ACTUAL STAGE OF WATER FILTRATION

ŢÎRŢOACĂ (IRIMIA) OANA[1*], NEDEFF VALENTIN[1], LAZĂR GABRIEL[1]

[1]*"Vasile Alecsandri" University of Bacau, 157 Calea Marasesti, 600115, Bacau, Romania*

Abstract: The main process of water's treatment can be mechanical, chemical and biological. From all mechanical treatment procedures, filtration is the most irreplaceable one in the scheme of a treatment plant. Filtration is the advanced clearing procedure, consisting of water's passing through a porous material, that has a certain granulometry, named filter layer, used for the retention of the natural suspended particles or previous coagulated particles. Filtering is influenced by a series of parameters.

Keywords: potable water, water's mechanical treatment, filtration, particle's shape.

1. INTRODUCTION

The restriction of water's resources, the need of a careful management and the importance to ensure a good water quality are now more obvious than ever [1, 2].

Treatment of water is accomplished through process of mechanical nature (retention on grates and separators, sediment exclusion, decantation, filtration), of chemical nature (coagulation – flocculation, ion exchange, chlorination, disinfection with UV radiations, aeration – oxidation) and of biological nature (adsorption on active coal, biological treatment using slow filter or semi – permeable membrane). Among these processes, filtration is the operation irreplaceable in the scheme of a treatment plant [3-9].

In the last three decades in the whole world were done multiple studies viewing the filtration of water, developing theories referring to the mechanism of removing the particles from the influent and referring to the parameters that influence the water's mechanical filtering process [10-15].

2. FILTERING MECHANISMS

The retention of the suspensions from water in filter layer, takes place on the strength of a large number of processes and mechanisms, from which [16, 17]:

- inertial impact;
- diffusion;
- interception;
- sieve effect.

Filtration mechanism through **inertial impact** (Figure 1) appears when, from a mixture liquid – solid, the liquid changes the initial flow direction, thus avoiding the filter material, while the suspended particles make direct contact with the filter material [13, 15].

[*] Corresponding author, email: oana.tartoaca@ub.ro

Fig. 1. The retention process of solid suspensions through inertial impact [16].

Diffusion (Figure 2) is specific to the particles that have the diameter up to 2 μm and is accomplished under the action of Brownian motion. This physical effect has a low weight in the case of water's filtration, taking into consideration the previous retention through coagulation – flocculation and sedimentation of the particles having these dimensions [13, 16].

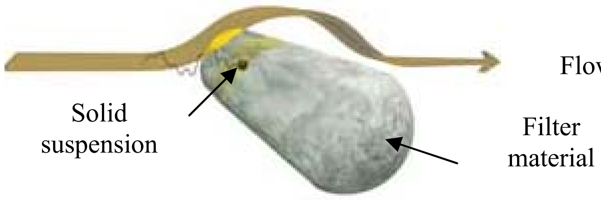

Fig. 2. The retention process of solid suspensions through diffusion [16].

Interception (Figure 3) appears when the radius of the particle that follows to be discharged is bigger than the distance between the filter material and the liquid flow lines [16, 17].

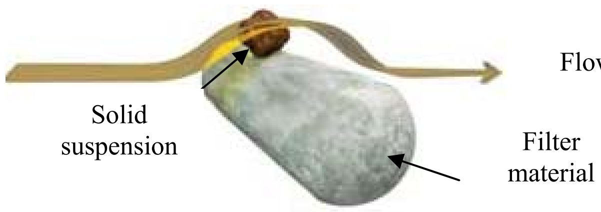

Fig. 3. The retention process of solid suspensions through interception [16].

Sieve effect (Figure 4) acquires the retention of the particles in the tangency area of the filter layer. The larger the particle's diameter is, the more efficient is the sieve [14, 16].

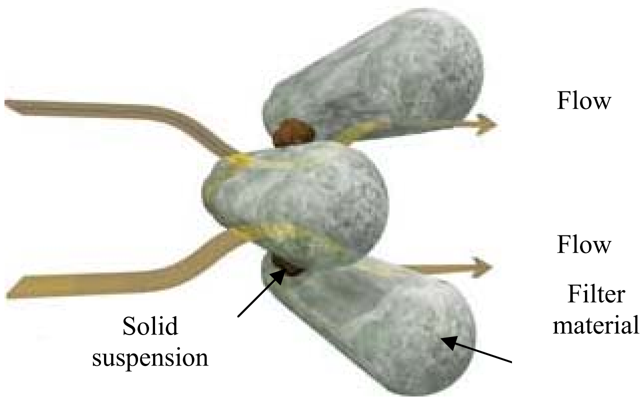

Fig. 4. The retention process of solid suspensions through sieve [16].

The retention of the suspensions in slow filters is accomplished through mixed processes having the following nature [17]:

- physical;
- chemical;
- biological.

Physical processes. On the surface of the filter environment and also in its superior layer take place sedimentation and sieve processes, respectively adsorption due to the electrostatic forces or ionic replacement. In this way are discharged the suspended solids, the colloidal particles, the bacteria and the remiss impurities [12, 14].

Biological processes. The biological activity is the base in removing the germs, viruses and organic matters, through slow filtration and is manifested on the surface and in the first centimeters of the filter layer [13, 25].

Chemical processes take place in the slow filters in the face of the oxygen remiss in water or during the oxidation of the adsorbed organic matters, in the face of the microorganisms [17].

3. PARAMETERS THAT INFLUENCE THE FILTERING OPERATION

The productive selection of the filtering process, of the filtering equipment and of the operating conditions is done taking into account multiple parameters that have an influence on filtering operation [16, 18]. These parameters can be synthesized in this manner:

3.1. Characteristic parameters of the liquid – solid mixture that influence the filtering process

Suspension's nature. The suspensions with spherical particles, and mostly acicular, give precipitates with a higher permeability and therefore there are admitted higher filtering rates than the suspensions with foil grains. When the foils are flexible, they produce the effect of some valve. The suspensions with big and incompressible particles are filtered easier than the suspensions with fine or colloidal particles that form compact and impermeable precipitates that are closing the pores of the filtering material [19].

Density. For a liquid – solid biphasic system the density can be defined through the relation (1) [20]:

$$\rho_s = \rho_a \cdot \varepsilon_p + \rho_p \cdot \varepsilon_a \tag{1}$$

where:

ε_p is the gaps rate of the solid phase;

ε_a – the gaps rate of the liquid phase (of water).

Viscosity. For the mixtures with low concentration of the solid phase, viscosity can be determined with the relation (2) [7, 20]:

$$\eta_s = \eta_a \cdot (1 + a \cdot \varepsilon_p + b \cdot \varepsilon_p^2 + c \cdot \varepsilon_p^3) \tag{2}$$

where:

η_s is the mixture's viscosity, Pa·s;

η_a – water's dynamic viscosity, Pa·s;

ε_p – gaps rate of the solid phase;

a, b, c – constants;

a = 2.5 for spherical, unadsorbent particles;

a $\in$ (2.5 ÷ 3.6) for adsorbent particles that increase their volume in water.

Due to the hydrodynamic interaction between the solid particles, the constants b and c have values between:

b $\in$ (2.5 ÷ 14.1);

c $\in$ (8.75 ÷ 36.3).

The viscosity of the mixtures with a high concentration of solid particles is mainly influenced by: the concentration of solid particles from the mixture, the shape and the dimension of the particles, the roughness of the particles surface. The viscosity can be determined with the expression (3) [20]:

$$\eta_s = \eta_a \cdot \left(1 - \frac{\varepsilon_p}{\varepsilon_{p,\max}}\right)^{-2,5} \quad (3)$$

where $\varepsilon_{p,\max}$ is the maximum concentration of the solid particles from the mixture.

3.2. Characteristic parameters of the precipitate that influence the filtering process

Precipitate's specific resistance α is constant for the incompressible layer of precipitate, but it is changing with time as a consequence of the precipitate's compaction. Usually, the precipitate layers are compressible and the specific resistance is changing along with the pressure difference from the precipitate layer Δp_p [Pa]. In this case the medium value of the precipitate's resistance α_m [m/kg] is expressed through the equation (4) [20, 21]:

$$\frac{1}{\alpha_m} = \frac{1}{\Delta p_p} \int_0^{\Delta p_p} \alpha(\Delta p_p) \cdot d(\Delta p_p) \quad (4)$$

if the value of the function $\alpha = f(\Delta p_p)$ is known from experimental determinations.

The quantity of precipitate laid-down on the unit of area ω [kg/m^2**]** is determined is the relation (5) [20]:

$$\omega \cdot A = C \cdot V_a \quad (5)$$

where:

A is the total area of the filter layer, m^2;
C – the concentration of the solid phase, kg·m^{-3};
V_a – the volume of filtrate (mixture) in the time t, m^3.

3.3. Characteristic parameters of the filter layer that influence the filtering process

Particle's shape. Whatever the obtaining process of the particles is, these don't have the same shape and this is a fact that makes difficult to create mathematical models concerning the sorting process. However, the scientists discovered various methods in which they use different approximations in order to determine the granular particles shape [22].

Taking into account the shape of the particles, these can be classified in four main categories depending on the relation between the three dimensions (L – length, l – width and h – thickness) [23]:

- particles with any shape (Figure 5.1.a), for which L > l > h;
- particles with the shape of oblate spheroid (Figure 5.1.b), for which L > l = h;
- spherical particles (Figure 5.1.c), for which L = l = h;
- lens – shaped particles (Figure 5.1.d), for which L = l > h.

The density and the gaps rate of a particle. The density ρ_p, of a solid particle is defined according to figure 6 with the expression (6) [12, 20, 24]:

$$\rho_p = \frac{m_p}{V_p} \quad (6)$$

where:

m_p is the mass of solid particle, kg;
V_p – the volume of solid particle, taking into account its non-porous surface, m^3;
ρ_p – hydrodynamic density, because V_p is the volume of the particle limited by the hydrodynamic boundary layer, kg/m^3.

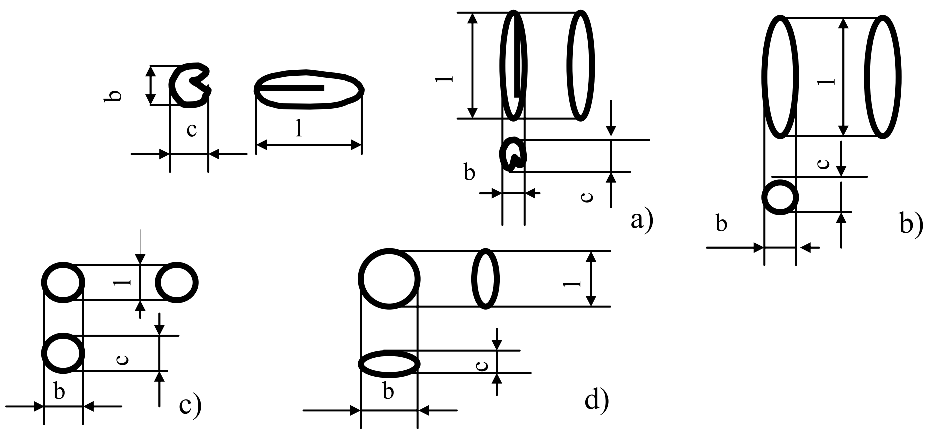

Fig. 5. The main dimensions of a granular particle [19].

Fig. 6. Conceptual figure of a solid particle with opened and closed pores [20].

In table 1 are rendered values of the gaps rate for different shapes of the solid particle with various dimensions [12].

Table 1. Solid particle's characteristics [12].

No.	Particle's shape	Dimension [mm]	Specific area [m²/m³]	Gaps rate [%]
1.	Spherical	d=0.794	7,600	0.393
		d=1.588	3,759	0.405
		d=3.175	1,895	0.393
		d=6.35	948	0.405
		d=7.94	756	0.416
2.	Cubical	l=3.175	1,860	0.190
		l=3.175	1,860	0.425
		l=6.35	1,078	0.318
		l=6.35	1,078	0.455
3.	Six-angled prism	l×h= 4.76×4.76	1,262	0.355
		l× h= 4.76×4.76	1,262	0.472
4.	Tetrahedron	l× h= 6.35×2.87	2,410	0.361
		l× h= 6.35×2.87	2,410	0.518
5.	Cylindrical	l× d=3.175×3.175	1,840	0.401
		l× d= 3.175×6.35	1,585	0.397
		l× d= 6.35×6.35	945	0.410
6.	Plate	l×L× h= 6.35×6.35×0.79	3,033	0.410
		l× L× h= 6.35×6.35×1.59	1,984	0.409
7.	Lenticular	d× h= 3.175×1.59	2,540	0.398
where: l is the length; L – the width; h – the height.				

The specific area of a particle. The specific area of a particle, a, in m^2/m^3 is the proportion between area a_p of the particle and its volume V_p (relation (7)) [12, 20].

$$a = \frac{a_p}{V_p} \quad (7)$$

Sometimes, the specific surface area of the particle is related to its mass resulting a_g, (relation (8)) (the specific area related to the mass of the particle), in m^3/kg:

$$a_g = \frac{a_p}{\rho_p \cdot V_p} \quad (8)$$

where ρ_p is the density of the particle.

For the spherical particles, a, respectively a_g, are expresses with the relations (9) and (10):

$$a = \frac{\pi \cdot d^2}{\frac{\pi \cdot d^3}{6}} = \frac{6}{d} \qquad [m^2/m^3] \quad (9)$$

$$a_g = \frac{6}{\rho_p \cdot d} = \frac{a}{\rho_p} \qquad [m^2/kg] \quad (10)$$

Particle's dimension. The dimension of a particle is expressed through its diameter if the particle is sphere. For the particles having the shape different from the sphere Allen (1975) shows 12 ways to express the dimension of a particle. From these, for modeling the flow of a liquid through a layer with solid particles, there are currently used three ways to express the equivalent diameter of a non-spherical particle (table 2, relations (11) ÷ (13)) [19, 20, 25].

Table 2. Equivalent diameters of a non-spherical particle [20].

No.	The name of the diameter	Symbol	Relation of computation	Rel. no.
1.	Volume equivalent diameter	d_v	$d_v = \sqrt[3]{\frac{6 \cdot V_p}{\pi}} = 1.24 \cdot V_p^{1/3}$	(11)
2.	Surface equivalent diameter	d_s	$d_s = \sqrt{\frac{a_p}{\pi}} = 0.56 \cdot a_p^{1/2}$	(12)
3.	Specific area equivalent diameter	d_{sv}	$d_{sv} = 6 \cdot \frac{V_p}{a_p}$	(13)

The equivalent diameters are obtained equaling a geometrical measure of the real particle with the same measure of an equivalent sphere. For example, d_v results by equaling the volume V_p of the particle, with the volume of a sphere having the diameter d_v (relations (14) and (15)) [25]:

$$V_p = \frac{\pi \cdot d_v^3}{6} \quad (14)$$

$$d_v = \sqrt[3]{\frac{6 \cdot V_p}{\pi}} \quad (15)$$

For the solid particles there is also used the concept of diameter of sedimentation, d_s, defined as the diameter of a sphere with the specific weight and the hydraulic measure identical with the ones of the real particle determined in the same kinematic conditions. It is used for particles having dimension smaller than 0.1 mm.

For expressing the dimension of a non-spherical particle there are, for particular cases, the following correlations [23]:

- for particles almost spherical: $d \cong d_{sv} \cong d_v$;
- for solid particles having regular shape (cylinder, spheroid, ellipsoid, parallelepiped etc.), with shape factor $\psi \cong 0.773$ (rel. (16)).

$$d_{sv} = 0.773 \cdot d_v \text{, error of } \pm 11\% . \quad (16)$$

In Table 3 is presented the classification of the solid particles taking into account their size [26].

Table 3. The classification of the particles on size [26].

No.	Particle's size		Class
	[mm]	[μm]	–
1.	4,000...2,000	–	Very big bowlders
2.	2,000...1,000	–	Big bowlders
3.	1,000...500	–	Medium bowlders
4.	500...250	–	Small bowlders
5.	250...130	–	Big rocks
6.	130...64	–	Small rocks
7.	64...32	–	Very big gravel
8.	32...16	–	Big gravel
9.	16...8	–	Medium gravel
10.	8...4	–	Fine gravel
11.	4...2	–	Small gravel
12.	2...1	2,000...1,000	Raw sand
13.	1...1/2	1,000...500	Big sand
14.	1/2...1/4	500...250	Medium sand
15.	1/4 ...1/8	250...125	Fine sand
16.	1/8...1/16	125...62	Very fine sand
17.	1/16...1/32	62...31	Raw mud
18.	1/32...1/64	31...16	Medium mud
19.	1/64...1/128	16...8	Fine mud
20.	1/128...1/256	8...4	Very fine mud
21.	1/256...1/512	4...2	Big clay
22.	1/512...1/1,024	2...1	Medium clay
23.	1/1,024...1/2,048	1...0.5	Fine clay
24.	1/2,048...1/4,096	0.5...0.25	Very fine clay

4. CONCLUSIONS

Optimizing the water's mechanical filtering process pursues to assure a maximum efficiency through a high productivity at a minimum price. Achieving these objectives is accomplished by taking into consideration and by studying all the factors interfering and influencing the filtering process.

The factors influencing the water's mechanical filtering process can have variable or constant values during filtration, depending on the filter process and the chosen operating conditions.

The particle's shape from the granular filter material is a characteristic with a great influence over the filtering process, influencing through the porosity given to the filter layer obtained in natural settlement.

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