Desalination and Water Treatment
www.deswater.com

10 (2009) 148–152

1944-3994 / 1944-3986

Pilot plant for wastewater treatment involving septic pit and biological filtration on sand of dunes of the Algerian Sahara

Youcef Touil[a], Samir Taha[b], Rachid Issaadi[c], Abdeltif Amrane[b*]

[a]*Laboratoire de Biogéochimie des Zones Arides, Université Kasdi Merbah, 30000 Ouargla, Algeria*
[b]*Equipe Chimie et Ingénierie des Procédés – ENSCR / Université de Rennes 1, UMR CNRS 6226, Sciences chimiques de Rennes, ENSCR, Campus de Beaulieu, av. du Général Leclerc, 35700 Rennes, France*
Tel. +33 (2) 23 23 81 55; Fax +33 (2) 23 23 81 20; email: abdeltif.amrane@univ-rennes1.fr
[c]*Laboratoire de Génie Chimique, Procédés de réactivité de surface et environnement, Université Saad Dahlab, Route de Soumaa, B.P.270, 09000 Blida, Algeria*

Received 18 September 2008; Accepted in revised form 3 September 2009

ABSTRACT

A pilot plant involving a septic pit followed by sand filtration was used to treat urban wastewater in the south of Algeria. Experiments carried out in triplicates simultaneously in three identical pilot plants showed the feasibility of the process, since BOD_5, COD and SS removals remained above 70% over 2.5 months of the experiment. The permeability of Sahara sand of dune allows therefore its use for water biofiltration; however an additional drainage should be considered to avoid salt problems. The next objective is the process validation on an industrial scale.

Keywords: Pilot plant; Sand biofiltration; Wastewater treatment

1. Introduction

In the basin of Ouargla (in the south of Algeria), the irrational exploitation of water and the use of irrigation system based on the immersion method involves many losses of water by infiltration joining the subjacent layers. Moreover, the discharges of wastewater in an anarchic way contribute considerably to the contamination of the groundwater and lead to the disruption of oasis ecosystems. The development of an alternative source of irrigation [1] in replacement of groundwater would therefore contribute to the fossil water protection.

Among the available processes for wastewater treatment, the use of septic pit followed by sand filtration appeared to be the most relevant in the south of Algeria, owing to the small agglomeration sizes. Sand filtration has been extensively studied [2–4] as well as the biological activity into slow sand filters [5]. This work deals with wastewater treatment using an anoxic tank (septic pit) [6] followed by biofiltration [7] using sand of dunes. The objective was to achieve the required water quality for irrigation [3].

2. Materials and methods

The pilot plant consisted of a feeding tank, the raw water was then pre-treated in an anoxic tank of 7.8 L (Plexiglas septic pit) according to Gougoussis [6], which was followed by the biofiltration unit containing 70 cm height of sand of dune (polyvinyl chloride column of 90 cm height and 24.2 cm diameter). 10 cm gravel of approximately 10 mm mean diameter was also added at the bottom of the biofiltration unit to ensure correct draining,

* Corresponding author.

Presented at EuroMed 2008, Desalination for Clean Water and Energy Cooperation among Mediterranean Countries of Europe and the MENA Region, 9–13 November 2008, King Hussein Bin Talal Convention Center, Dead Sea, Jordan.

according to Guagne and Brissaud [8]. The system was completed by a collecting tank. Experiments were carried out in triplicates simultaneously in three identical pilot plants, which were fed with urban wastewater. The pulsed feed of 2.6 L/d led to a loading rate of 5.6 cm/d [9].

The following parameters were monitored for 72 days on triplicate pilot plants: pH, conductivity, chemical oxygen demand (COD) by the colorimetric method [10], biological oxygen demand (BOD_5) (Oxitop IS6, WTW, Weilheim, Germany) and suspended solids (SS) by the filtration method [10].

The sand was also physically (Table 1) and chemically (Table 2) characterized. Mean diameter, uniformity coefficient, porosity and permeability were considered for the physicochemical characterization. In addition to pH and conductivity, the carbonate and organic matter contents were determined to characterize chemically the sand of dune.

To achieve correct bacteriological quality of the treated water, chlorination was carried out in the feeding tank.

3. Results and discussion

3.1. Characterization of the sand of dune

Sand of dune from several (15) quarries was considered (Tables 1 and 2). Their characterization confirmed their potential to be used as filtration media [11], since the equivalent diameter, the uniformity coefficient, the porosity and the permeability were in the ranges 0.09–0.14 mm, 1.57–2.60, 38–57% and 0.13–0.41 m/h respectively, showing that sand size can be characterized as thin to medium.

Physicochemical (Table 1) and chemical (Table 2) characterization of the sand of dunes showed that the characteristics of all the considered quarries were close to those reported in the available literature [8,9,12,13]. It should only be noted high salinity and carbonate values for some quarries: Temacine quarry for salinity, Guemar and El Oued quarries for carbonate values.

3.2. Wastewater treatment

No significant variation of the conductivity was observed after the anoxic tank (Table 3). However, a clear increase was recorded after the aerobic treatment (1.3±0.1 for regular sampling over 72 days — Table 3), indicating sand leaching and organic matter transformation.

A weak increase of the pH was recorded after both treatments (Table 3). The pH increase between the anoxic and the aerobic treatment (0.3±0.2 for regular sampling over 72 days) was clearly related to the mineralization of the organic matter, since it follows a clear increase of the conductivity (1.3±0.1). Contrarily, in the wastewater and after both treatments, the pH increase recorded on the whole run (about 2 pH units — Table 3) cannot be related to an increase of the conductivity and may therefore be attributed to the transformation of the organic matter, but not its mineralization.

The increase of the yields of removal of suspended solids in the anoxic and aerobic tank during the first days of experiment corresponded to a transitory phase; it corresponded to a colonization of the biofiltration support (sand) by microorganisms. Yield became nearly constant from less than 20 days of the experiment (Fig. 1). It was 82±3 after the anoxic tank and increased to 87±4 after the

Table 1
Physico-chemical characterization of the sand of dune

Quarry	Equivalent diameter (mm)	Uniformity coefficient (CU)	Porosity (%)	Permeability (mm/h)
Gara Krima	0.14	2.00	44.40	408
Ain Bieda	0.12	2.50	47.57	394
Aouinet Moussa	0.09	2.22	43.60	229
Bamendil	0.10	2.30	45.60	308
N'Goussa	0.10	2.20	43.88	265
Frane	0.10	2.50	47.56	385
Oued N'sa	0.09	2.22	49.56	186
Hassi Messsaoud	0.12	2.08	47.00	333
Temacine	0.12	1.75	50.80	134
Touggourt	0.10	2.10	50.45	290
Guemar	0.10	2.60	40.80	261
El Oued	0.09	2.22	38.28	169
Guerrara	0.14	1.57	51.75	264
Ghardaia	0.10	1.89	57.05	277
El Golea	0.09	2.33	44.94	240

Table 2
Chemical characterization of the sand of dune

Quarry	pH	Conductivity (mS/cm)	Carbonate (%)	Organic matter (%)
Gara Krima	7.48	2.41	0.59	0.056
Ain Bieda	7.82	3.01	0.81	0.212
Aouinet Moussa	7.58	2.40	0.83	0.106
Bamendil	7.91	3.58	4.14	0.873
N'Goussa	7.90	3.26	0.34	1.111
Frane	7.41	0.83	0.82	0.635
Oued N'sa	8.00	0.23	1.02	0.372
Hassi Messsaoud	7.21	2.34	0.83	0.370
Temacine	7.20	7.64	2.95	0.212
Touggourt	7.39	2.02	3.71	0.952
Guemar	7.40	1.81	11.66	1.216
El Oued	7.32	2.07	11.90	1.031
Guerrara	8.10	0.16	3.33	0.106
Ghardaia	7.67	0.10	1.13	0.423
El Golea	7.30	2.18	0.75	0.926

Table 3
Effect of the treatment on the pH and the conductivity

Samples		Conductivity[a] (mS/cm)					pH[a]				
		Wastewater	After the septic pit		After the biofiltration		Wastewater	After the septic pit		After the biofiltration	
No.	Day			σ		σ			σ		σ
1	8	4.65	4.59	0.04	5.96	0.01	6.40	6.76	0.01	6.99	0.01
2	13	4.40	4.35	0.02	5.74	0.00	6.80	7.27	0.22	7.83	0.00
3	15	4.23	4.33	0.00	5.65	0.01	6.45	7.12	0.06	7.62	0.01
4	20	4.33	4.24	0.02	5.56	0.02	7.18	7.10	0.06	7.51	0.05
5	27	5.46	5.07	0.00	6.58	0.03	7.22	7.43	0.07	7.79	0.08
6	35	4.87	5.10	0.02	6.43	0.06	7.46	7.55	0.03	7.88	0.05
7	41	5.09	5.12	0.02	6.29	0.02	8.70	8.66	0.05	8.81	0.01
8	48	4.33	4.40	0.02	5.81	0.11	8.52	8.57	0.10	9.02	0.07
9	52	4.21	4.25	0.01	5.53	0.02	8.16	8.47	0.02	8.87	0.00
10	57	4.30	4.36	0.02	5.60	0.02	8.71	9.00	0.22	8.96	0.01
11	62	4.18	4.09	0.01	5.35	0.01	7.23	8.44	0.03	8.90	0.09
12	72	3.96	4.00	0.01	5.39	0.00	8.60	8.81	0.05	9.00	0.01

[a]pH and conductivity values were the mean values recorded in the three identical pilot plants.

[b]the standard errors were calculated as follows: $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x-m)^2}{n}}$, with $n = 3$ (three pilot plants), x the measured parameter value and m the mean value.

sand biofiltration, leading to an almost complete removal (98±1 — Fig. 1). The slight decrease of the biofiltration yield observed at the end of the run corresponded most likely to a saturation of the sand.

Variations of chemical oxygen demand (COD) were recorded after the septic pit (Fig. 2), which can be most likely related to qualitative disturbances of the raw water. However, the yield of COD removal always remained above

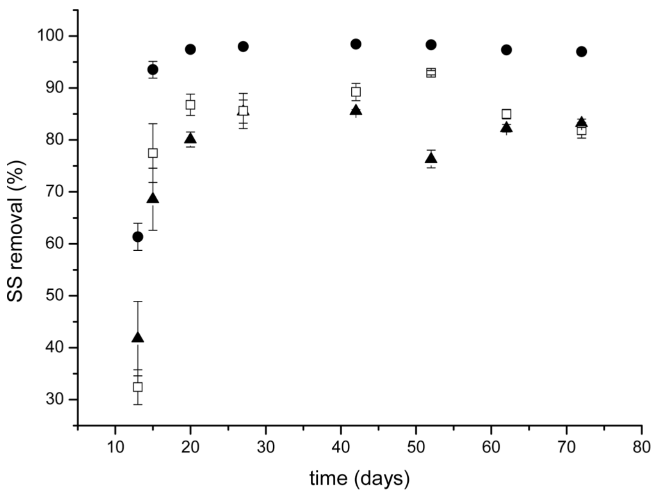

Fig. 1. Time courses of removal of the suspended solids in the anoxic (▲) and aerobic (□) tanks, as well as the global removal yield (●).

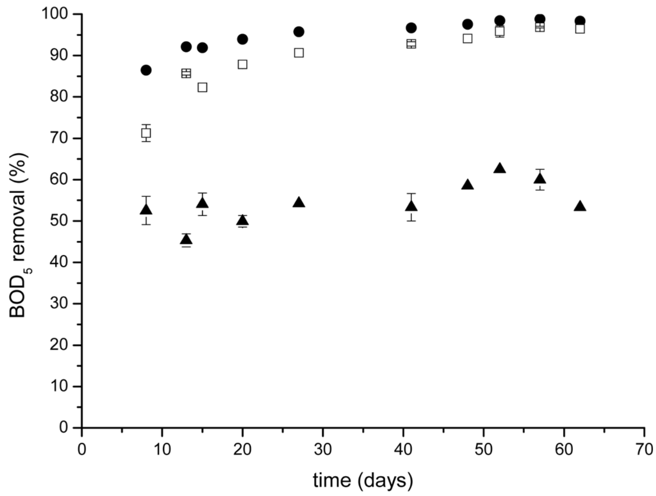

Fig. 3. Evolution of the yield of biological oxygen demand decrease in the anoxic (▲) and aerobic (□) tanks, as well as the global removal yield (●).

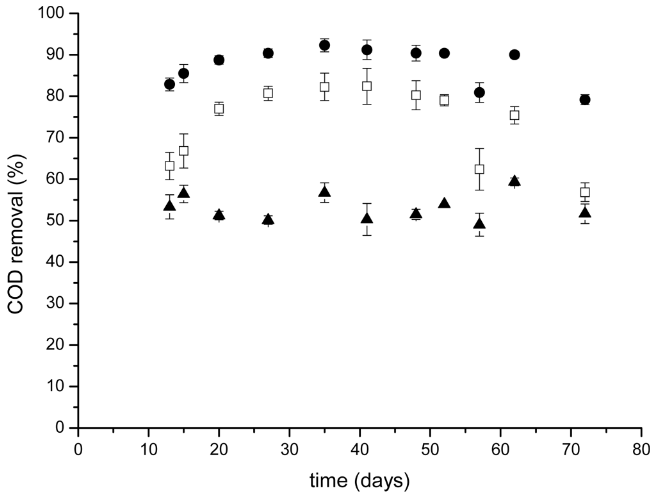

Fig. 2. Evolution of the yield of chemical oxygen demand decrease in the anoxic (▲) and aerobic (□) tanks, as well as the global removal yield (●).

50% after the anoxic tank. Until approximately 35 days of the experiment, an increase of the COD removal could be observed, before constant yield was observed until about 52 days running (Fig. 2). Then and until the end of the experiment, the yield of COD removal decreased after the aerobic tank, while it remained nearly constant after the anoxic tank illustrating fouling of the filtration system (sand). Consequently, the global chemical oxygen demand in the system also decreased slightly after 52 days of running. On the whole run, the average COD decrease was 53±3 after the anoxic tank and increased to 75±8 after the sand biofiltration leading to a global COD removal of 87±5.

The decrease of the biological oxygen demand after the anoxic treatment remained nearly constant throughout the experiment (54±5) (Fig. 3). It illustrated anaerobic degradation of the organic matter. Contrarily, after the biological filtration, it increased from 71±2 to an almost constant value of 96.4±0.4 recorded from the 52the day of the experiment leading to an increase of the global BOD_5 removal from 84.4±0.1 to an almost constant value of 98.5±0.2 (Fig. 3).

Bacteriological characterization of the treated water showed a high removal of the faecal coliforms, at least 96% corresponding to a final number of colony forming units of 9 (Table 4), namely in agreement with the standards of irrigation (10 UFC per 100 m/L). High colibacilli removal could also be noted, above 99% corresponding to a final CFU of 7 (Table 4), namely below the standards of irrigation (10 UFC per 100 m/L). The water did not contain faecal enterococci owing to the quality of the considered raw water (urban wastewater). More than 99% removal of the total germs was also obtained (Table 4). After both processes, anoxic and aerobic, the treated water showed interesting bacteriological quality, which was improved after disinfection (250 mg/L chlorination). It can be observed that this bacteriological quality was mainly achieved after the anoxic treatment.

4. Conclusion

The overall physicochemical and bacteriological quality of the treated water showed that it was in agreement with the standards of irrigation. The process proved its efficiency since the BOD_5, COD and SS elimination yields remained above 70% over 4 months of the experiment. However, an additional drainage should be considered

Table 4
Effect of the treatment on the bacteriological characteristics of the treated water

Set of analysis	Germs	Raw water	Septic pit	Yield (%)	Filtration	Yield (%)	Chlorination	Yield (%)
1	Faecal coliforms	252.10^4	2640	99.9	132	99.99	00	100
	Faecal enterococci	40	—	—	00	100	00	100
	Total germs	368.10^8	392.10^6	98.9	332.10^6	99.1	300.10^6	99.2
2	Faecal coliforms	>240	>240	—	35 28	>85.4 >88.3	09	96.2
	Colibacilli	>240	>240	—	35 28	>85.4 >88.3	07	97.1
	Faecal enterococci	00	00	00	00	00	00	00

to avoid salt problems. Pilot-scale results have to be subsequently confirmed at an industrial scale.

This study shows that the permeability of Sahara sand of dune allows its use for water biofiltration. Subsequent experiments at an industrial scale are needed to complete the validation of the process.

References

[1] M. Rodgers, M.G. Healy and J. Mulqueen, Organic carbon removal and nitrification of high strength wastewaters using stratified sand filters. Water Res., 39 (2005) 3279–3286.

[2] M.M. Ahammed and M. Chaudhuri, Sand-based filtration/adsorption media, Aqua – J. Water Supply: Res. Technol., 45 (1996) 67–71.

[3] M.F. Hamoda, I. El-Ghusain and N.Z. Al-Mutairi, Sand filtration of wastewater for tertiary treatment and water reuse, Desalination, 164 (2004) 203–211.

[4] D.H. Mantz and P. Eng, New horizons for slow sand filtration, Proc. 11th Canadian National Conference and Second Policy Forum on Drinking Water and Biennial Conference of the Federal-Provincial-Territorial Committee on Drinking Water, Promoting Public Health Through Safe Drinking Water, Calgary, Alberta, 3–6 April 2004, pp. 682–692.

[5] K.V. Ellis and M.E. Aydin, Penetration of solids and biological activity into slow sand filters, Water Res., 29 (1995) 1333–1341.

[6] C. Gougoussis, Assainissement individuel et aptitude des sols à l'épuration des effluents domestiques. Série de Documentations du BRGM, no. 38, 1982.

[7] T. Hidaka, H. Tsuno and N. Kishimoto, Advanced treatment of sewage by pre-coagulation and biological filtration process. Water Res., 37 (2003) 4259–4262.

[8] T. Guagne and F. Brissaud, Etude des limites de l'épuration par infiltration sur sable des eaux usées fortement chargées en matières oxydable de l'abattoir de Ouagadougou au Burkina Faso, Sud Sci. Technol., 9 (2002) 34–41.

[9] A. Lakel, M. Baudu and C. Dagot, Hydrodynamique d'un filtre biologique en système insaturé avec nitrification d'un effluent septique, Water Res., 32 (1998) 3157–3167.

[10] J. Rodier, Analyse de l'eau, 8éme éd., Edition Eyrols, 1996.

[11] Y.W. Kang, K.M. Mancl and O.H. Tuovinen, Treatment of turkey processing wastewater with sand filtration. Bioresource Technol., 98 (2007) 1460–1466.

[12] B. Jimenez, A. Chavez, A. Leyva and G. Tchobanoglous, Sand and synthetic medium filtration of advanced primary treatment effluent from Mexico city, Water Res., 34 (1999) 473–480.

[13] S. Chabaud, Y. Andres, A. Lakel and P. Le Cloirec, Comparison of packing materials in on-site wastewater treatment system, Water Practice Technol., 1 (2006) 1–7.