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STUDY ON THE SEPARATING PROCESSES OF IMPURITIES FROM WASTE WATER BY USING TANGENTIAL FILTERS

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Abstract: *The paper presents the methodology and the experimental research installation of the efficiency of impurities separation from the wastewaters by the use of the tangential filters connected in series. The experimental installation (pilot installation) used consists of two tangential filters mounted in series, with filtering elements with stainless steel sieves, having a fineness of 475 µm, and 80 µm. To establish the filtration efficiency to a given feed flow rate were determined by measurements the liquid pressures and concentrations of the suspension in clear (in mg/l) at the entrances and at the exits from the filters, after certain durations of operation (throughout of 60-minute). Finally are presented the conclusions on the efficiency of separation of mechanical impurities of the analyzed filtration system.*
Keywords: *wastewater, concentrations of suspensions, tangential filtration, experimental installation, filtration efficiency,*

1. INTRODUCTION

Filtration is the separation process of removing solid particles, microorganisms or droplets from a liquid by depositing them on a filter medium (granular layers, sieves, membranes), also called filters, which is essentially permeable to only the fluid, haze of the mixture being separated. The particles are deposited either at the outer surface of the filter medium and/or within its depth. The permeation of the fluid phase through the filter medium is connected to a pressure gradient [1; 2; 3].
The liquid more or less thoroughly separated from the solids is called the filtrate, effluent, permeate or, in case of water treatment, clean water. As in other separation processes, the separation of phases is never complete: liquid adheres to the separated solids (cake with residual moisture) and the filtrate often contains some solids (solids content in the filtrate or turbidity). The purpose of filtration may be clarification of the liquid or solids recovery or both. In clarification the liquid is typically a valuable product and the solids are of minor quantity and are often discarded without further treatment. During a dynamic filtration the collected solids on the filter media are continuously removed, mostly with a tangential flow to the filter medium (cross-flow filtration). Cross-flow filtration is a standard operation with membranes as a filter medium [4; 5; 6]. The flow parallel to the filter medium reduces the formation of a filter cake or keeps it at a low level. So it is possible to get a quasi-stationary filtrate flow for a long time. The four idealized filtration models are: cake filtration, blocking filtration, deep-bed filtration and cros-flow filtration (Fig.1).
Cross-flow filtration, called *tangential filtration*, is a form of a dynamic filtration. In cross-flow filtration the build-up of a filter cake on the surface of the filter media is hindered by a strong flow tangentially (parallel) to the filter surface. Clear liquid passes through the filter medium (mostly a membrane) and the concentrate (respectively the retentate) with higher concentrations of the rejected components is discharged from the filter. The cross-flow stream over the filter media has often a linear velocity in the range of 1 to 6 m/s. This cross-flow is achieved in most cases by pumping the suspension through a membrane module, which e.g., contains the membrane in form of a bundle of membrane tubes. Alternatively the cross-flow is achieved by rotating inserts. The limitation of the deposition of particles and macromolecules on the membrane surface enables to filter very fine particles, which otherwise would form a cake with prohibitively high resistance. Even submicron, nonparticulate matter can be retained by membranes with a corresponding separation characteristic according to

this principle. The shearing action on at the membrane surfaces limits the deposition of retained matter due to lift forces and diffusion processes back from the membrane. In normal operation the filtrate (respectively permeate) is collected and the concentrate is re-circulated until the desired concentration of retained components is achieved, or pumping cannot be longer performed due to raised viscosity of the suspension. Typical units comprise one or more membrane modules and a recirculation pump. Depending on the size of the species retained, a distinction is made between microfiltration, ultrafiltration, nanofiltration, and reverse osmosis.

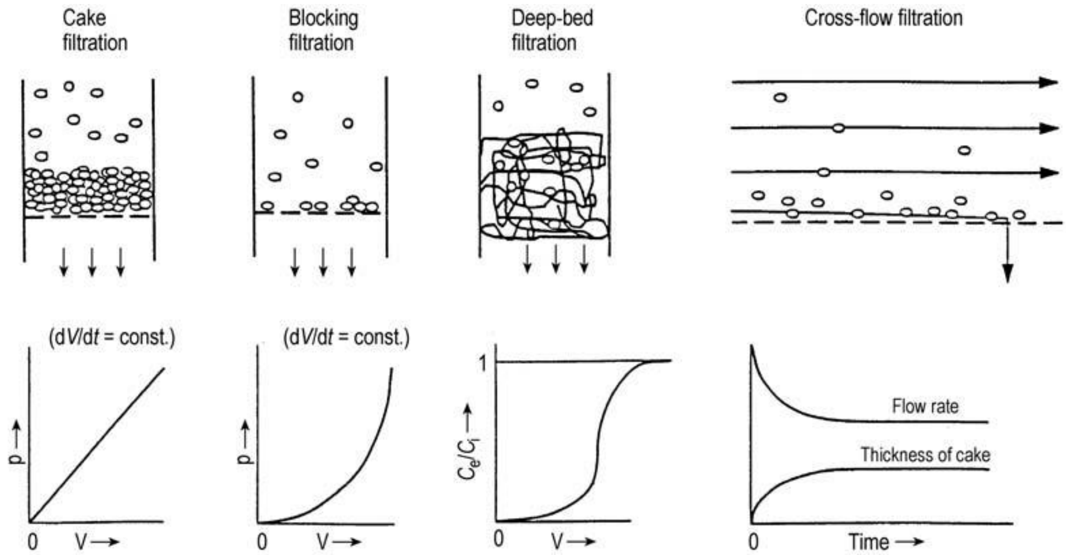

Figure 1: The four idealized filtration models: cake filtration, blocking filtration, deep-bed filtration and cros-flow filtration

Microfiltration retains particles and microorganisms down to 0.1 µm in size. In steady-state cross-flow filtration these particles are conveyed onto the membrane by convection due to the filtrate flow and transported away from it by hydrodynamic lift forces due to the parallel shear flow (forces *FY* and *FL* in Fig. 2). For particles below a certain size the lift force becomes smaller than the convection, $FL < FY$, and they are deposited on the membrane. After deposition they are retained by van der Waals' adhesion forces *FA* and not easily swept away even if there is no filtrate flow (irreversible cake formation). In case of a steady-state microfiltration there is an equilibrium between the lift force and the drag force due the convection by the filtrate flow and a critical particle size. This steady-state flow is often mentioned as critical flux. In most practical applications also colloidal particles are present and they are transported according to the mechanisms of ultrafiltration or they are able to permeate through the microporous membrane of microfiltration. The cut-off size of a microfiltration membrane is usually defined as the size of particles of a test suspension (generally a suspension of microorganisms) which are nearly absolute retained.

Ultrafiltration retains colloidal particles or macromolecules. The cut-off sizes are ca. < 0.1 µm. Such particles are subject to Brownian diffusion (*Br* in Fig. 2) and only weakly influenced by the hydrodynamic lift force. The smaller these particles are, the more they are transported away from the filter medium by diffusion. This is why in ultrafiltration the smaller particles are preferably swept away and the bigger ones are collected on the membrane (contrary to microfiltration). The cut-off size of an ultrafiltration membrane is usually defined as the molar mass (in g/mol) of a test solution (generally protein or dextrin molecules of defined molar mass in the range of 103–105 g/mol). In practical application the cut-off size depends not only on the pore size of the membrane, but to a large degree on a gel layer on the membrane consisting of retained colloids.

Nanofiltration combines features of ultrafiltration and reverse osmosis with a high selectivity. Its name is derived from its approximate cut-off size of some nanometers or more exactly molar masses of 200–600 g/mol. This is achieved with special nanofiltration membranes which still have pores of a defined size, but their retention depends also on the electrostatic charge of the molecules to be separated (bivalent anions are typically retained).

Reverse osmosis retains molecules or ions using selective membranes without pores. Certain molecules permeate through the membrane because they are soluble in the membrane material. Other molecules are not (or less) soluble and are retained (or concentrated) on the upstream side of the membrane. A particular feature of reverse osmosis is the high pressure required to overcome the osmotic pressure of the retained molecules. An important application is desalination of seawater. In the food industry it is applied to concentrate juices and other sugar solutions at low temperatures.

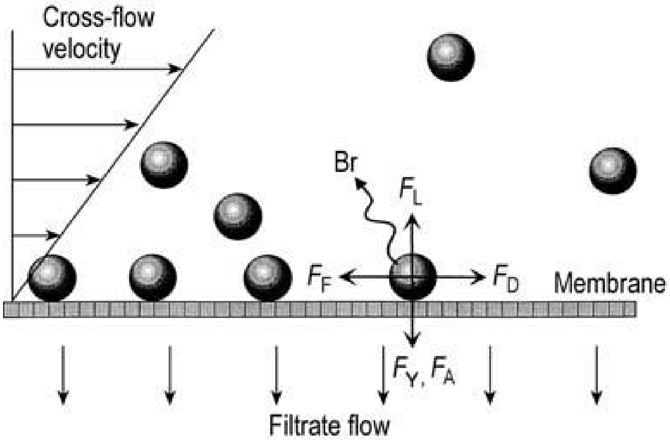

Figure 2: Forces and transport effects onto a particle in cross-flow filtration:
Br - Brownian motion; F_A -adhesion to the membrane; F_D - drag from the cross-flow; F_F- friction force; F_L- hydrodynamic lift force; F_Y - drag from the filtrate flow

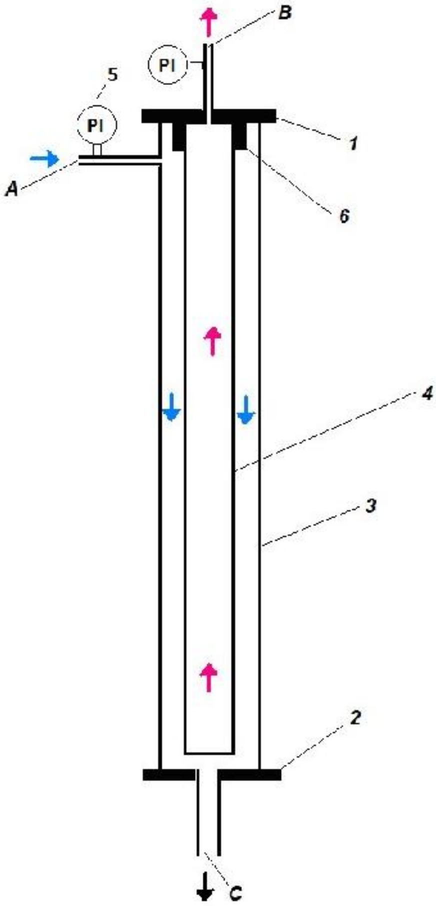

Figure 3: The constructive and functional diagram of a tangential flow filter: A - liquid inlet; B- filtered liquid outlet; C- evacuation fluid that has not passed through the membrane:
1- upper lid; 2- lower lid; 3- filter body; 4- filtering element; 5- differential pressure gauge connection fittings; 6- fixing plate of the filtering element.

Tangential filtration is a more efficient method compared with the filtration of surface and of depth, because most of the liquid to be filtered flows parallel to the surface of the filter, a much smaller part flowing through the filter membrane. Due to the effect of "sweeping" and of cleaning is prevented premature the filters clogging and the occurrence of differences in concentration of the filtered fluid. Tangential flow filtration allows the use of much higher flows than to the perpendicular flow (normal), of surface and of depth, being used increasingly in the industrial processes [3]. Regeneration of the filter permeability structure can be done by washing the filter element by directing the liquid in counter-flow [4]

Figure 3 shows the functional diagram of a tangential flow filter, at which the cylindrical casing of the filtering element 4 is closed with two caps, upper 1 and lower cap 2. After a certain operating time of the filter is possible the plugging (clogging) the pores or orifices of the filtering element, with negative effects on the efficiency of the filtration process. To eliminate this inconvenience the filter is provided with the possibility of performing a washing procedure by the inverse filtration. For determining when it is necessary the inverse filtering, the inlet and outlet connections from filter are coupled through a differential pressure gauge, which measures the pressure difference between the entrance of the wastewater and the exit of the filtrated liquid. In practice, cleaning the filters by washing performed by inverse filtering is recommended when the differential manometer indicates a pressure drop of more than 2 bar between the filter inlet and outlet.

2. MATERIALS AND METHODS

The basic objective of the undertaken researches consists in experimental determination of the optimum moment at which is imposed the washing of tangential filters through the reverse filtering operation. For this is used the method of the measurement of pressure differences between Ins and Outs of filters, whose values depend on the degree of fouling (clogging) of filter elements.

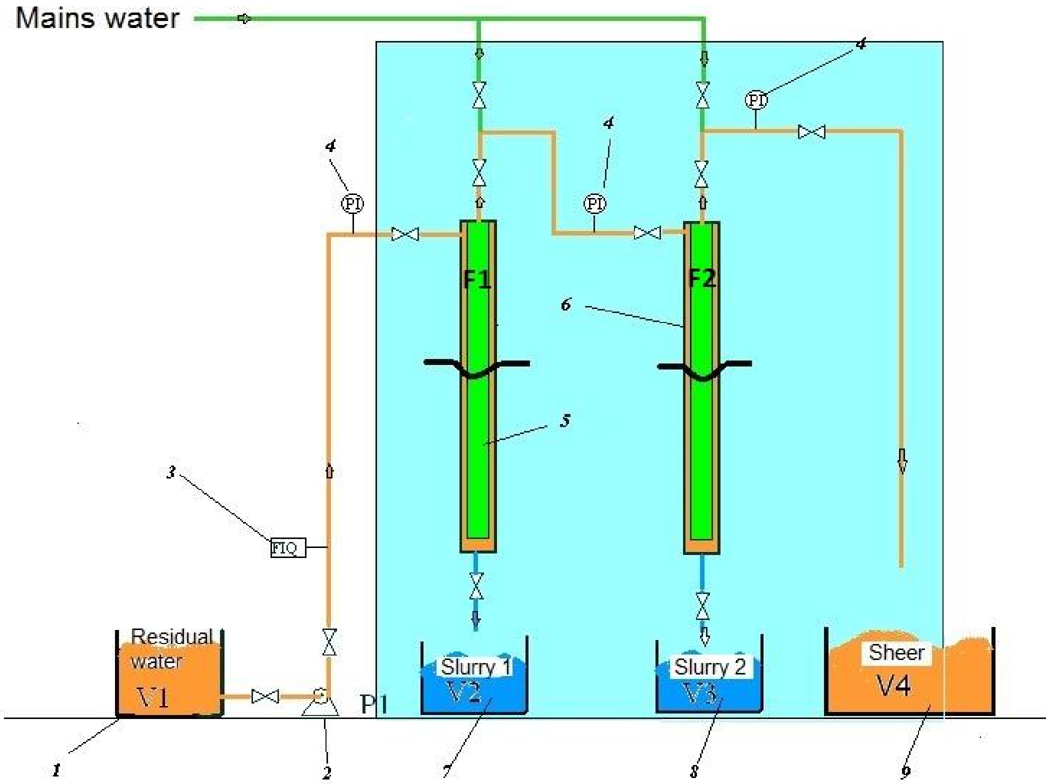

Figure 4: The scheme of the experimental plant (pilot plant) with two filtration steps coupled in series: 1-tank (V-1) with waste water that will be submitted to filtration; 2- hydraulic pump (P1) for supplying the filters ; 3-. electromagnetic flowmeter (FIQ) ; 4- manometers (PI); 5. coarse filter element (F1) with 475μm steel sieves ; 6- fine filter element (F2) with steel sieves of 80 μm ; 7- tank (V2) to collect slurry / sterile resulting from the coarse filter F1 ; 8- tank (V3) to collect slurry / sterile resulting from the fine filter F2; 9- tank (V4) to collect the filtered product (clear)

For the experimental study of the functional behaviour and of the filtration efficiency when using tangential filtration systems of the industrial waste water was designed and built an experimental installation (pilot plant) with two filtration steps (Fig. 4), which allows retaining the solid suspensions from 4000 mg / l up to a value of approx. 400 mg / l. The experimental installation consists of two tubular filtering modules serially connected: the coarse filtration module F1 equipped with filter with stainless steel sieves having a fineness of 475μm and the microfiltration module (fine filtration) F2, equipped with stainless steel filter with sieves having a fineness of 80 μm. To measure the flow discharged by the pump 1 is used the electromagnetic flowmeter FIQ (type YOKOGAWA) and for measuring the pressures are used the pressure gauges PI (type Bourdon tube type with separation membrane MS) All the elements of the installation are mounted on a supporting plate.

The waste water subjected to analysis is stored in the tank V1 (with a capacity of approx. 200 l) and is sent in the filtration system by means of the centrifugal pump P1. In the first stage the water reaches the coarse filter F1 (with the sieve of 475 μm), at the upper part being discharged the filtered liquid (who has passed through the filtering element F1) and at the lower part occurs the discharge in the tank V2 (approx. 60 l) of the liquid with impurities (the liquid that has not passed through the filter membrane F1. In the second stage, the filtered liquid into the filter F1 reaches into the fine filter F2 (with the sieve of 80 μm), out of which at the upper side is discharged the filtered fluid which is collected in the tank V4 (approx. 200 l), and at the lower part occurs the discharge in the tank V3 (approx. 50 l) of the liquid with impurities which has not passed through the filter F2 . The filtrate quality is targeted in the clear liquid accumulated in the tank V4. To clean (desilting) the filters is used the water from the current network (the circuit marked with green), with exhaust in the system slurry / sterile of the two filters. To determine the effectiveness of the filtration system tested in the tank V1 was introduced a wastewater with an initial concentration of suspensions of approx. 4.000 mg/l. After certain durations of operation of the filtering installation, in the range of from 0 to 60 min, were measured the pressures at the gauges mounted in the filter F1 entry and at the exits from the filters F1 and F2 and were determined by measuring the concentrations of the mechanical suspensions (in mg/l). The concentration of the liquid suspensions was determined by gravimetric analysis of the taken samples

3. RESULTS AND DISCUSSION

The time variations of the pressures and concentrations of the mechanical suspensions from liquid experimentally determined at the outflows from the filters of the filtering installation are presented in Table 1. Based on data from Table 1 were constructed the graphs with the variations in time of the pressures (Fig. 5) and of the suspensions concentrations in clear (Fig. 6) at the inlets and outlets from the filters of the filtration installation, allowing an analysis of the filtering process conducted by the pilot plant used.

Table 1: The variations in time of the suspensions pressures and concentrations l at the entry into F1 filter and the goings from the filters F1 and F2

Time	Pressure before F1	Pressure at the exit of F1	Pressure at the exit of F2	Concentration suspension before the F1	Concentration suspension at the exit of F1	Concentration suspension at the exit of F2
min	bar	bar	bar	mg/l	mg/l	mg/l
0	3	2.1	0.9	4058	1059	587
20	3.2	2.2	1.1	4058	826	436
40	3.4	2.6	1.2	4058	514	325
60	4	3.1	1.3	4058	468	216

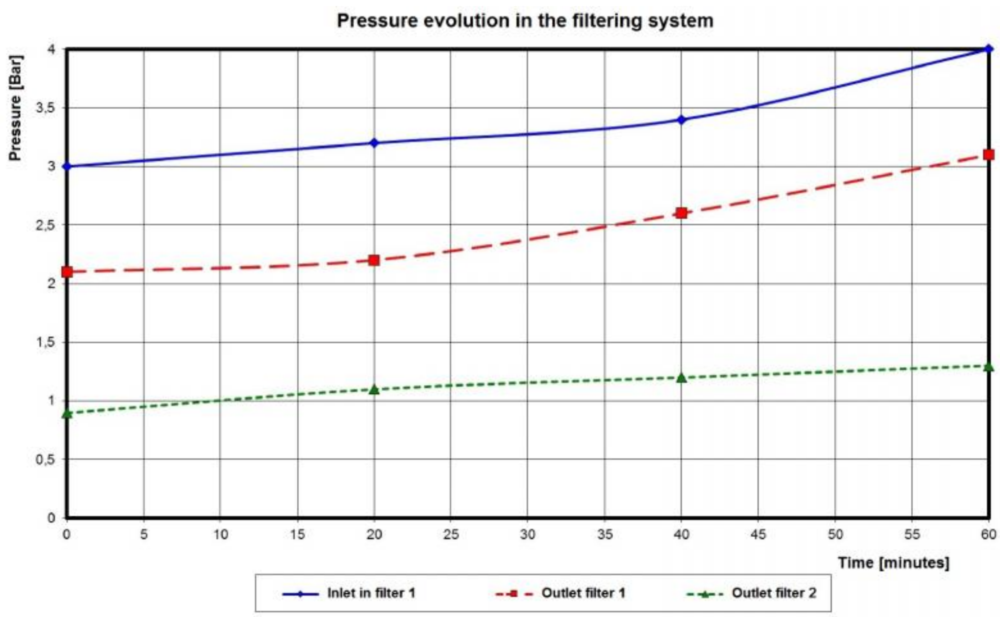

Figure 5: Evolution in time of the pressures in filtering system at the entrance into the filter F1 and the goings of the filters F1 and F2

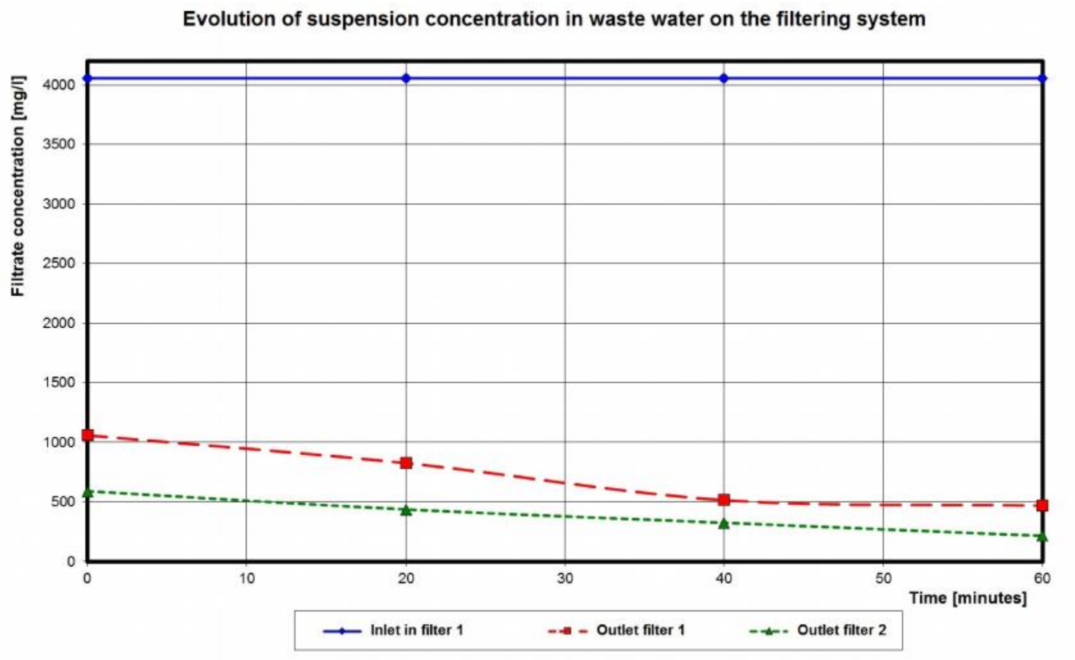

Figure 6: Evolution in time of the suspension concentration in the waste water in the filtering system at the entrance into the filter F1 and the goings of the filters F1 and F2

4. CONCLUSIONS

From the analysis of the results presented as tables and graphics revealed the following conclusions:

- the pressures at the entrance into the first filter (coarse filter) and at the outlet of the both filters increase with the duration of the filtration process;
- the first filter (coarse filter) retained around 95% of the suspensions mass contained in the waste water analyzed;
- By using the system with tangential filters coupled in series the suspension concentration from the analyzed wastewater was reduced from the original value of approx. 4000 mg/l to a final value of approx. 200 mg/l in the filtered liquid (clear), obtaining a reduction of over 90% of the initial content of mechanical suspensions from the wastewater.

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