# THEORETICAL STUDIES VIEWING THE INFLUENCE OF PARTICLES' SHAPE FROM FILTER LAYER IN THE MECHANICAL FILTRATION PROCESS

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**Abstract:** The paper describes the theoretical aspects regarding the influence of granular particles' shape from the filter layer during water's mechanical treatment. In order to optimize a process of water's treatment in terms of filter layer the granular layer's characteristics and a series of geometrical parameters must be known. Particle's shape is a fundamental parameter that has an influence over the filtration process.

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

## 1. INTRODUCTION

The treatment of potable water derived from various sources is accomplished through different operations and processes that have the purpose to ensure the quality indicators required by the customers / active standards [1, 2, 3].

The main proceedings of water's treatment can be mechanical, chemical and biological [1-3]. Big bodies, heavy particles that subside or float on water are discharged through the mechanical process of water. From all mechanical treatment procedures, filtration is the most irreplaceable one in the scheme of a treatment plant [4-6]. In Figure 1 and Figure 2 is represented the framing of the filtration process in the scheme of treatment plant belonging to Bacau, Romania, respectively to Torino, Italy [7].

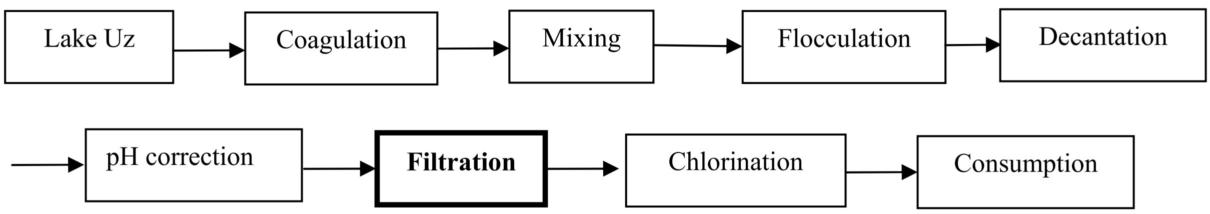


Fig. 1. Technological scheme of water's handing for treatment plant in Bacau.

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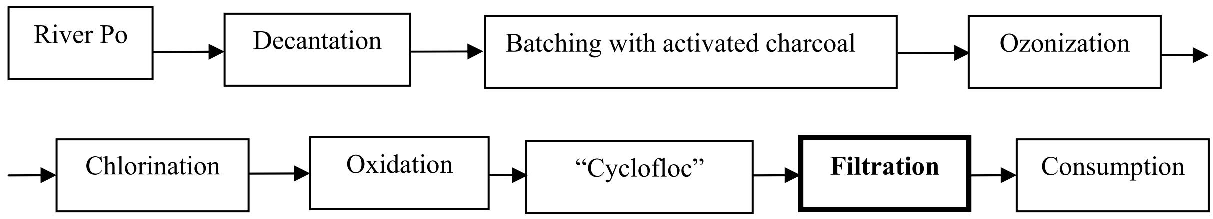


Fig. 2. Technological scheme of water’s handing for treatment plant in Torino.

## 2. FILTRATION PROCESS DESCRIPTION

Filtration is a separation proceeding of solids from liquids; particles are filtered off from liquid by sifting the mixture through a porous material (filter layer) that has the role of retaining the solid matter and leave the liquid to pass through [4, 8-10]. Figure 3 presents the adapted schemes of the filtration process according to the filtrate’s flow direction [11].

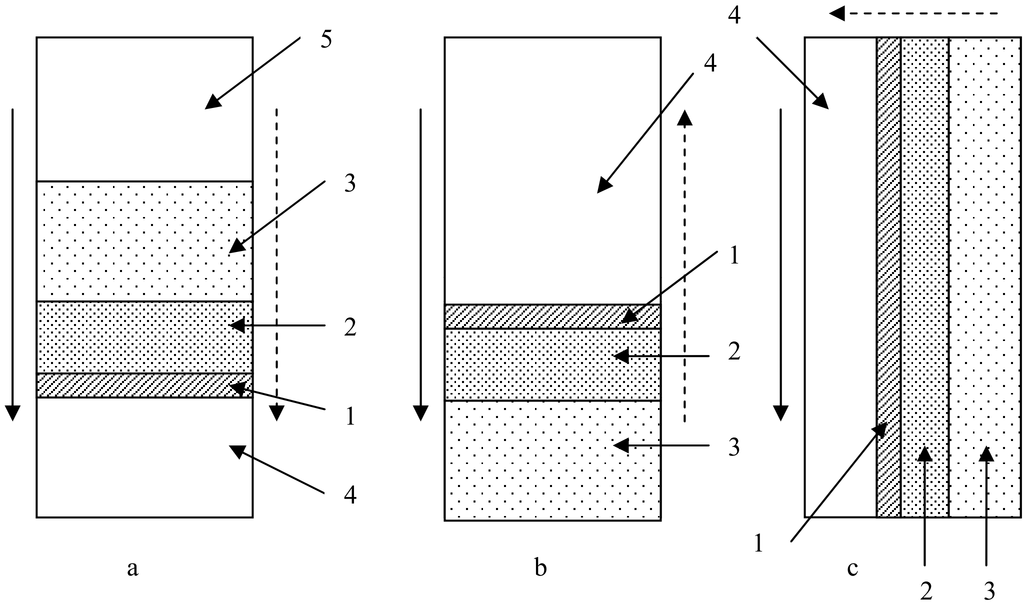


Fig. 3. Schematically representation of the filtration process [11]:
a – cocurrent; b – countercurrent; c – crosscurrent; ⟶ – direction of gravity force action; - - ➝ – direction of filtrate motion;
1 – filter plate; 2 – cake; 3 – sludge; 4 – filtrate; 5 – clear liquid.

Filtration equation bases on Darcy’s principle [5, 6, 9-11]:

$$Q = K \cdot \frac{A \cdot \Delta p}{\eta_s \cdot L} \qquad (1)$$

Where:

Q is the mixture’s flow that follows to be filtered, ($m^3/s$);
K – the permeability of the filter layer;

A – filter material area, ($m^2$);
$\Delta p$ – the pressure difference, (Pa);
$\eta_s$ – the mixture's viscosity/thickness, (Pa · s);
L – the thickness of the filter layer, (m).

The filtration process is influenced by a series of factors (Table 1), highly important when it comes to defining the operating conditions and choosing the equipment which directly determines the required efficiency. During filtration, the factors can have constant or variable values according to filtration process and by the chosen operating conditions [6, 12].

Table 1. Factors influencing the filtration operation [12].

| No. | Refers to: | Factors: |
|---|---|---|
| 1. | Water | Water properties |
| 2. | Solid | Particle's nature, particle's shape and size, granulometry |
| 3. | Suspension | Producing mode, concentration, suspension's age, rheological properties, quantity or flow, temperature |
| 4. | Sediment | Homogeneity, final moisture, compressibility, hydraulic resistance |
| 5. | Filter layer | Nature, area, thickness, pore's size, hydrodynamic resistance, chemical resistance, mechanical strength, regenerative capacity |
| 6. | Filtration operation | Continuous or intermittent activity, filtration temperature and pressure, filtration rate, filtration length |
| 7. | Washing phase | Nature of wash liquid, flow, concentration, duration |

## 3. THE SHAPE OF SOLID PARTICLES FROM THE GRANULAR FILTER LAYER

Viewing the shape, the particle is defined by three dimensional factors: length, width and thickness (Figure 4) [13].

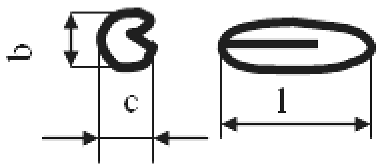


Fig. 4. Schematic representation of the main particles' dimensions [13]:
b – width; c – thickness; l – length.

Wadell was the first scientist who proved that the particle's shape is composed of two independent geometrical concepts: roundness and sphericity (Figure 5) [7].

Natural or processed particles have extremely diverse shapes, practical any unthinkable shape (Figure 6) [8, 15].

The scientists have discovered diverse methods of approximating the particle's shape. The most frequent way to characterizing the particle's shape is the sphericity ($\psi$) in the viscous flow matter [16-19].

For the spherical particles $\psi$=1, for the nonspherical particles $\psi$<1, while for the most materials 0,64<$\psi$<1. Sphericity can be also calculated, from the information about particles' dimension, with the viscosity relations [16-19]:

$$\psi = \left( \frac{d_v}{d_s} \right)^2 \tag{2}$$

$$\psi = \frac{d_{sv}}{d_v} \quad (3)$$

Where:

$d_v$ – volume equivalent diameter, (m);
$d_s$ – surface diameter, (m);
$d_{vs}$ – specific surface diameter, (m).

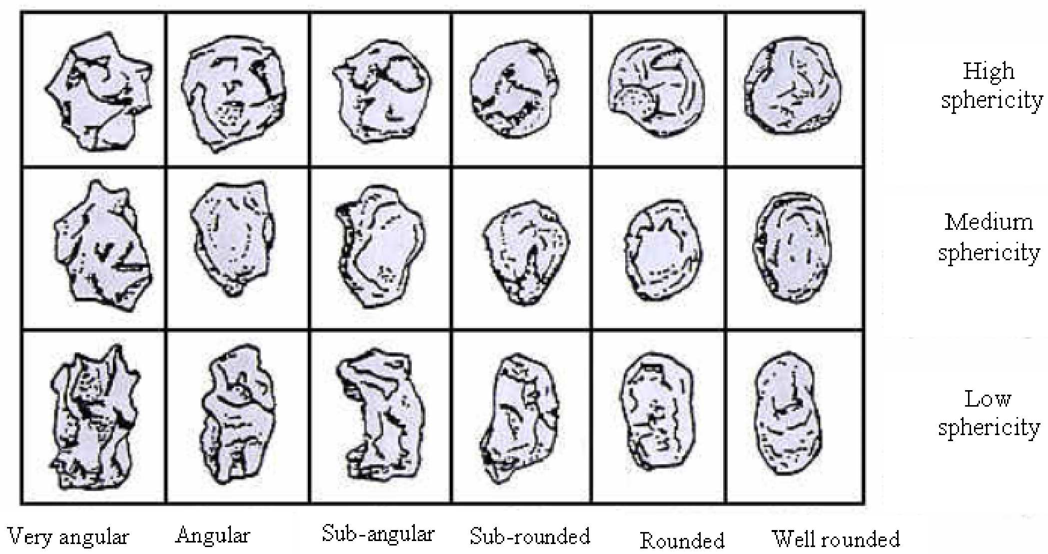


Fig. 5. Classification of sand particles by shape [7].

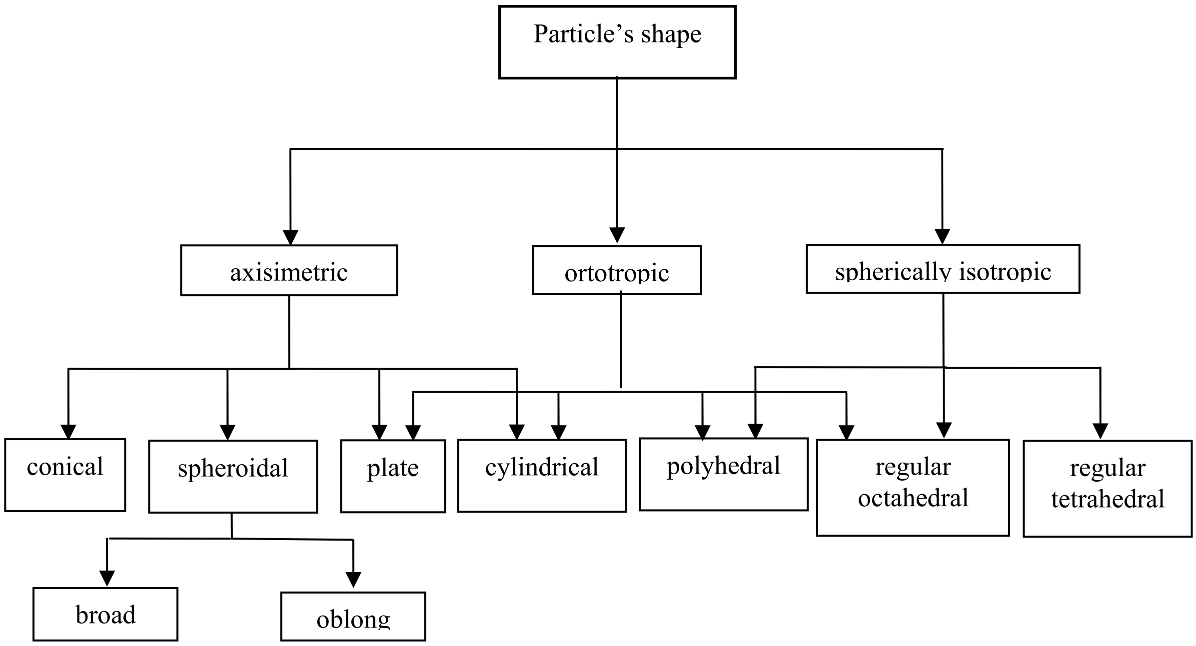


Fig. 6. Classification of the symmetrical nonspherical particles [12, 15].

The deviation from the spherical form is expressed through the shape factors presented in Table 2, having as reference the sphere, the geometric form with the lowest area compared to other geometric bodies of equal volume [12, 15, 20].

Shape factors are defined by identifying two of the particle's characteristic parameters [12, 15, 20]:
- $V_p$ – particle volume, ($m^3$);
- $a_p$ – particle surface area, ($m^2$);
- $A_p$ – estimated particle area, ($m^2$);
- $P_p$ – estimated particle perimeter, (m).

Table 2. Nonspherical particles'shape factors [12].

| No. | Factor | Symbol | Definition | Account relation | No. rel. |
|---|---|---|---|---|---|
| 1. | Sphericity (shape factor) | $\psi$ | $\psi = \frac{a_0}{a_p}$ | $\psi = \frac{\pi \cdot d_0^2}{a_p}$ <br> $\psi = 4,84 \cdot \frac{V_p^{2/3}}{a_p}$ | (4) |
| 2. | Volumetric shape factor | $k$ | $k = \frac{V_p}{d_A^3}$ | $d_A = \sqrt{\frac{4 \cdot A_p}{\pi}}$ <br> $k = \frac{V_p}{\left(\frac{4 \cdot A_p}{\pi}\right)^{3/2}}$ | (5) |
| 3. | Roundness factor | $\varphi$ | $\varphi = \frac{P_A}{P_p}$ | $\varphi = \frac{\pi \cdot d_A}{P_p}$ | (6) |
| 4. | Area equivalent factor | $\Sigma$ | | | (7) |

Where:
- $a_0$ – volume sphere area that equals the volume $V_p$, ($m^2$);
- $d_0$ – volume sphere diameter that equals to the volume $V_p$, (m);
- $d_A$ – sphere diameter having the same projected area $A_p$ as the particle, (m);
- $P_A$ – the equivalent sphere perimeter with the same projected area $A_p$, (m);
- $P_p$ – particle projected perimeter, (m);
- $A_p$ – sphere area surface having the same perimeter with that of the particle, ($m^2$).

## 4. CONCLUSIONS

Optimizing the filtration process views the insuring of a maximum efficiency by achieving a high productivity, meaning water quantity and the sludge produced to be of a required quality and at a minimum price. The accomplishment of these objectives can be done only by analyzing and taking into consideration all the factors that are involved and which influence the filtration process.

The particle shape is a fundamental attribute that influences the porosity, permeability, viscosity, fluidity, and the behavior of the precipitate layer.

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## REFERENCES

[1] Bianucci, G., Ribaldone, E., Porlezza, C., Il trattamento delle acque, Milano, 2001.
[2] Cheremisinoff, N., Handbook of water and wastewater treatment technologies, Elsevier Butterworth-Heinemann, 2002.
[3] Teodosiu, C., Tehnologia apei potabile şi industriale, Editura Matrix Rom, Bucureşti, 2001.
[4] Mulligan, C.N., Davarpanah, N., Fukue, M., Inoue, T., Filtration of contaminated suspended solids for the treatment of surface water, Chemosphere, 2009.
[5] Rushton, A., Ward, A.S., Holdich, R.G., Solid-Liquid Filtration and Separation Technology VCH Verlagsgesellschaft mbH, Weinheim, 1996.
[6] Russell, D.L., Filtration theory and practice, Practical Wastewater Treatment, 2006.
[7] http://www.agcsa.com.
[8] Coccagna, L., Lasagna, C., I materiali filtranti granulari, Fondazione AMGA, Genova, 2010.
[9] Purchas, D., Sutherland, K., Handbook of Filter Media, Elsevier Science & Technology Books, 2002.
[10] Richardson's, J.F., Chemical Engineering, Elsevier Butterworth-Heinemann, 2002.
[11] Svarovsky, L., Solid-Liquid Separation, Elsevier Butterworth-Heinemann, 2001.
[12] Jinescu, G., Vasilescu, P., Jinescu, C., Dinamica fluidelor reale în instalațiile de proces, Editura Semne, Bucureşti, 2001.
[13] Moşneguțu, E.F., Panainte, M., Savin, C., Măcărescu, B., Separarea amestecurilor de particule solide în curenți de aer verticali, Editura Alma Mater, Bacău, 2007.
[14] Jinescu, G., Procese hidrodinamice şi utilaje specifice în industria chimică, Editura Didactică şi Pedagogică, Bucureşti, 1983.
[15] Robescu, D.N., Robescu, D.L., Constantinescu, I., Szabolcs, L., Fluide polifazate, Editura Tehnică, Bucureşti, 2000.
[16] Anlauf, H., Sorrentino, J.A., The influence of particle collective characteristics on cake filtration results, Chemical Engeneering Tehnics, 2004.
[17] Boskovic, L., Influence of submicron particle shape on behavior during filtration and separation processes, Griffith University, 2008.
[18] Conell, H., Zhu, J., Bassi, A., Effect of particle shape on crossflow filtration flux, Journal of Membrane Science, 153(1), 1999, p. 121-139.
[19] Mota, M., Teixera, J., Yelshin, A., Cortez S., Effect of the particle shape on flow through porous media, Proceedings of International Conference FILTECH 2005, October 11 - 13, 2005, Weisbaden, Germany, Vol. 1, p. I-341 – I-349.
[20] Florea, J., Robescu, D., Petrovici, T., Stămătoiu, D., Dinamica fluidelor folifazice şi aplicațiile ei tehnice, Editura Tehnică, Bucureşti, 1987.