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Wastewater Reclamation by Intermittent Sand Filter From Lagunas Treatment

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This work is carried out under the research project "Wastewater Reuse by using unconventional technologies". We present the first data from a study of the behavior of Intermittent Sand Filter for the regeneration of the effluent from the lagooning system. The results corroborate that the effluent, after of the Intermittent Sand Filter meet the requirements for most applications envisaged in the Spanish Royal Decree 1620/2007, establishing the legal framework for the reuse of treated water.

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Introduction

The pond systems (PS), formed by a anaerobic, facultative and maturation pond, are a preferred wastewater treatment system for small communities (i.e.<2000 person equivalent, PE) [1-2-3-33]. These systems are used increasingly more in the Mediterranean strip, for example in France there are now some 2500–3000 WSP installations each for on average 600 person equivalent (PE) representing 20% of sewage treatment plants in France [4]. However, the seasonal variability and high concentrations of algae in the PS effluents can limit their implementation when a highquality effluent is required (e.g. in the case of fragile receiving surface water bodies). When strict standards are set, the PS effluent does not often satisfy such quality requirements [4-5-6-7]. Therefore, a complementary treatment is often required.

Several methods for upgrading the quality of PS effluent have been studied [8-9-10-11-12-13]. The capacity of intermittent sand filters (ISFs) to retain algae [14- 15- 16], remove organic matter and nitrify the filter influent [17] make them suitable polishing treatment systems.

ISF is an extensive treatment which it has been increasingly used for the treatment of primary or secondary wastewater effluents because of its low energy and maintenance requirements [1-18-19-20]. It consists in the intermittent application of sewage on buried or constructed sand filters or permeable native soils. The infiltrated water percolates through unsaturated porous medium. The treated water is collected by a drainage system or percolates down to the underlying aquifer [21]. Filters behave as aerobic fixed biomass reactor. When percolating through the filter, water is treated by aerobic biological process resulting in the mineralization of organic matter and the oxidation of nitrogen compounds. In most plants, COD of the filtered water is less than 50 mg/L [2]. Nitrogen is oxidized in the upper layers of the filter; residual $N\text{–}NH_4$ concentration less than 1 mg/L are not rare [22-23]. Research and field experiments have shown that intermittent filtration can provide high removal efficiency of bacteria if properly designed and operated [16-24-26].

If the quality of the filtered treatment effluents is permitted by corresponding law, it can be used for many uses: unrestricted agricultural irrigation, irrigation of public parks, lawns and golf courses [26-27] and groundwater recharge as is the case of the

RD 1620/2007 [28-34]. Microorganisms are eliminated through numerous physical, physico-chemical and biological interrelated processes [29]. Elimination of helminth eggs was proved to be very effective [30]. Fecal coliform removal has been often observed at the laboratory and on full-scale plants [1-16-25]. It has been extensively investigated and shown to mainly depend on water detention times in the filtering medium and on oxidation effectiveness [31]. Achieving total oxidation requires the oxygen amount needed for organic matter and nitrogen oxidation to be balanced by convective and diffusive oxygen supply. Intermittent infiltration allows maximizing the convective renewal of the air phase [30].
The first aim of this study was to determine the performance of FIA function of dosage and the hydraulic load. The second objective is to determine the influence of an air chamber in the bottom of the filters, and third place to observe the reclaim capacity with respect to Royal Decree 1620/2007.

Materials and methods

1. Experimental design

The study was performed on laboratory scale in the Carrión de los Céspedes Experimental Plant (PECC), at homonymous town, in Seville (Spain). The experiment design consisted in 6 sand filters, made of PVC, 20 cm in diameter and one meter high, with a filling of fine sand 70 cm high, supported by 5 cm of thick sand and 5 cm of fine gravel. Two of them had one additional air chamber in the bottom of 30 cm in height. The fine sand had distribution with an effective diameter (d10) of 0.27 mm and a uniformity coefficient (Cu: d60/d10) of 1.77. Different hydraulic loads and dosing frequencies were tested for each filter in order to establish the impact of the operational mode on their hydraulics and performance. The daily number of dosing–drainage cycles ranged from 1 to 24, and the hydraulic loads oscillate between 60 and 480 L/m^2d (Table 1). The filters were alternately fed for 5 days followed by a rest period of 2 days, for five months.

Tab 1: Diary dosing–drainage cycles

Filter	Diary dosing – Drainage cycles	Air chamber
F1	1	yes
F2	1	no
F3	12	yes
F4	12	no
F5	24	no
F6	8	no

The influent of the filters came from impoundment system of PECC, which consisted of an anaerobic lagoon of 200 m3 and 4 m deep, a facultative pond of 2700 m2, and 1.8 m deep with a total volume of 3500 m3 and maturation pond of 560 m2, 1 m deep and 400 m3 of volume. Feeding is done through a tank of 100 l, with slow stirring, which was changed daily.
A five months monitoring program consisting of analysing 24-h composite samples, as shown in Table 2. Samples were taken from the influent and the effluent of the filters and then preserved, stored and analyzed (Turbidity, TSS, COD, N-NH4, N-NO3, TP an E. coli) following standard methods [32].

Tab 2: Samples

Month	Applied hydraulic load (l/m^2d)	Days between sampling	Nº of samples
1	60	2	16
2	120	2	14
3	180	3	10
4	240	7	5
5	480	7	5

2. Data analysis

Statistical analysis was performed using the SPSS program (SPSS Inc; Version 12.0.1) and the Excel statistic packet. The analysis of variance was performed to assess the influence of different design process variables on the removal of each pollutant. Statistical significance was established at $p < 0.05$.

Results and discussion

Explain the presented work in details and gives theoretical discussions [2-4]. The results may be presented as tables, figures and schemes. The authors must ensure that all tables (Tab. 1), figures (Fig. 1) and schemes (Scheme 1) are cited in the text in numerical order.
The results obtained as both the influent of the filters are presented in Table 3. The benchmarks for the data are the values that appear in the RD 509/1997 both for the discharge of treated wastewater and the RD 1620/2007 for the reuse of reclaimed wastewater. For the first, core values are: <125 mg/L COD, <25 mg/L BOD_5 and <35 mg/L TSS, although the latter value and if the effluent lagoons comes from the value goes up to 150 mg/L.

Tab 3: Range of the average values

	I	F1	F2	F3	F4	F5	F6
Turb. NTU	45-100	10-24	8,6-25	2,2-4,5	2,5-7,8	3,5-7,4	3,8-6,7
TSS mg/l	54-195	11-34	8,6-28	2,1-5,6	2,8-5,0)	2,8-6,7	3,5-5,3
COD mg O2/l	190-339	72-139	74-134	40-64	39-124	36-56	36-60
NH_4^+ mg N/l	7,8-13	1,2-5,9	0,14-5,8	0,05-5,2	0,08-3,8	0,06-3,8	0,04-2,9
NO_3^- mg N/l	0,05-3,7	7,4-20	11-20	18-23	16-25	15-22	15-25
Total P mg P/l	6,6-5,3	2,8-6,2	2,7-6,3	2,6-6,5	2,4-6,6	2,5-6,3	2,5-6,7
E. coli (u log) UFC/100 ml	1,74-3,03	1,87-2,8	1,5-2,68	0,24-1,0	0,24-0,76	0,0-0,87	0,35-0,8

For the second, the target values are raised concerning the use 2.1 (RD 1620/2007): crop irrigation with water application

system that allows direct contact of reclaimed water with edible parts for human food fresh. Whose basic control values are: <1 egg intestinal nematodes in 10 L, <100 cfu/100 mL of E.coli, <20 mg / L TSS and <10 NTU. NO^{3-}

The results obtained from influent means PS results above stipulated by the law of discharges (RD 509/1997) in most analyzes, although these values are indicative for treatment plants have over 2000 and the design of this system it is for impoundment 750 He. However, the effluent met the six filters for this law. Dosed four filters (F3, F4, F5 and F6) fully comply with the requirements for use of the 2.1 RD 1620/2007.

The difference in behavior of the filters is statistically significant ($p<0.05$) between the filters F1 and F2, the difference is the air chamber in the bottom of the F1 and is also significant between these two filters and the other four. The performance is not statistically significant ($p>0.05$) between the four dosed filters, so that in this case, there is no significant difference or daily dosages (8-24) or the presence of the air chamber in the filter F3.

__1. Removal of nutrients.__

A significant aspect is the removal of nutrients (NH4+, NO3- and Total P) as it occurs in the six filters in a similaire manner ($p> 0.05$).

1.1. Ammonium

The elimination of ammonium (Fig. 1) is carried out mainly by two mechanisms, the first one by adsorption acts in the first 2-3 days, and quickly loses effectiveness. The second by nitrification, lasts about 10-12 days to be fully operational. We reach the minimum removal of the ammonium when the effectiveness of both processes is the same.

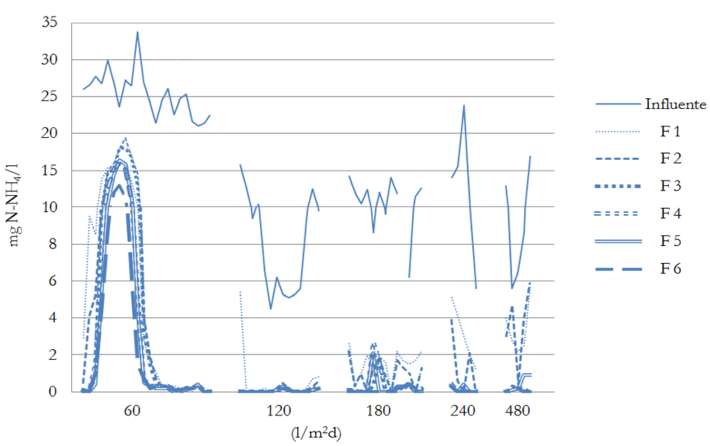

Fig. 1: Variation of the Ammonium concentration

1.2. Nitrate

Consequent to the elimination of ammonium nitrate is formed by nitrification, and since the necessary conditions do not exist in the various filters so that denitrification, so the elimination of this nutrient is not given (Fig. 2). Otherwise, in the first experiment (60 L/m²d), the nitrification process is established. Comparing both figures, we can observe a relation between ammonium nitrate influent and effluent.

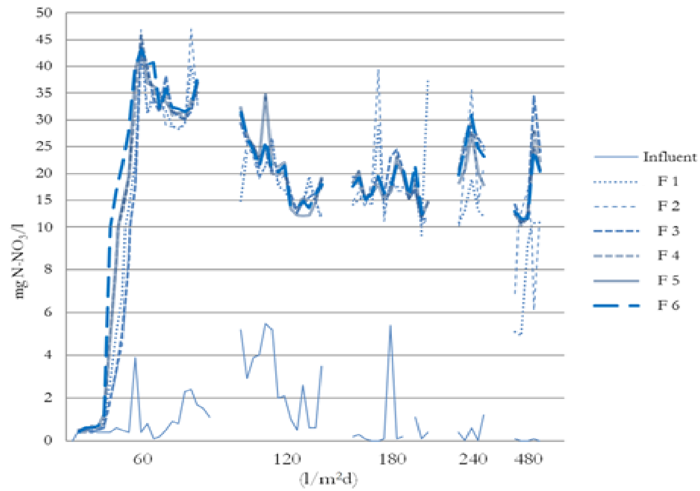

Fig. 2: Variation of the nitrate concentration

1.3. Phosphor

In FIA, phosphorus removal occurs almost exclusively by adsorption, even if the loss of effectiveness occurs in a more progressive way than with respect to ammonia as reported in Figure 3. Once we have established the adsorption balance and practically no more phosphorus is retained.

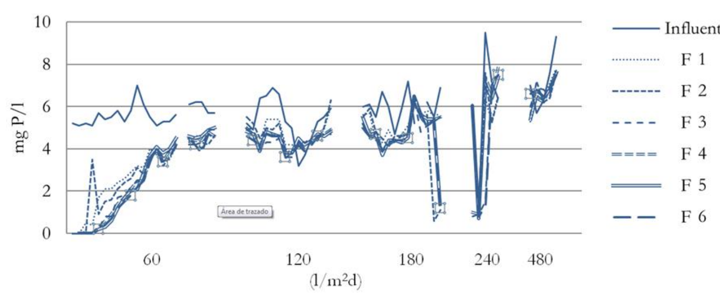

Fig. 3: Variation of the phosphor concentration

__2. Effect of dosing__

As discussed above, titration effects are statistically significant only when the results are compared with the filters applied to them water once a day and those who are dosed. This is consistent with the model of Eddie Metcalf (2004) but only with respect to saturation model (filters F1 and F2) which have clearly underperformed. With respect to the other four filters, no statistically significant differences only, therefore no preferential behavior from 8, 12 or 24 daily dosages.

__3. Effect of hydraulic load__

The effects of increased hydraulic load are felt almost exclusively in the F1 and F2 filters that not being dosed are more sensitive to increases in hydraulic load. F3 filters , F4 , F5 and F6 to be dosed are more robust against changes both the

hydraulic load as those of pollutant loads fluctuating along experiments , with no statistically significant changes in any of the cases .

The only episodes of filter saturation, occurred in the F2 filter twice, but disappeared after the break of two days.

4. Effect of the air chamber.

The intent of the experiment was to verify the existence of significant differences having an air chamber under the filter or not. The result by comparing the filters which differed only in this respect, the filters F1 and F2 on one side and the F3 and F4 on the other filters, is that there are statistically significant differences in favor of filter tubeless (F2) when there dosage and conversely , there are no statistically significant differences when if any, although the best values are when air chamber (F3).

Conclusions

As findings include the high regenerative capacity of intermittent sand filters, as unconventional systems for tertiary treatment technologies, given the degree of quality effluent reaches them.

To achieve the highest quality, the filter must be dosed as a single application of water not the level of quality required for reuse is achieved.

For hydraulic load range used (60-480 L/m^{2}d) the effectiveness of the filters was almost constant.

The effect of the air chamber in measured doses filters is not statistically significant.

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