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Application of the new solution ACTIDisc® on secondary effluent reclamation in Castellón de la Plana

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Abstract

During the month of May 2005, the performances of ACTIDisc® process were tested in Castellón de la Plana WWTP (waste water treatment plant), in collaboration with FACSA and Entitat de Sanejament d'Aigües Residuals de la Generalitat Valenciana. The purpose of the analysis was to prove the suitability of ACTIDisc® process in wastewater reclamation of the WWTP secondary effluent. The process aimed, mainly, to achieve a low level of suspended solids and turbidity in compliance with the regulations proposal for direct reuse of treated effluents, suggested in 2005 as AEAS guidelines.

Keywords: Wastewater reclamation; ACTIDisc; Ballasted sedimentation; Actiflo; Surface filtration; Discfilter

1. Introduction

In the last years, Spain has been suffering simultaneously an episode of drought and a constant water demand increase for agricultural irrigation, landscape irrigation (e.g. golf courses) and urban reuse. Under these conditions, the development of new technologies on water reclamation using WWTP facilities becomes fundamental.

A treatment installation is considered viable only when, complying with the future restrictive legislation on water reclamation uses (see AEAS minimum quality proposal), it can be implemented on existing WWTP from an economical (in terms

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of construction and operation) or physical (in terms of dimensions) point of view [1].

The frequently used UV disinfection requires an influent with low suspended solids concentration and turbidity, which would guarantee the maximum values of UV transmittance at a 254 nm wavelength on the raw water [2].

The WWTP of Castellón de la Plana treats annually more than 15 hm^3 of wastewater. This WWTP was built in 1982 and it has been enlarged twice. The last enlargement in the year 2003 included a tertiary treatment and a UV disinfection system.

In this plant, the raw water passes through an aerated grit chamber where sand and non-emulsified fats are extracted. After a primary decantation, the residual water passes to a series of biological reactors (conventional activated sludge), after which it is filtered by tertiary treatment based on Hydroclear® technology (pulsed-bed filter) and disinfected by UV light in an open channel.

The objective of the present study is to evaluate the efficiency improvement of Castellon's secondary effluent treatment by the new process ACTIDisc®, which combines Actiflo® process [3–5] and surface filtration by Hydrotech Discfilter® [6]. Water quality improvement was quantified measuring suspended solids and turbidity removal and UV transmittance increase at 254 nm wavelength. This study has evaluated the performances of the combination of the two technologies and its suitability for secondary effluent reclaim, in order to comply with water qualities required on the new legislation proposal for water reclamation. This proposal demands for direct wastewater reclamation when possible in all different uses, and establishes the limits for turbidity (lower than 2 NTU) and total suspended solids (lower than 10 mg/l).

2. Experimental work

The purpose of the test was to get knowledge on the efficiency of the ACTIDisc® process. After the installation of the testing plant, the period of tests began on 10th May and it concluded on 24th May 2005. Four test series were performed under different operating conditions. The main sampling series was taken intensively between the 12th May and 19th May.

The experimental work was scheduled and performed as follows:

- Period between 9th May and 11th May: All elements of the plant were checked and samples were taken for analysis in the WWTP and IPROMA (official agreed organism) laboratory.
- Period between 12th May and 18th May. Plant operation was supervised introducing small variations in its operation. A complete analytic campaign was carried out by three different laboratories (WWTP, IPROMA and AGBAR).
- Period between 18th May and 19th May. On the 18th of May, an important malfunctioning occurred on the WWTP due to a loss of electricity supply on the biological reactor. The electricity cut lasted 12 h and caused important variations on the secondary effluent. During this day tests were performed to analyse the gradual increase of the coagulant dose, in order to quantify the effluent quality variations according to the coagulant dose.
- Period between 20th May and 24th May. Some tests were carried out by FACSA with analysis performed in WWTP laboratory.

2.1. ACTIDisc®

ACTIDisc® process for tertiary treatment is composed of two successive processes, which are described below.

2.1.1. Actiflo®

The Actiflo® process is a patent technology based in a very compact and simple physico-chemical treatment process. The process combines "weighted flocculation" with lamella settling. The Actiflo® process uses microsand as a seed for floc formation. The microsand provides a surface area that enhances flocculation and acts as ballast, causing quick sedimentation and very short times of retention (only 5–7 min). The experimental unit used had 1 m^2 of lamella water surface in the lamella separator.

2.1.2. Hydrotech Discfilter®

Surface filtration is a form of mechanical filtration used to remove particulate matter based on the physical size of the particulate. In this demonstration study, Hydrotech Discfilter® employs polyester as filter media in an absolute pore size of 10 µm. The experimental unit had a total installed surface area of 5.6 m^2, and operated at approximately 60% submergence. In the process, water from Actiflo flows by gravity into the filter panel segments of a central drum. Solids are separated from the water by the filter panels mounted on the two sides of the disc segments. The solids are retained within the filter disc while the clean water flows to the outside of the discs into a collection tank.

2.2. Chemicals

Considering the experimental character and the short period of operations, the chemical reagents were selected according to the results obtained previously in other experiences with ACTIDisc® demonstration plant. For the Actiflo® process treatment the following types of chemical products were used:

2.2.1. Coagulant

The coagulant used was polyaluminium chloride (17.0 ± 0.5 expressed as Al_2O_3). The use of polyaluminium suphate chloride of high basicity was considered but never performed.

The coagulant dose was calculated according to previous trials and the standard dose was fixed at 7.8 mg Al/l, with a maximum dose of 17.8 mg Al/l, a minimum dose of 4.6 mg Al/l and an intermediate dose of 10.7 mg Al/l. The biggest doses (intermediate and maximum) were only used during simulations of degenerated secondary effluent quality.

2.2.2. Microsand

Microsand used had an effective size of 130 µm and a uniformity coefficient of 1.50. It was composed of 98% pure silica (SiO_2).

2.2.3. Polymer

Anionic flocculant Hydrex 6161 was used according to previous trials on experimental plant of Actiflo®. Hydrex 6161 is based on medium anionic polyacrilamide with high molecular weight. Polymer doses were fixed to a standard of 0.6 mg/l, an intermediate dose of 0.8 mg/l and a maximum dose of 1 mg/l.

2.3. Tests conditions

Hydraulic load on Actiflo® unit varied from 75 to 90 m^3/h and it was of 45 m^3/h for Hydrotech Discfilter unit (filtration rate 13.4 m^3/m^2.h). Dosing of reagents remained constant during the period of work in stationary state, and was increased during the episodes of simulation of alterations on flowing load. It was also modified to a decrease to obtain the corresponding data.

Activated sludge extracted from secondary clarifier was pumped to head of experimental plant to simulate the occasional increase of total suspended solids load. Also, the cleaning of the channels of secondary clarifiers revealed the presence of algae and biofilm stuck to the walls. This operation was planned and integrated in the normal operation of the plant and provided punctual increments of solids suspended in the influent. Its application on the experimental plant allowed confirming the high efficiency of the system before peak loads.

3. Results and discussion

Water analysis was mainly carried out in three different laboratories: Castellón de la Plana WWTP by FACSA and two independent laboratories agreed by ENAC (National Accreditation Body): IPROMA and Sant Joan Despí laboratory of AGBAR.

Total suspended solids and turbidity tests were carried out in the WWTP laboratory. Analyses corresponding to the stationary state operation of the demonstration plant and to light variations of the operating conditions (in order to adjust secondary effluent quality) were carried out in AGBAR laboratory, WWTP laboratory and IPROMA.

Other parameters susceptible of reduction under the combined process were considered for analysis: total phosphorus, absorbance to 254 nm wavelength, dissolved organic carbon, specific absorbance to 254 nm wavelength, bacterial indicators, particle size distribution, pH, conductivity, residual aluminium and residual acrilamide. Bacteriophages tests were also carried out by the University of Barcelona, and morphological analysis by scanning electronic microscopy (SEM-EDS) of the materials deposited in the filters used in the total suspended solids determination by the University of Girona.

Determination of helminths eggs in experimental plant was unnecessary because it was historically proved that the number of eggs of intestinal nematodes in secondary effluent remained under 1 ova/10 L.

All results presented in this paper were obtained from sampling series realised between 12th May and 19th May and analysed by AGBAR laboratory, except for TSS and turbidity during start-up by WWTP laboratory.

3.1. Total suspended solids and turbidity after start-up

On the 12th of May a start-up test was conducted. A trial was carried out after a total break down (out of service overnight). During the start-up samples were taken in Actiflo outlet for turbidity determination and total suspended solids in WWTP laboratory. The start-up test was carried out between 1 and 20 min after start-up.

Fig. 1 shows total suspended solids and turbidity as a function of time. Inlet turbidity and total suspended solids values were 7.2 NTU and 18.5 mg/l respectively.

As it is shown in Fig. 1, total suspended solids and turbidity of the effluent decrease immediately after start-up. Only 10 min after start-up, the turbidity value was already very near to 2 NTU (2.2 NTU). After 20 min, the turbidity was approximately 1.7 NTU.

In the case of total suspended solids, as it is seen in Fig. 1, the TSS value of the effluent decreased after start-up and was lower than 5 mg/l (3.7 mg/l) after 10 min. After 20 min, the total suspended solids value was lower than 2 mg/l.

3.2. Total suspended solids

Table 1 provides a summary of total suspended

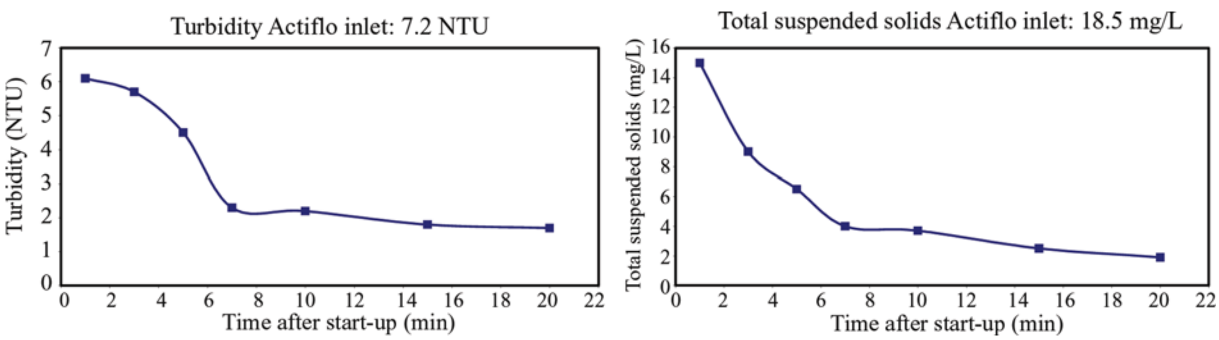

Fig. 1. Turbidity and total suspended solids removal after start-up.

solids values obtained during the test. As it is shown, high efficiency of the ACTIDisc process can provide an effluent with a TSS value lower than 5 mg/l on the average and with a 90th percentile. It is necessary to mention that the limits of quantification were 2 mg/l. This fact affects directly the calculation of yields and the statistical calculations based on percentiles.

3.3. Turbidity

Table 2 summarizes the turbidity values obtained. As shown, efficiency of the ACTIDisc can provide an effluent with a turbidity value lower than 2 mg/l on average and 90th percentile.

3.4. High TSS load test (episode of 18th May)

On the 18th May an electric supply failure took place, which left the biological reactor without oxygen supply during some hours. The problem persisted from 00:30 h until 12:00 in the morning of that same day. Secondary effluent quality changed and TSS, turbidity and number of particles increased. This accidental situation allowed taking an advantage to investigate total suspended solids, turbidity and number of particles removal efficiency in case of peak loads.

In this situation and using the standard operation parameters (7.8 mg/l of coagulant as Al and 0.6 mg/l of anionic flocculant), the TSS and

Table 1
Total suspended solids removal (values in mg/l)

	Inlet ACTIDisc (*n* = 10)	Outlet Actiflo® (*n* = 12)	Outlet ACTIDisc® (*n* = 10)
Minimum	4.0	2.0	2.2
Maximum	79.0	14.0	8.8
Average	32.6	6.5	2.9
Standard deviation	27.7	4.5	2.1
10th percentile	5.6	2.6	2.0
50th percentile (median)	23.5	4.9	2.0
90th percentile	68.2	13.0	4.3
95th percentile	73.6	13.5	6.6

Table 2
Turbidity removal (values in NTU)

	Inlet ACTIDisc (*n* =10)	Outlet Actiflo® (*n* = 12)	Outlet ACTIDisc® (*n* = 10)
Minimum	1.2	0.8	0.6
Maximum	35	3.7	3.2
Average	32.6	1.8	1.2
Standard deviation	11.9	0.9	0.9
10th percentile	1.7	0.9	0.6
50th percentile (median)	10.8	1.5	0.8
90th percentile	28.7	3.2	2.0
95th percentile	31.9	3.4	2.6

turbidity removal efficiency decreased to a value of 70–75%. To increase this efficiency to 95%, the quantity of the coagulant dose was increased at the demonstration plant. The results obtained with ACTIDisc process during this test are shown in Fig. 2.

The anoxia problem in the biological reactor allowed comparing the versatility of the demonstration plant under special discharge conditions. The behaviour of the plant on high colloidal solids coagulated (18th May) was compared to an increment of solids due to the injection of activated sludge from biological reactor performed on 12th May. The comparison of the results was carried out under the same conditions of load hydraulics (90 m^3/h) and of reagent dosing (7.8 mg/l as Al and 0.6 mg/l flocculant). Fig. 3 shows the content of total suspended solids in the effluents at high TSS loads but with different particle size distribution.

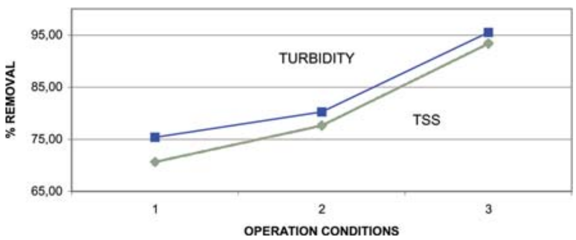

Fig. 2. Removal efficiency for TSS and turbidity during high load test (episode of 18th of May). Operation conditions: 1. 7.8 ppm Al and 0.6 ppm flocculant; 2. 10.6 ppm Al and 1 ppm flocculant; 3. 17.8 ppm Al and 0.8 ppm flocculant.

3.5. Particles

Secondary effluent had a total amount of >1 µm particles between 40,096 and 531,440 per 1 ml. On average, secondary effluent contained 237,495; 44,470; 13,978 and 154 particles per 1 ml in the ranges of >1 µm, >2 µm, >10 µm and >40 µm respectively. On 90th percentile secondary effluent contained 396,476; 83,342; 33,692 and 350 particles per 1 ml in the ranges of >1 µm, >2 µm, >10 µm and >40 µm respectively.

Outlet Actiflo effluent had a total amount of >1 µm particles between 13,528 and 225,740 per 1 ml. On average, Actiflo outlet contained 58,139; 6,856; 518 and 16 particles per 1 ml in the ranges of >1 µm, >2 µm, >10 µm and >40 µm respectively. On 90th percentile Actiflo outlet contained 130,616; 8,713; 919 and 33 particles per 1 ml in the ranges of >1 µm, >2 µm, >10 µm and >40 µm respectively.

Outlet Discfilter had a total amount of >1 µm particles between 10,428 and 361,950 per 1 ml. On average outlet Discfilter contained 68,986; 7,091; 220 and 13 particles per 1 ml in the ranges of >1 µm, >2 µm, >10 µm and >40 µm respectively. On 90th percentile outlet Discfilter con-

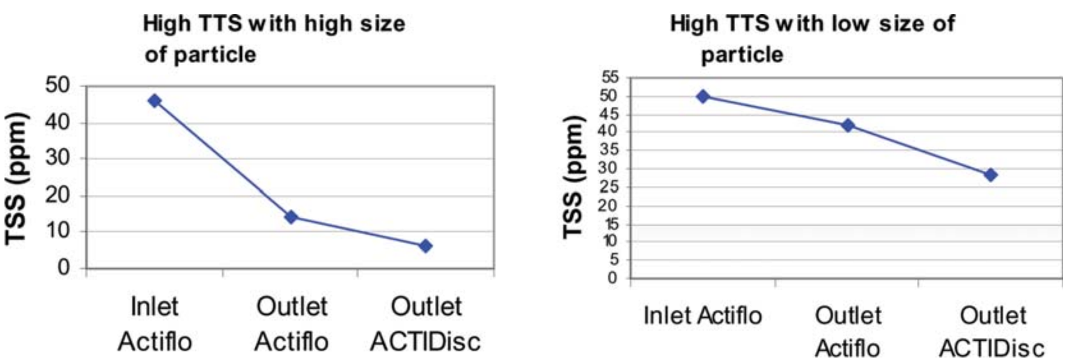

Fig. 3. Removal efficiency for TSS and turbidity during high load test (episode of 18th of May).

Table 3
Particle removal (log reduction)

Range (μm)	Outlet Actiflo®	Outlet ACTIDisc®
1–1.5	0.69	0.74
1.5–2	0.72	0.75
2–3	0.83	0.91
3–5	0.86	1.12
5–7	0.76	1.09
7–10	0.78	1.17
10–15	0.86	1.47
15–40	1.02	1.99
>40	1.34	2.21

tained 141,747; 19,296; 677 and 13 particles per 1 ml in the ranges of >1 μm, >2 μm, >10 μm and >40 μm respectively.

Particle size distribution analysis indicated a reduction of 87.1% (on median) of >1 μm particles and 98% (on median) for >10 μm particles under conditions tested for the complete process.

Table 3 shows the particle removal efficiency (log reduction) obtained.

3.6. Transmittance

The measurement of UV absorbance at a wavelength of 254 nm were transformed into transmittance, to use it as an indicator of treatment improvement on the conditioning of water previous to UV disinfection. Table 4 shows transmittance results obtained.

3.7. Dissolved organic carbon

Coagulation and flocculation processes in the system Actiflo® produced a partial reduction of the concentration of dissolved organic carbon, by means of adsoption reactions onto flocs generated. Table 5 provides a summary of the efficiency data obtained in the combined process Actiflo® and Discfilter®.

4. Conclusions

The ACTIDisc® process, a combination of the process Actiflo® with the surface filtration system Hydrotech Discfilter® both of property of VEOLIA Water, was tested for water reclamation of secondary effluent at WWTP Castellón de la Plana, Spain, during the period between 10th May and 24th May 2005.

Tests conducted showed that the combined processes were able to treat this water and achieve the agreed quality objectives for total suspended solids and turbidity, according to the normative draft on water reclamation legislation proposed by AEAS.

Average total suspended solid of the secondary effluent, under normal conditions of operation of the WWTP, was 17.0 mg/L and of 2.0 mg/l at for the effluent of ACTIDisc® process. Considering accidental episodes of deviation of the quality in the secondary effluent, the average results were

Table 4
Transmittance at a wavelength of 254 nm

	Inlet ACTIDisc (n = 10)	Outlet Actiflo® (n = 12)	Outlet ACTIDisc® (n = 10)
Minimum	55.0	63.1	63.1
Maximum	67.6	74.1	74.1
Average	64.3	70.1	70.3
Standard deviation	4.5	3.8	4.2
10th percentile	57.3	64.9	64.4
50th percentile (median)	66.1	69.2	70.8
90th percentile	67.6	74.1	74.1
95th percentile	67.6	74.1	74.1

Table 5
Dissolved organic carbon DOC removal

	Inlet ACTIDisc (n = 8)	Outlet Actiflo® (n = 10)	Outlet ACTIDisc® (n = 10)
Minumum	11.0	8.6	8.6
Maximum	25.0	19.0	17.0
Average	16.4	11.8	11.9
Standard deviation	6.0	4.0	3.8
10th percentile	11.0	8.7	8.6
50th percentile (median)	13.0	10.5	10.5
90th percentile	25.0	19.0	16.5
95th percentile	25.0	19.0	16.8

23.5 mg/l for the secondary effluent and 2.0 mg/l for ACTIDisc® process effluent.

Average Turbidity of the secondary effluent, under normal conditions of operation of the WWTP, was of 8.1 NTU and 0.7 NTU for ACTIDisc® process effluent. Taking account of accidental episodes of deviation of the quality in the secondary effluent, the average results were 10.8 NTU for the secondary effluent and 0.8 NTU ACTIDisc® process effluent.

Particle size distribution provided information about reduction of the amount of particles between 1 μm and 100 μm. In the range of particles bigger than 20 μm, which includes the dimensions interval where helminths parasite eggs are found, the ACTIDisc® process achieves a reduction of 2 logarithmic units.

The treatment tested also allowed to reduce the concentration of dissolved organic carbon partially (34%), and to improve transmittance at 254 nm wavelength (until 74%).

It has been demonstrated that still in the case of episodes of external incidences to the WWTP that deteriorate the quality of the secondary effluent, it is possible to adjust the reclamation process to the temporary wastewater conditions. During an anoxia episode in the biological reactor, the increase of the load in colloidal solids not coagulated was only corrected with the increase of the dosage of coagulant, maintaining intact the surface load (90 m^3/m^2.h). In the case of an increase of the load of solids by injection of active sludge from the biological reactor, the system allowed to maintain a concentration of total suspended solids lower than 10 mg/l at the effluent of the demonstration plant.

The results obtained allow to assure a quality of the reclaimed water that would comply with the draft normative of minimum qualities demanded for the direct reuse of reclaimed water, according to the different possible uses, proposed by AEAS.

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