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UTILISATION OF TANGENTIAL FILTERS FOR INCREASING ECONOMIC AND QUALITATIVE PERFORMANCE OF WASTEWATER TREATMENT PROCESSES

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Abstract: *The paper discusses basic aspects of the filtering process and the construction of tangential filters used in wastewater treatment. Further presented are the schematic, flow and construction of an experimental (pilot) test rig of the filtration system efficiency, consisting of 4 filtering modules equipped with stainless steel sieves of 475 µm, 100µm, 80µm and 20 µm mesh size, respectively, included in the system subsequently to pre-filtering through a 1µm mesh size filter. In order to determine filtering efficiency for a given feed flow rate, liquid pressure and the concentration of suspended particles in clear water (in mg/l) were measured at the filter inlets and exits after certain functioning times (within an interval of 60 minutes). Eventually the variation graphs of the determined parameters versus time are presented, followed by conclusions concerning the efficiency of the analysed filtration system.*
Keywords: *wastewater, tangential flow filtration, filtering efficiency, experimental rig, fluid pressures, suspended particle concentrations*

1. INTRODUCTION

Filtering is a separation process of solid particles (impurities) from fluids when the suspension flows through porous permeable media called filtering media of filters. The flow of the suspension at a rate Q through the filtering medium is caused by a pressure drop Δp between pressure $p_1$preceding and pressure p_2 succeeding the filtering medium (fig. 1) [2; 5; 6].

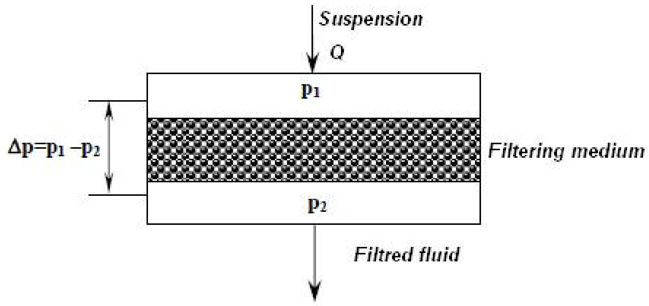

Figure. 1 . Principle schematic of the filtering process

A series of physical, physical-chemical and biological phenomena occur in the filtering processes of fluids (considering the general case of wastewater), the complexity of which is influenced by a number of factors: type and characteristics of the filtering medium, type and characteristics of the suspension in the filtered fluid (size, shape and type of the particles, density and concentration), as well as by the filtering conditions (filtering flow rate, pressure, temperature, filtering procedure) [1; 2;5;6].
The filtering media most used for wastewater treatment are granule beds, sieves and membranes. The filtration mechanism can be explained by two approaches: retention of the solid particles at the surface of the filtering medium pores and retention of the particles within the filtering medium. Depending on the direction of flow and

the particle size (d_i) – to – pore size (D_p) ratio, fluid filtration can be conducted in three distinctive ways (fig. 2): surface, depth and, respectively, tangential filtration. The graphs of figure 2 present the variation versus time of the liquid flow rate *Q*, the pressure drop *Δp* and the thickness of the particle layer built up in the filter, wherefrom follows that tangential filtration (bottom figure) is more efficient than surface filtration and depth filtration (top figures) [5; 6].

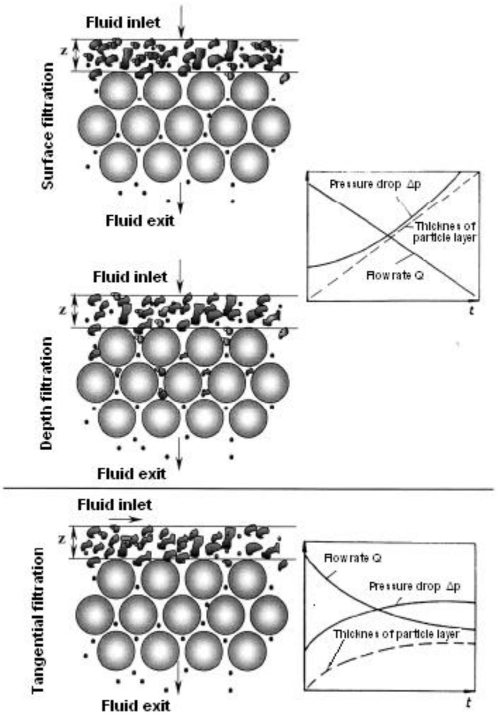

Figure 2. Filtration methods through permeable media (surface, depth and tangential filtration) and variation versus time of the basic parameters of these methods

Surface filtration occurs for $d_i > D_p$, when practically all particles are retained at the inlet surface of the permeable porous medium in the direction of flow.

In *depth filtration* the finer particles can penetrate the thickness of the permeable porous layer, while being gradually removed from the fluid consequently to their impact with a large number of obstacles within the filtering medium.

As in *tangential filtration* the fluid's direction of flow is parallel to the permeable porous medium, the fluid „flow-sweeps" the filter surface, thus diminishing clogging and preventing the building up of a particle layer at the filter surface. The structure of the permeable medium can be regenerated by counter-current flushing, thus rendering tangential more efficient than surface and depth filtration. As in the latter two the flow rate falls abruptly to zero, the pressure drop increases exponentially consequently to the growing thickness of the particle layer. Tangential filtration allows closed circuit recirculation and simultaneous recovery of both filtrate and separated concentrate, a further benefit under the aspect of specific energy consumption.

The developments in high performance synthetic membrane manufacturing technology led to increased utilisation of *membrane filtration of liquids* in various configurations [3; 5; 6]. A membrane can be seen as a barrier separating two compartments, being a selective filtration medium that allows the preferential transfer of a particle, molecule, phase or substance under the action of a motor transporting force. The filtering membranes are manufactured from various materials: organic (polymers), inorganic (metallic, ceramic, glass, active coal), mixed (hybrid polymers, composites, etc.).

Wastewater treatment utilises the following types of filtering membranes: large pore *microfiltration* membranes *(MF)* that retain large solid particles and various microorganisms, smaller pore *ultrafiltration* membranes *(UF)*that in addition to large particles and microorganisms can also retain bacteria and soluble macromolecules; *reverse osmosis* membranes *(OI)* that retain particles as well as numerous species of small molecular weight, like salt ions, organic compounds, etc.) and *nanofiltration* membranes *(NF)* with pore sizes of 10 Å or smaller, that have an operational behaviour between that of *OI* and *UF* membranes.

The relative flow of the liquid in relation to the membrane surface can be parallel (tangential flow) or perpendicular (frontal or piston type flow). In the case of *tangential flow filtration (TFF)* most of the filtered flows in parallel to the membrane surface, and a much smaller part flows through the membrane. The *„sweeping"* and cleaning effect of such flow prevents premature colmatation and differences in concentration.

TFF is increasingly used in industrial processes, as it allows the utilisation of significantly greater flows than perpendicular (normal) flow.

In wastewater filtration technology multiple tangential flow filters are used (fig. 3), which includes several parallel-connected filtering elements. Such a filter consists of a cylindrical casing 3 enveloping a system of pipes with tangential flow filters (*TFF*) elements. These pipes are welded to two caps size perforated pipes that provide tangential flow filtration fluid subject. The cylindrical housing is closed with two lids that separate three chambers: chamber *A* for filtered liquid collection (the liquid that has passed through the membrane), chamber *B* for feeding of the liquid to be filtered and distribution to the filtering elements, and chamber *C* for evacuation of the unfiltered liquid that has not passed through the membrane (or the concentrated liquid in relation to the substance the concentration of which is to be increased). After lengthy operation the membrane pores can clog (colmatation), thus affecting process efficiency. This inconvenient is eliminated (decolmatation) the construction of the filter allows reverse filtering, by means of a special circuit of the liquid to be filtered, that under a greater pressure passes through the membrane in the opposite direction. Thus the liquid is fed to chamber *A* and evacuated through chamber *C*. In order to determine when reverse filtration has to be induced, the installation was equipped with fittings 5 connected to the pressure gauges that measure the pressure in chambers *A* and *B*. In practice membrane cleaning by reverse filtration is recommended when the gauge indicates a pressure drop between inlet and exit of filter that exceeds 2 bar.

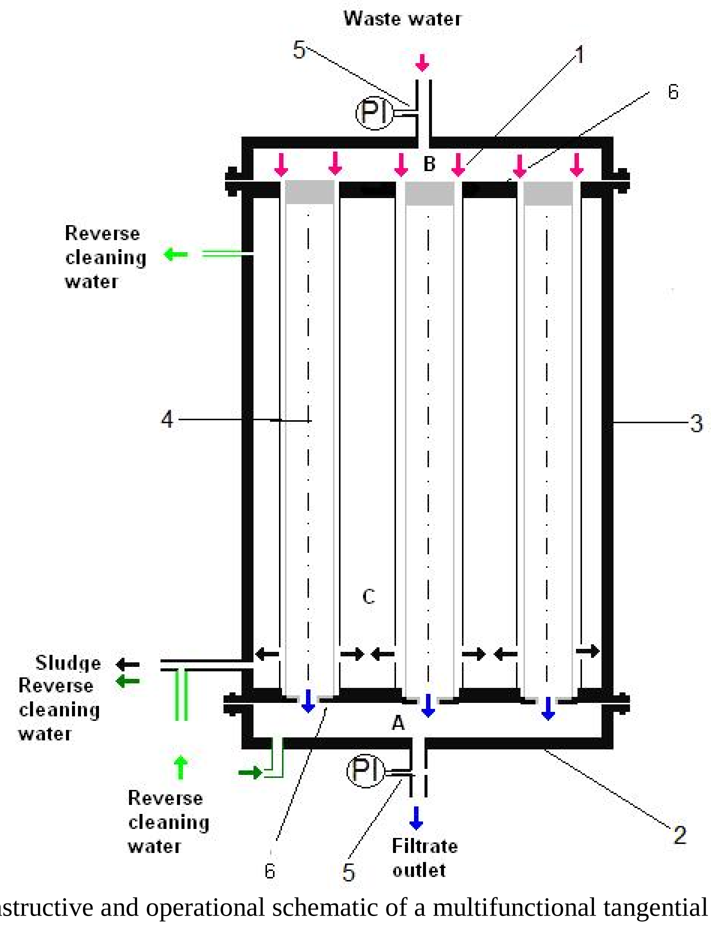

Figure 3. Constructive and operational schematic of a multifunctional tangential flow filter (TFF): 1- upper lid; 2- lower lid; 3- filer body; 4- filtering element; 5- fittings to the pressure gauge; 6- holding plate of filtering elements.

3. EXPERIMENTAL RESEARCH

The experimental research of the operational behaviour of tangential flow filtration systems of industrial wastewater was conducted on a specially built multi-level filtration pilot rig that ensures the retention of suspended particles up to 400 mg/l. The installation consists of a modular tubular filtration system operating under conditions specific for coarse filtration and microfiltration. The filtration system (fig. 4), consists of 4 filtering modules *F1, F2, F3* and *F4 (*of TFF type) endowed with stainless steel sieve filters [4] of 475 µm,

100 µm, 80 µm and 20 µm mesh size, respectively, included in the system after pre-filter *M1* of 1µm mesh size. The installation also includes a wastewater collection/neutralizing vessel *VS* where also the initial separation of coarse suspended particles is conducted; pump *P* and an heat recovery system, for collection of the wastewater resulted from the first filtration level, consisting of filters *F1* and *F2* (endowed with series-connected 475 µm and 100 µm mesh size filtering elements). Filters *F3* and *F4* form the second filtration level. Filters *F1, F2, F3, F4,* are endowed each with 7 filtering elements like the one in figure 3. The installation was equipped with the pressure gauge *PR1, PR2, PR3, PR4* and *PR5* that measure the pressures at the inlets and the exits of the filters *F1, F2, F3, F4.*
Figure 5 shows a view of the pilot rig and figure 6 presents the schematic of the flow of operations for the experiments carried out on the tested installation.

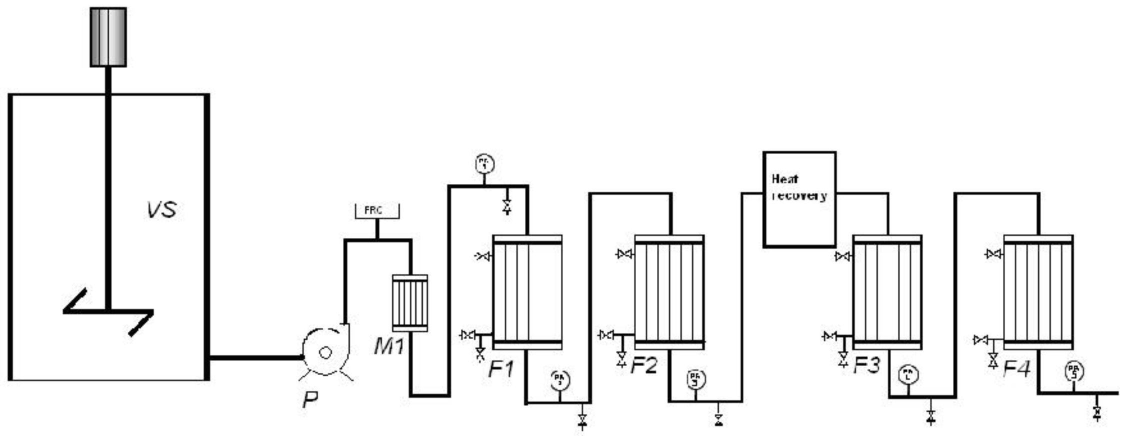

Figure 4. Flow diagram of the pilot rig used in experimental research

Figure 5.General view of the pilot filtration rig used in experimental research

Table 1: Variations versus time of pressures and suspension (suspended particle) concentrations in clear water at the inlets and exits of the filters.

Time	Pressure at filters					Concentrationof suspension (suspended particle) concentration in clear water				
	Before F1	After F1	After F2	After F3	After F4	Before F1	After F1	After F2	After F3	After F4
min	bar	bar	bar	bar	bar	mg/l	mg/l	mg/l	mg/l	mg/l
0	3	2.7	2.5	1.2	0.4	15878	5264	4568	3129	587
20	3.2	2.9	2.6	1.4	0.4	15878	3171	2825	2042	361
40	3.6	3.4	3	1.8	0.4	15878	2800	2350	1850	336
60	4	3.9	3.4	1.9	0.3	15878	1224	640	570	269

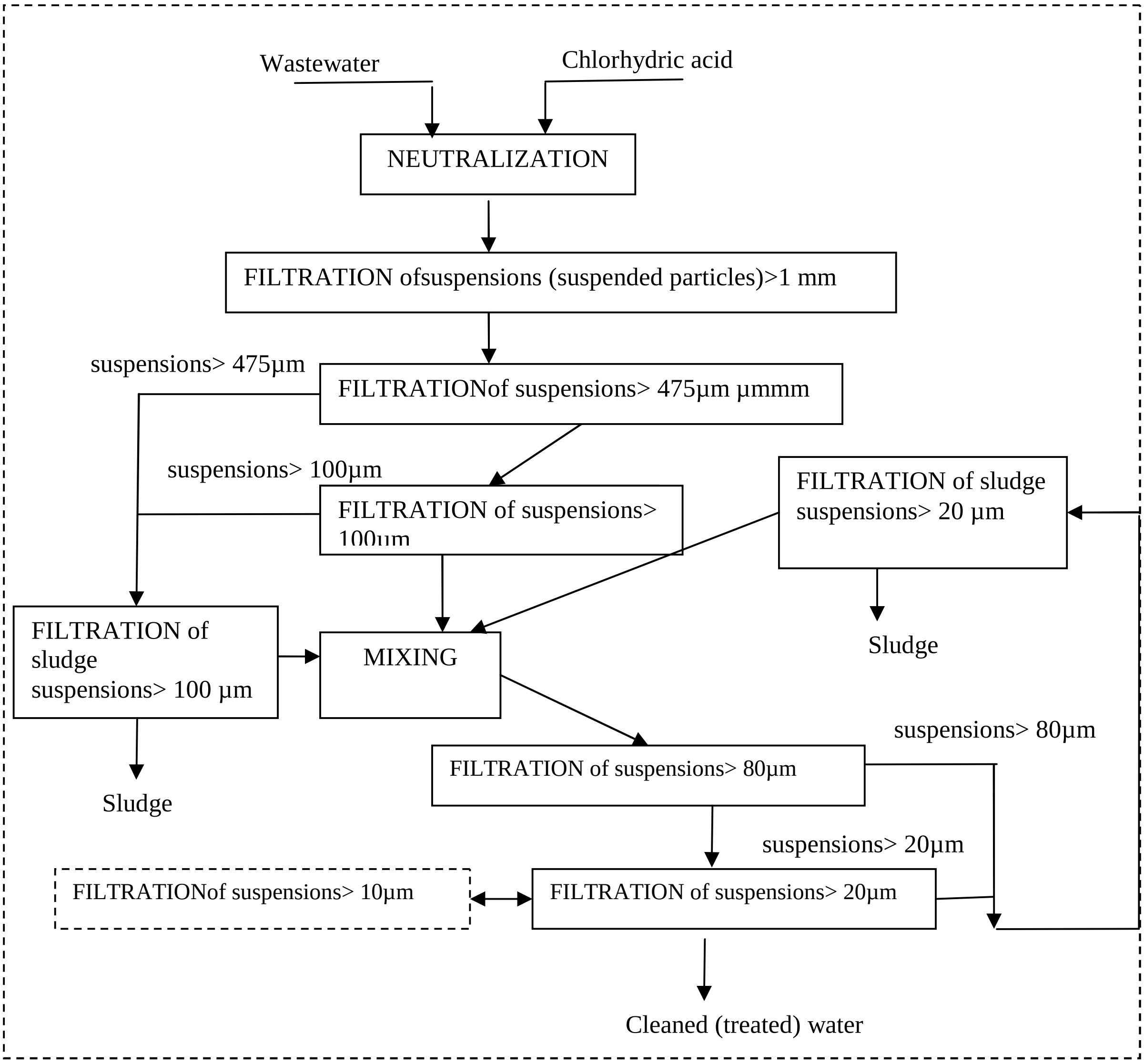

Figure 6. Flow of operations of the filtering process in the pilot rig

3. ANALYSIS OF RESULTS

In order to determine the *efficiency* of the tested filtration system, wastewater containing suspended particles of 16,000 mg/litre initial concentration (concentration in clear water) was fed into vessel *VS* and circulated by means of pump *P*. After certain operation times, within an interval from 0 to 60 minutes, the pressures were measured at the inlet of filter *F1* and the exits of filters *F1*, *F2*, *F3* and *F4*; also samples of suspension were collected in order to determine the concentrations in clear water (mg/l). The pressures were measured by the gauges included in the circuit (s. fig.4), and the concentration of the suspension was determined of the collected samples. Table 1 features the obtained experimental data.
Based on the experimental data of table 1 the graphs of variation versus time of pressures (fig. 7) and suspension (suspended particle) concentrations in clear water (fig. 8) were plotted at the inlets and exits of the filtration rig, allowing the analysis of the filtration process achieved by the studied pilot rig.

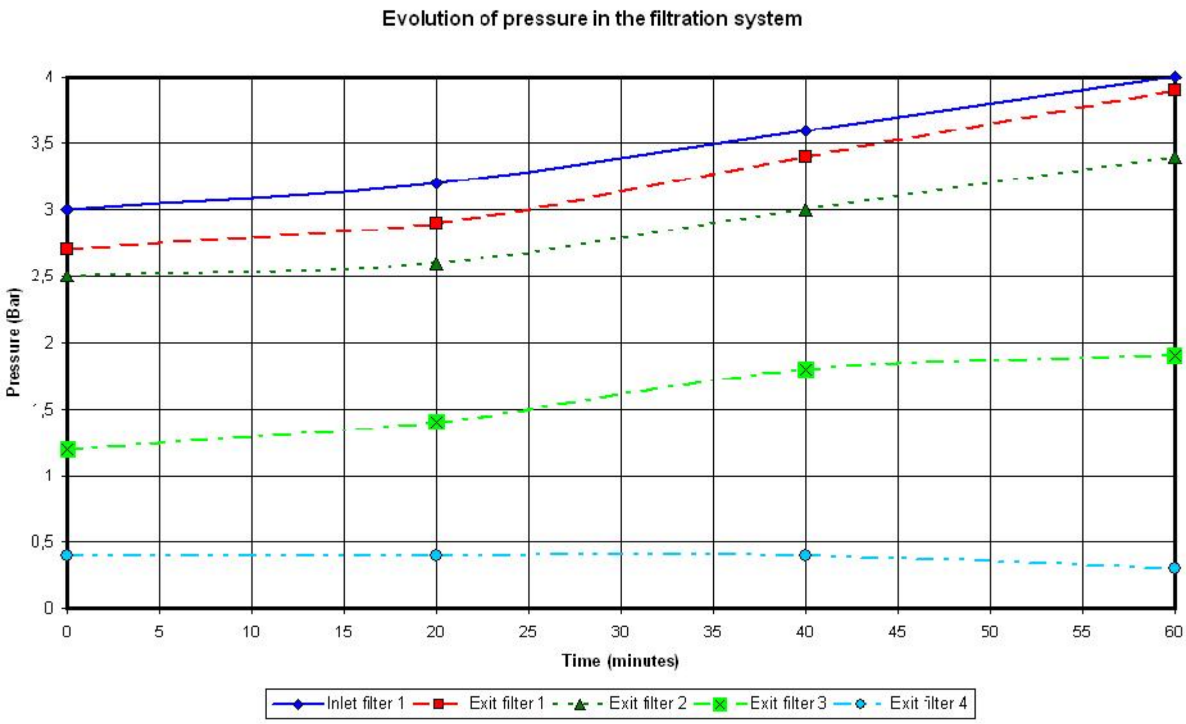

Figure 7. Evolution versus time of pressures (in bar) at the inlet of the filter *F1* and the exits of filters *F1*, *F2*, *F3* and *F4*, over a 60 minute interval

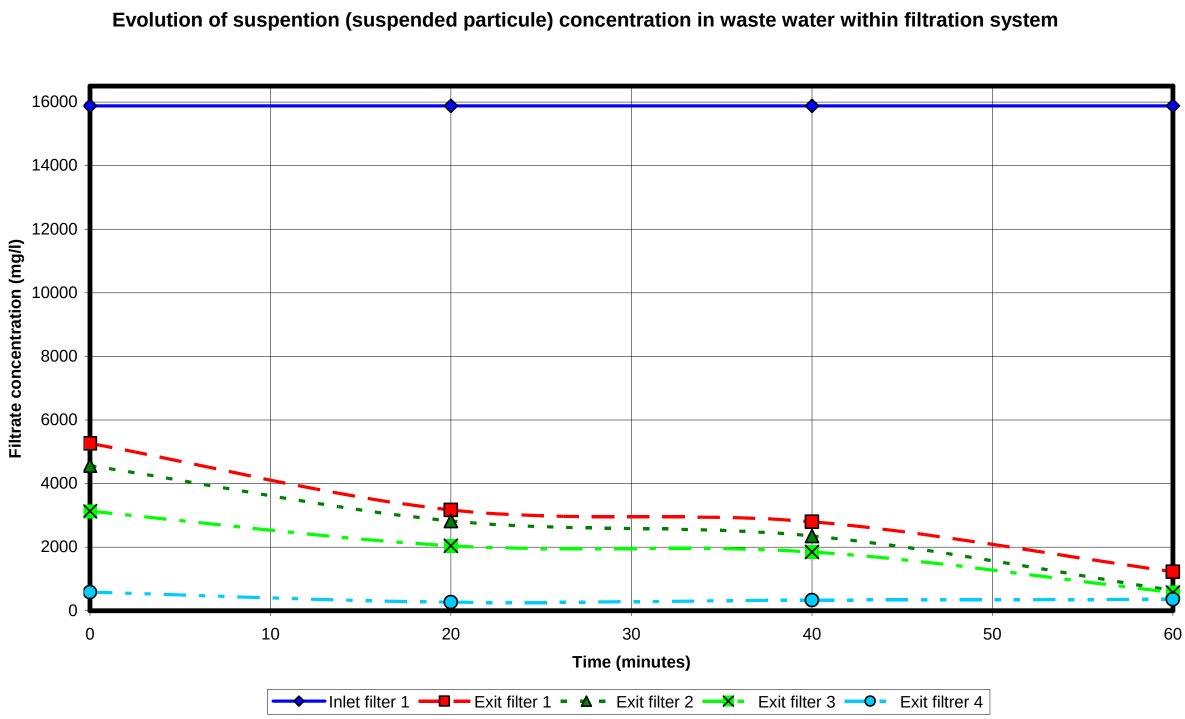

Figure 8: Evolution versus time of suspension concentration in clear water (in mg/l) at the inlet of the filter *F1* and the exits of filters *F1*, *F2*, *F3* and *F4*, over a 60 minute interval

4. CONCLUSIONS

An analysis of the graphs of figure 7 reveals that system pressures increase at the inlet of filter *F1* and the exits of filters *F1, F2* and *F3* and remain approximately constant at the exit of final filter *F4*.
An analysis of the graphs of figure 8 shows that the studied filtration system is operational, does not clog (colmatation is avoided) and has the following characteristics:

- after filtering module *F1* (with sieves of mesh size 475 µm) retention was of 80% and no particles larger than 475 µmwere found in the filtered water); the content of suspended particles decreased from initial approx. 16000 mg/l to 5264 mg/l;
- after filtering module *F2* (with sieves of mesh size 100 µm) retention was of 82,5% and in the filtered water 24,82% particles larger than 100 µm were found (because of sieve defects); the content of suspended particles decreased from initial approx. 2800 mg/l to 1224 mg/l;
- after filtering module *F3* (with sieves of mesh size 80 µm) retention was of 95,3% and in the filtered water 6,68% particles larger than 80 µm were found (because of sieve defects); the content of suspended particles in wastewater decreased from initial approx. 3100 mg/l to 570 mg/l;
- after filtering module *F4* (with sieves of mesh size 20 µm) retention was of 98,3%.the content of suspended particles in wastewater decreased from initial approx. 570 mg/l to 269 mg/l;

Overall it could be established that after the first 3 filtering modules (*F1, F2, F3*) about 95% of the initial total of suspended particles in wastewater are retained. Thus, in the completed experiment the initial concentration of the filtrate of about 16000 mg/l was reduced to 570 mg/l.

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