

DECENTRALISED WASTEWATER TREATMENT SYSTEMS FEEDED BY RENEWABLE ENERGY FOR SMALL COMMUNITIES

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Abstract

The efficient use of energy and water resources is the key to achieve a sustainable development for the Mediterranean countries. Decentralised wastewater treatment systems fed by renewable energy can contribute to the sustainability goals by offering wastewater treatment as well as renewable water and energy sources in those areas with limited resources and no access to centralised wastewater systems. In this work the results of the first stages of a cooperative research project between University of Cantabria (Spain) and Balqa Applied University (Jordan) granted by AECID focused in the study of the wastewater treatment needs of a Mediterranean country: Jordan and the viability of implementation of Membrane Bioreactor Technology self-supplied by photovoltaic solar modules (PSPMBR) as decentralised wastewater treatment systems in rural areas of Jordan with reuse purposes are presented.

Keywords: Decentralised wastewater treatment, renewable energy, small communities, Jordan

Introduction

The energy consumption in The Hashemite Kingdom of Jordan has grown a big rate (10 to 14% per year) and the energy bill averaged more than 20% of the gross domestic product (GDP). The supply of imported oil and other energy products has been unreliable due to the regional political conflicts. Jordan has no legislation that affects the use of renewable energy and has no policies for appliance or equipment labelling related to energy consumption. The high population growth rate together with the country's rapid economic development has been accompanied by an increase in water demand, while Jordan's water resources are, on per capita basis, among the lowest in the world. The available amounts of water failed to less than 91 m³/capita/year by the year of 2025, while the international water poverty line of 1000 m³/yr. The increase in water demand in addition to the limited resources has enforced Jordan to prospect for new nontraditional water resources; treated wastewater reuse is considered an attractive option for this goal. Just 54 % of Jordan population is connected to central sewage systems. Studies indicated that about 41% and 71% of Jordan's communities have population less than 500 and 2000 inhabitants respectively, which makes the application of centralized wastewater system in these areas infeasible. 67% of the area has a population density less than 10 persons /km² making difficult the use of centralized wastewater treatment systems. The energy cost represents about 35% of the total operation cost of wastewater treatment in Jordan. This result explains the importance of using low source of energy such as solar energy.

In the last years solid-state energy conversion technologies, such as photovoltaic (PV) cells, are providing very attractive prospects for sustainable, environmentally clean and grid-competitive

energy generation for small communities, (Dominguez et al., 2009). At the same time in the last years membrane based technologies have increase their presence in the wastewater treatment processes. The conventional activated sludge technology is being substituted by the so-called membrane bioreactors (MBRs) which can produce high-quality effluent suitable for unrestricted irrigation and other applications, (Ortiz et al., 2010).

According to the former, the objective in this work is the study the wastewater treatment conditions in a Mediterranean country: Jordan, and the development of wastewater treatment systems in small communities by means of MBR technology self-supplied by photovoltaic solar modules.

Methodology

In order to achieve the objectives in the work the following activities have been performed: i) Determination of the characteristics of wastewater in Jordan. Review of applied technologies in wastewater treatment in Jordan., ii) Evaluation of the Jordan legal limits for water discharge and reuse, ii) Review of the state of the art about a) implementation of the MBR technology related to geographical areas with similar physic and climate characteristics to Jordan, and b) integration of self-supply sources by means of photovoltaic solar modules in water treatment systems, ii) Evaluation of the energy requirements of the MBR process and preliminary design of a MBR prototype self-supplied by photovoltaic solar modules.

Results and Discussion

The huge recompilation of data regarding the wastewater characterisation and treatment technologies in Jordan carried out in the project are summarised in the following: There are 23 municipal treatment plants, 4 of which are stabilization ponds, 16 as mechanical mode, and 3 are used to treat the septic waste. These plants serve about 56 % of the population. About 78% of wastewater is treated by stabilization ponds. This treatment is climate dependent, which explains the low efficiency obtained by these plants especially during winter season. All stabilization ponds in Jordan are overloaded based on both hydraulic and organic load, which is considered an additional reason for low efficiency. The total inflow to these plants is around 216,412 m³/d, of which 186223 m³/d inflow correspond to Asamra WWTP. Data concerning wastewater characteristics, treatment, operations, and method of treatment for all treatment plants in Jordan was collected from water authority of Jordan (WAJ). The mean values of typical compositions analyzed in this work are based on one year (2008). The average monthly concentration for each plant was used to calculate and analyze the overall efficiency indicators. In order to determine the characteristics of wastewater, the team took samples from four WWTP (Table 1)..

Table 1 Influent and effluent characteristics of selected WWTP in Jordan. Data from WAJ (2008)

PARAMETER	Jordanian W.W.T.P.				
	Al-Samra	Irbid	Ramtha	Wadi Hassan	Average
BOD in (mg/L)	705	1030	915	870	880
BOD out (mg/L)	140	32	13	12	49
BOD removal %	80	97	98	98	93
COD in (mg/L)	1890	2205	1980	1710	1946
COD out (mg/L)	605	110	70	63	212
COD removal %	67.8	95	96	96	89
TSS in (mg/L)	591	1040	780	770	795
TSS out (mg/L)	117	51	30	25	56
TSS removal %	80.2	95	96	96.7	92
NH4-N in (mg/L)	90	108	90	118	102
NH4-N out (mg/L)	97	12	1	4	28
NH4-N removal %	No data	88	99	96.6	95
DO out (mg/L)	1.8	3.9	4.3	5.8	4

Influent characterisation values can be used to describe the characteristics of not treated wastewaters in Jordan. All influent parameters are high enough to need treatment prior to discharge or reuse. In 1995, Jordan's Department for Standards published a comprehensive reuse standard for treated domestic wastewater principally developed by the Water Authority of Jordan. The standards establish a variable standard for wastewater quality for 7 categories of discharge or direct reuse. They provide values for a range of parameters that are to be considered for guidance only, the most representative are summarised (Table 2).

Table 2. Jordanian most significant guidance standards for domestic wastewater reuse (JWA)

Parameter	USE A	USE B	USE C-I	USE C-II	USE C-III
BOD ₅ (mg/l)	60*	15	30	200	300
COD (mg/l)	150**	50	100	500	500
DO (mg/l)	>1	>2	>2	----	-----
TSS (mg/l)	60**	50	50	150	150
Turbidity	10	2.0	10	----	-----
E-coli	1000	100	100	1000	1000
TDS (mg/l)	1500	1500	1500	1500	1500
T-nitrogen (mg/l)	70	45	45	70	70

USE A: allowable limits for discharge of water to streams, wades or water bodies. **USE B:** allowable limits for use in artificial ground waters aquifers. **USE C:** allowable limits for reuse in irrigation, **USE C-I:** cooked vegetables, parks, playgrounds and slides of roads within city limits; **USE C-II:** fruit trees, slides of roads outside city limits and landscape; **USE C-III:** field crops, industrial crops and forest trees; *: for biological plants or plants with polishing ponds BOD₅ is considered as the filtered BOD; **: for biological plants or plants with polishing pond the allowable limit is twice this number

According to the values shown in Table 2 both, influents and effluents from Jordanian WWTP need further treatment prior to some reuse activities. MBR technology can provide the degree of treatment able to reach Jordanian reuse standards, Ibáñez et al (2010). The application of MBR as decentralised

wastewater technology for isolated areas has mostly been reported in the literature in the last five years. Examples at pilot plant scale have been considered in this work in order to determine the most adequate configuration and operational parameters for the desired application, (Garzón, 2010). Regarding the integration of self-supply sources by means of photovoltaic solar modules in water treatment systems Reverse Osmosis (RO) is till now the most the preferred technology used in combination with solar photovoltaic modules (42% of literature reviewed), On the other side, the integration of MBR with self supply systems is not described in the literature, thus indicating the need of research work in this field. Although some application at real scale can be found, most literature is referred to laboratory and pilot plant scale, thus indicating that although both technologies are mature by themselves integration of both technologies needs deep research work in order to obtain competitive and reliable systems.

Taking advantage of the previous literature pilot plant viability studies have been performed by means of a Zenon pilot plant. Experimental conditions and complete results are detailed somewhere else (Ibáñez at al, 2010). Based on the pilot plant results the energy requirements for an autonomous MBR system for three case studies, 4, 20 and 60 equivalent inhabitants are presented (Table 3) as well as the photovoltaic module characteristics needed to satisfy those energy requirements obtained by means of PVSYST software system.

Table 3. Autonomous MBR pilot plant energy requirements and corresponding Photovoltaic Modules (PM) characteristics.

Eq Inh	MBR Energy requirements (W)	PM Model	P.M. Number	P.M. Configuration	P. M. Power (kWp)
4	2421	HIT-240HDE4	4	2 SER – 2 PAR	0.96
20	6017	VSG-435	5	1 SER – 5 PAR	2.17
60	15181	VSG-435	11	1 SER –11 PAR	4.79

Conclusions

The characterization of Jordanian domestic wastewaters and WWTP effluents indicates that the conventional centralized technologies, when available, used do not allow the Jordanian standards for wastewater reuse.

Jordanian energy consumption and water ability data indicates the need of decentralized wastewater systems and the opportunity of integration of self –supply energy sources.

The state of the art regarding integration of self-supply sources by means of photovoltaic solar modules in MBR systems indicates that although both technologies are mature by themselves integration of both technologies needs deep research work in order to obtain competitive and reliable results at large scale.

Energy needs for a BMR systems able to attend the wastewater treatment needs of small communities, 2, 20 and 60 equivalent inhabitants, have been obtained, thus allowing the obtention of preliminary results regarding the adequate photovoltaic system to provide such energy requirements.

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