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Tertiary Filtration with Rotating Discs Unit for Effluent from Urban or Industrial Wastewater Treatment Plants: Hydraulic Study and Granulometric Distribution Influence

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Continuous tertiary filtration with rotating polymeric discs were studied as post treatment of effluent urban wastewater in real plant (10,000 PE) and of landfill leachate or zootechnical wastes in laboratory scale. For the urban flow, different TSS and hydraulic loads were tested to determine the performances of the device. The particle size distribution, the microscope analysis and the filamentous count for the treated flows was executed to better understand the effect of the bulking sludge characteristics in terms of solids removals and of number of performed backwashing cycles. The average TSS removals were found equal to 89%±12% (11 micron) and the TSS effluent concentrations were always lower than 5 mg/l. Bimodality granulometric distribution and filamentous bacteria presence increase the performances of the filtration phase. The not applicability of this treatment for the tested industrial wastes was demonstrated in laboratory scale.

1. Introduction

The characteristics of the final effluents from wastewater treatment plants (WWTP) of urban or industrial flows need often to be improved in terms of suspended solids also considering that the solid fraction contains usually micropollutants or recalcitrant compounds (Nielsen et al., 2015). Moreover this aspect is emphasized when the WWTP receives more elevated influent flow for wet period or for hydraulic peak load during dry condition. In this scenario the tertiary filtration of wastewater secondary effluent is usually necessary in environmentally sensitive areas where tight regulatory discharge requirements are needed (Ncube et al., 2016). Tertiary treatment is therefore always more common to minimise pollution which includes particulate biochemical oxygen demand (BOD), chemical oxygen demand (COD), microbes and other suspended chemical contaminants from wastewater secondary effluent (Illueca-Munoz et al., 2008). In this scenario rotating discs unit for tertiary filtration represents one of the possible engineering solutions to solve this problem. Notwithstanding many number and range of parameters influence the design phase of this device both in terms of mechanisms and flows in rotating cylindrical phase and in terms of influent characteristics (Jeffrin et al, 2008).
In this paper, continuous tertiary filtration with rotating polymeric discs was studied with meshes between 11 and 18 micrometers coupling the hydraulic and the removal efficiencies with the study of the granulometric size distribution. The activities were realized for the treatment both of effluent of urban wastewater in real plant and of industrial or zootechnical wastes in laboratory scale.

2. Materials and Methods

2.1 Tertiary filtration for urban wastewater: the pilot device

The rotating filtration system (Model MCF, 2,22-C by B&B Service S.A.S.) was installed in full scale urban wastewater treatment plant with nominal size of 10,000 PE. The device is composed of two discs with

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diameter of 2.2 m, each one is made of 28 filter tissues with maximum filtration area of 6.5 m2. The package rotates on the central axis, one part is submerged in the water, the other upside part is above the water level. In the centre of the disc, there is a static part where the influent is fed. Instead, in the moveable boundary part the filtration process happens in inside-out mode, retaining the particles into the filter.
The internal water level changes like/as function of the hydraulic pressure drop. The disc rotation starts when the level of control L1 is reached. At the same time, the backwashing phase is actuated in the upside section (submerged pump Panelli 95PR3/22 with pressure up to 7 bar). Another safety level L2 activates the by-pass and the flow is directed to the primary settler. The total installed power is equal to 0.75 kW. The system is equipped of two flowmeters, for the influent and the effluent flow measurement (Siemens) and two insertion probes to online measure the solids concentrations in the same streams (SOLITAX Hach Lange). One differential pressure device measures the water level difference inside-out the filter. The general flow scheme is shown in Figure 1.
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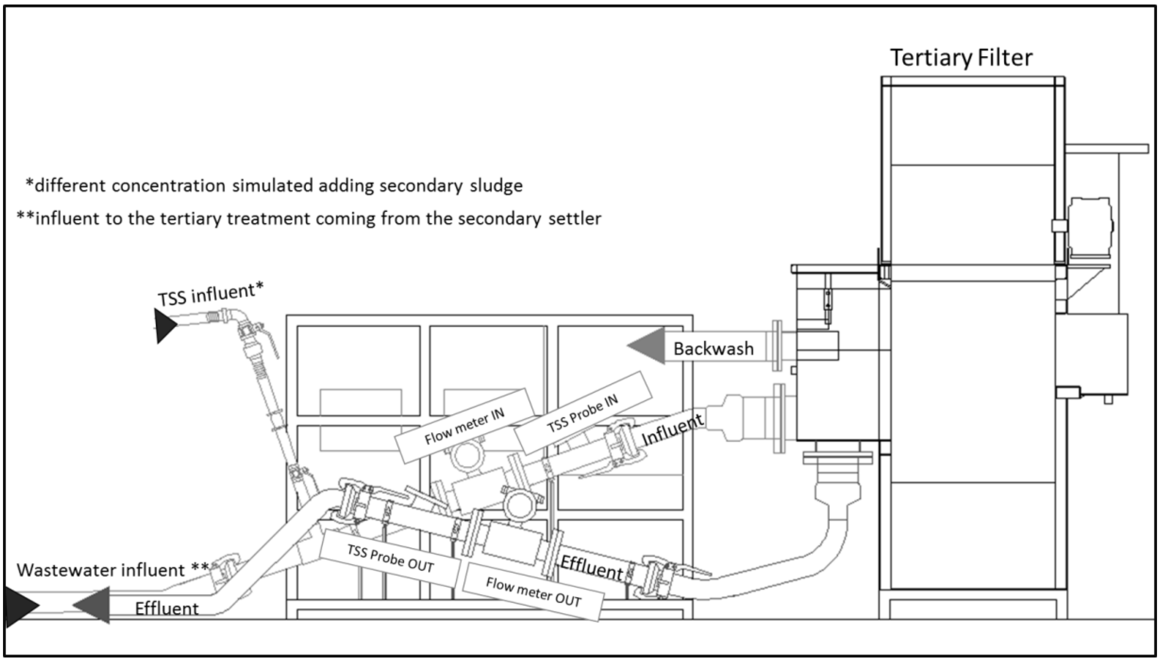

Figure 1 Flow scheme of the experimental pilot plant

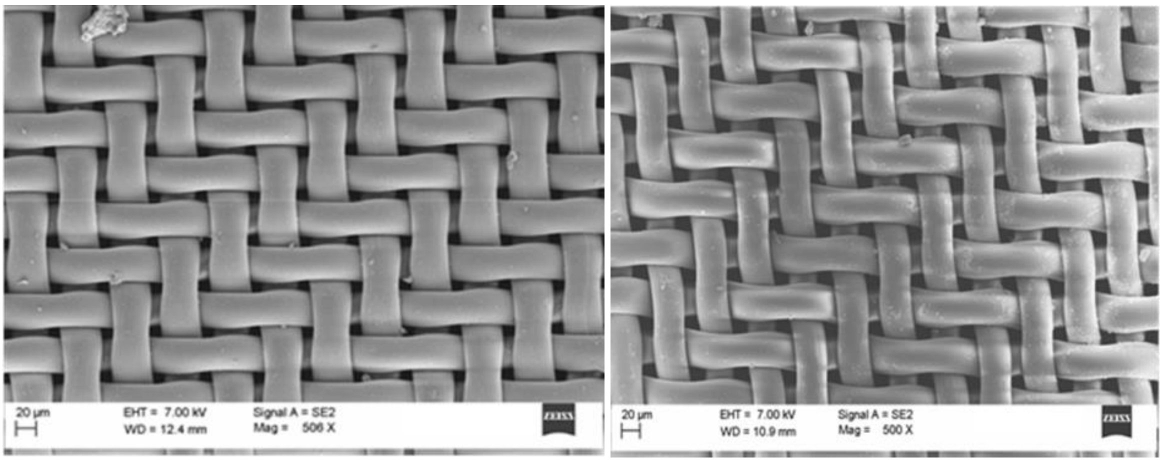

Figure 2: -a Filter mesh 11 um -b Filter mesh 18 um

The filtration system can be supplied by polymeric tissues with nominal pore sizes of 11 and 18 µm. The Scanning Electron Microscope (SEM) analysis highlighted (Figures 2 a and b) the effective mean dimensions of the pores respectively equal to 11.17 and 16 µm. Further, the open surface percentage referred to the entire filter area were 5% and 8.1% correspondingly to the nominal size of 11 and 18 µm.

2.2 Tertiary filtration for urban wastewater: experimental tests and granulometric distribution

The first filtration tests were done at short-time using 27 m3/h of influent flow rate with filtration discs at 11 micrometres of mesh and changing the influent solids concentration between 50 and 150 mg/L. Variations of the TSS from the secondary clarification effluent were made by adding portions of mixed liquor collected into the recirculation sludge flow. Furthermore, long-term tests were done (up to 10 days) with the experimental system increasing the influent flow rate from 25 to 35 m3/h (11 µm size) at the TSS concentration from 5 to 35 mg/L. All the test described were executed at temperature greater than 20°C. In addition, one test at 21 m3/h (TSSin of 90 mg/L) was done during the winter period at temperature lower than 15°C.
The removal performances and the final solid concentrations were coupled with the granulometric analysis (CILAS U.S., 920 Particle Size Analyzer) made on the influent samples and also with the filamentous bacteria number study (Beccari, 1998). Finally, the obtained data were compared with the granulometric distribution of activated sludge samples collected in others wastewater treatment plants of medium size as design capacity (WWTP1, WWTP2, WWTP3, WWTP4). The analytical characterization of the main parameters was carried out according to standard methods (APHA 2005).
The hydraulic incidence of the backwashing (sent to the main influent of the WWTP) was defined like HIB% parameter. The value is fixed at 5% of backwashing referred to the influent flow rate as sustainable value of overload.

2.3 Tertiary filtration for industrial wastewater

Some industrial wastes were tested in laboratory scale to verify the applicability of the tertiary filtration. The microfilter unit was simulated in laboratory scale with static downflow column closed at bottom with the synthetic tissue at 18 micrometres of meshes. The effluent from biological reactor and secondary settling phase of industrial platform treating landfill leachate (20 litres) was tested (Eusebi et al., 2015). Moreover 20 litres of effluent by biological process fed with anaerobic digestates of zootechnical matrices (bovine and swine wastes) were studied (Santinelli et al., 2013). All the influents to the downflow column were characterized in terms of granulometric distribution (CILAS U.S., 920 Particle Size Analyzer). The final filtered cumulative volume was measured.

3. Results and Discussion

3.1 Tertiary filtration for urban wastewater: experimental tests and granulometric distribution

The results of the three tests realized with different influent TSS concentrations were reported in Table 1 using the filtration polymeric discs at 11 micrometers of mesh. The influent flow (about 28 m3/h) was characterized by the real TSS concentrations of 55 mg/l (Test 1), 99 mg/l (Test 2) and 153 mg/l (Test 3). Notwithstanding the increment of the influent TSS concentrations, the effluent concentrations were always lower than 5 mg/l and specifically equal to 3.01 mg/l (Test 1), 3.5 mg/l (Test 2), 3.23 mg/l (Test 3) with removal efficiencies higher than 94%. The number of backwashing phases increased by elevating the influent TSS load from 1.56 kg/h (Test 1), to 2.82 kg/h (Test 2) up to 4.27 kg/h (Test 3). Specifically the backwashing cycles changed from 23 n°/h of Test 1 to 36 n°/h of Test 3. The hydraulic impact of the backwashing flows (HIB%) was measured and calculated for the experimental tests. The data of HIB% between 2-3% was founded, always lower than the imposed safety value of 5%. Average specific energy consumption in the range of 0.04-0.06 kWh/m3 was registered mainly for the impact of the backwashing phases numbers.

Table 1: Summary of the results of filtration tests with rotating discs unit

Test		1	2	3
Average TSS in	mg/l	55	99	153
Average influent Qin	m3/h	28.15	28.44	27.89
LTSS in	kg/h	1.56	2.82	4.27
TSS out	mg/l	3.01	3.50	3.23
Backwashing flow	m3/h	1	1	1
Backwashing number	n°/h	23	30	36
HIO%	%	2.0	2.6	3.2
EE	kWh/m3	0.039	0.051	0.062

Moreover, correlation was identified between the influent suspended solids and the realized backwashing phases as reported in Figure 3. The linear equation was shown in Figure 3 with elevated value of approximation (R2 of 0.9175).
The sludge used for these tests was characterized by granulometric approach. The statistical elaboration identified respectively at 50° and 80° percentile the average granulometric size of 47 and 90 micrometers . Therefore the granulometric characterization resulted almost with mono-modality distribution with small particle sizes of the total influent suspended solids (Li, 2016).

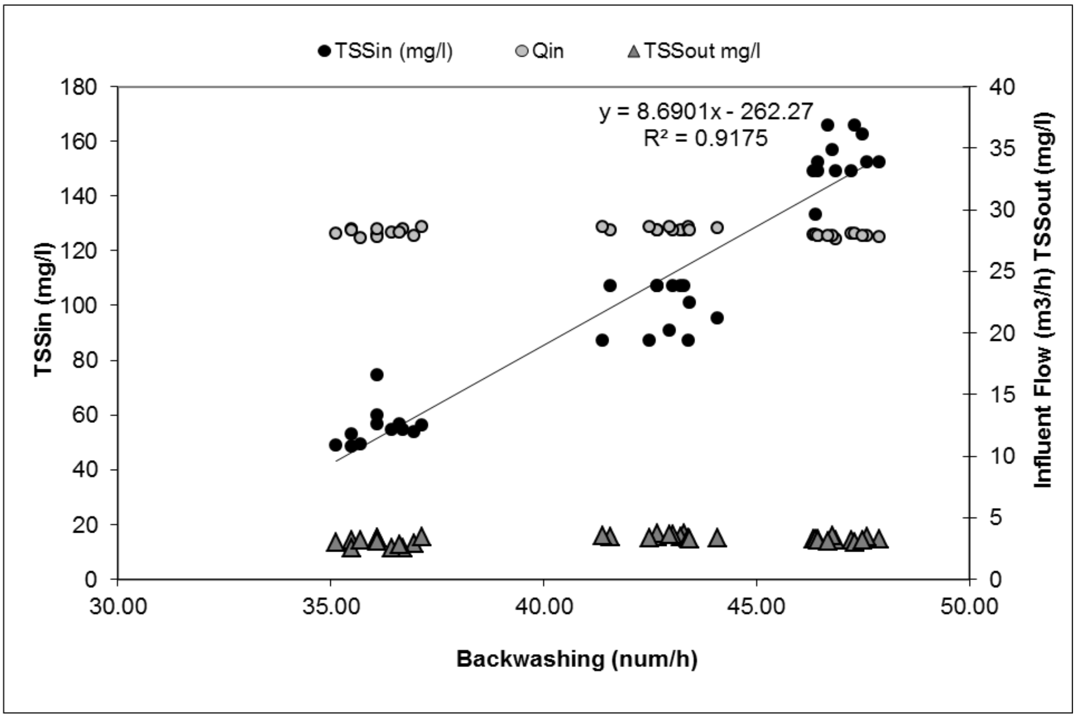

Figure 3. Influent Flow, TSS influent (TSSin) and effluent (TSSout) and backwashing numbers

Moreover, longer tests (up to 10 days) were realized incrementing the influent hydraulic flow. The results of these phases were reported in Table 2. The hydraulic impact of the backwashing flows (HIB%) was measured and calculated for the longer experimental tests by determining values lower than 3%. The average energetic consumption was confirmed in the range of 0.03-0.04 kW/m3. The granulometric distribution founded in this WWTP was compared with the data analysed in the activated sludges of others urban wastewater treatment plants with medium nominal dimension (WWTP1 85000 PE, WWTP2 60000 PE, WWTP3 185000 PE, WWTP4 100000 PE). This comparison was executed to determine the representativity of the obtained performances data of the rotating discs unit. The granulometric distributions in these WWTPs respectively at 50° and 80° percentile highlighted range of data equal to 42 and 75 micrometres (WWTP1), 37 and 65 micrometres (WWTP2), 30 and 57 micrometres (WWTP3), 42 and 70 micrometres (WWTP4). Only the WWTP2 was characterized by the primary settler phase, this aspect does not influence the granulometric distribution result. Therefore, the granulometric size of the analysed sludges resulted mainly characterized by mono modality trend similar and comparable to the TSS distribution of the small WWTP where the filtration tests were carried out.

Table 2: Summary of the results of long filtration tests with rotating discs unit

Long Test		1	2	3
Average TSS in	mg/l	7	6	34.6
Average influent Qin	m3/h	26.1	33.3	36.0
LTSS in	kg/h	0.182	0.199	1.24
TSS out	mg/l	4.9	5.0	4.8
Backwashing flow	m3/h	1	1	1
Backwashing number	n°/h	15	16	25

All the reported tests were made during summer periods (Temperature of the influent higher than 20 °C). Moreover, one long filtration test (5 days) was executed during winter period at influent temperature of 13 °C with influent flow of 20.2 m3/h at average TSS of 88 mg/l (influent TSS load of 1.71 kg/h). At these conditions the average effluent TSS concentration was 3.1 mg/l with 14 n°/h of backwashing cycles and 1.76% of HIB%. The data confirmed the ones obtained during the previous tests and highlighted higher performances (TSS removal of 96%) with lower number of backwashing phases. In fact, for 1.7 kgTSS/h of influent solids the number of cycles of backwashing for hour was 14 n°/h compared to the 23-25 n°/h at similar influent loads of the previous tests (Table 1 -Test 1 and Table 2-Test 3). The granulometric distribution of this sludge respectively at 50° and 80° percentile was of 70 and 150 micrometers. This aspect showed the higher particle distribution of the winter season and the more evident bi-modality trend of the granulometric size. Moreover, the microscope analysis of the TSS using for the filtration test showed elevated presence of filamentous bacteria with total length of 85,800 micrometer/microliter. This granulometric distribution was compared with the ones at 50° percentile of WWTP1, WWTP2 and WWTP4 with respectively values of 120 micrometers, 110 micrometers and 120 micrometers by testifying the representative of the obtained data. All these aspect suggested that the performances of the rotating filtration unit improved during the winter period because of the surface layer of the filamentous bacteria by improving the clarifying effect of the solids cake and determining lower effluent solid concentrations in the winter season more than during the summer period.
Finally, important secondary effect was founded in all the tests in the terms of total phosphorous reduction related to the particulate quote removed with the TSS.

3.2 Tertiary filtration for industrial wastewater

The tests in laboratory scale were carried out with industrial and zootechnical wastes to better understand the applicability level of this tertiary treatment. The results are reported in Table 3. In the cases of landfill leachate effluents after biological process and secondary settling separation, the particle size distribution is extremely small and the influent concentrations of suspended solids were very elevated. Immediate phenomena of clogging happened and the filtered volume after 1 hours is almost null.
Moreover, the possible optimization removal of the suspended solids for zootechnical anaerobic supernatants effluent after biological and secondary processes was tested. The granulometric distribution defining at 50° and 80° percentile average size of 20 and 100 micrometres and 11 and 30 micrometres respectively for swine (S) and bovine (B) feeds. The filtered cumulative volume was almost null for both the matrices (0.33 l after 1 hour for Bovine and 0.1 after 1 h for Swine).
In both of cases the particle size distribution and the possible presence of colloids and EPS at elevated concentrations determine the not applicability of this type of tertiary filtration for the category of the tested wastes.

Table 3: Summary of the results of filtration tests in downflow column for industrial and zootechnical wastes

Test	50%ile	80%ile	TSSin	TSSout	Filtered Volume
	um	um	mg/l	mg/l	l after 1 hour
Effluent Leachate 1	20	35	8160	2080	0.008
Effluent Leachate 2	20	55	8150	720	0.043
Effluent Bovine	11	30	320	300	0.333
Effluent Swine	20	100	1440	520	0.110

4. Conclusion

The study of rotating discs unit for filtration of urban effluent was realized. Elevated performances in terms of TSS effluent concentrations and low energy consumptions were registered. The hydraulic overload was founded in sustainable conditions at the operative parameters tested. Linear correlation was identified between the influent TSS and the number of backwashing cycles. The net effect of the granulometric distribution and of the presence of filamentous bacteria was demonstrated as filtration performances in the rotating discs unit for urban wastewater effluent post treatment.
Differently, samples of landfill leachates and zoothecnical manures, biologically pretreated and settled, were used to evaluate the use of the rotating discs in these fields. The filtered cumulative volume was almost null for these studied matrices testifying the not applicability of this technology for the tested liquid wastes.

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