabat.

[3] B.El Hamouri (2004). Réacteur Anaerobie et Chenal à Haut Rendement pour l'Épuration des Eaux Usées des Petites Communautés. Réalisation, Exploitation et Performances. Institut Agronomique et Vétérinaire Hassan II. ISBN 9981-1769-8-2.

[4] World Health Organisation (2006). WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume II. Wastewater Use in Agriculture. WHO Press. Geneva, Switzerland.

[5] Ministre de l'Équipement et du Ministre chargé de l'Aménagement du Territoire, de l'Urbanisme, de l'Habitat et de l'Environnement du Maroc (2002). Directives marocaines pour la réutilisation des eaux usées en agriculture. Directive n° 1276-01 du 10 Chaabane 1423.

[6] Gérôme Brassard-Duperré (2008). Impacts de la réutilisation des eaux usées traitées sur les terres agricoles irriguées par la station d'épuration d'El Attaouia. Rapport du stage final en Technologie Agricole et Développement Internationale. Université Guelph-Campus d'Alfred.

[7] Pettygrove, G.S. (Edit) (1990). Irrigation with Reclaimed Municipal Wastewater-A Guidance Manual. Lewis Publishers Inc., Chelsea, MI.

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