STUDIES CONCERNING THE BEHAVIOR OF THE SUSPENDED SOLIDS IN THE MIXING PROCESS

MIHAELA-ELENA DASCĂLU[1*], EMILIAN MOŞNEGUŢU[1], VALENTIN NEDEFF[1], ALEXANDRA-DANA CHIȚIMUȘ[1], NARCIS BÂRSAN[1]

[1] *"Vasile Alecsandri" University of Bacău, Calea Marasesti 156, Bacau, 600115, Romania*

Abstract: A high importance is given to the studies concerning the most reliable mixing process with a minimum of energy consumption, because the mixing process is an often used operation in various industries. The main purpose of this paper is to determine and to identify the behavior of the dispersed phase, in this case, the solid particle, during the mixing process. Through the experiment, the mixing process was recorded using a High-Speed camera, which enables following the behavior of the solid particle. The resulting data were used for different types of charts.

Keywords: solid suspensions, dispersion, the travel speed, mixing process

1. INTRODUCTION

The mixing process needs the movement of phases, the method involves placing the material in movement and then maintaining it in that condition. This operation is influenced by the material properties, which largely determines the nature of the mixture. That is why the mixing operations differ depending on the properties of the analyzed mixture [1, 2].

Mixing systems are either fluid or consisting of solid particles. Depending on their condition, fluids are divided into gases and the liquids. From the point of view of the mixing process, liquids are divided into Newtonian and non - Newtonian liquids. The gases and Newtonian fluids which are in the motion obey to the same laws, while the non - Newtonian fluids behave differently. The movement of the fluids obey also to the some special laws [2, 3]. The attempt to investigate and optimize the mixing process following different parameters needs re-evaluation of existing knowledge and even the development of new equipment [4, 5].

Depending on the conduct of operations in a process of mixing technology, it can be [2]:
- with discontinuous development, when the operation are conducted in a limited time, comprising the alimentation time of phases and the exhaust of the final system;
- with continuous progress when dosed phases, in view of mixing are subjected concomitantly with their transport to the next operation in the process.

The mixing operation is used in many processes and industries, especially in wastewater treatment processes.
Water from lakes, rivers or wastewater contain the numerous compounds that cause turbidity, color or toxicity of these waters (for example, coarse particles, colloids and dissolved materials) [4, 6]. All over the world are various treatment processes using physical - chemical wastewater, but the most widely used is the physical - chemical process in which are used coagulants and flocculants. In these coagulation - flocculation stage the mixing operation is used as shown in Figure 1. [6]. In water treatment, coagulation process is used to facilitate aggregation and transform the unstable suspension in a stable suspension.

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

Coagulation is an intermediate step which is essential in the physic - chemical treatment of wastewater. Coagulation represents a process which is a complex phenomenon, physically as well as chemically. Reactions between particles and coagulant lead to the formation of aggregates and consequently in the sedimentation [6, 7]. After the coagulation phase, the very small particles in the suspension meet and form the flocculates.

The coagulation process is performed in two types of units positioned in series:
- the unit of quick mixing in which the dosage of the coagulant is performed, mixture and the destabilization of the particles;
- flocculation unit in which is performed the contact between the particles.

The physical process that realize the contact between particles (aggregation) is called flocculation.

Flocculation represents an assembly of physic - chemical phenomena leading to the particle aggregation to form the flocculates. This process is performed faster as the water temperature is higher and how its viscosity is the lower [5, 7, 8]. This phenomenon is reversible, which means that the flocs can break with a strong agitation to the liquid in order to arrive to the initial colloidal solution. In order to achieve these processes are used a series of coagulation-flocculation reagents. These are products of mineral origin (aluminum or iron salts), natural polymers or synthetic polymers [5, 7, 8].

The vessel in which takes place the mixture must be specially designed such that to favor making a connection between molecules and colloidal particles from the water and coagulant. These contacts are controlled by the hydrodynamic parameters, the geometric, molecular properties of water which are treated and the kinetics of coagulation reactions that take place in the units of the rapid mixing. The rapid dispersion of the coagulant into water is performed by creating a strong turbulence [7, 8]. Therefore, coagulants and flocculants are used in water treatment with the aim of unite the particles and colloids contained in order to increase their size to facilitate their separation [6].

In this article is presented a practical study conducted to identify behavior of a solid body within the mixing process. For this purpose the mixing process is filmed with a high-speed camera and the resulting data are used to create different types of charts.

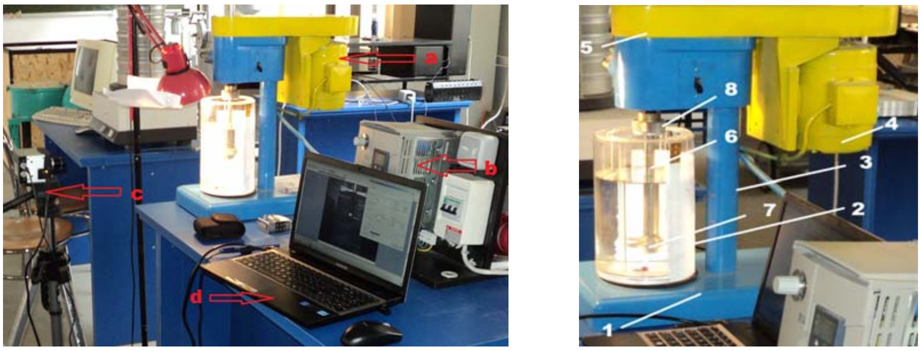
2. WORKING EQUIPMENT

Within experimental determinations it was used a mechanical stirrer fed to the 380 V, whose engine speed can vary with a frequency converter with three phases. The mixing device is equipped with a transparent glass vessel, having a diameter of 150 mm and a height of 300 mm (Figure 1). As a mixing device, it was used a propeller, the position of which, in relation with the bottom of the vessel, was able to modify using a mandrel.

The mixer used in the experimental measurements is composed of the frame (1) on which is situated the mixing vessel (2). On the frame is hooked the mixer support (3) which supports the upper part composed of three-phase electric motor (4), which by a transmission through trapezoidal straps under the carcass (5) set in motion the mixer shaft (6) coaching the propeller (7). Height adjustment of the mixing device is performed using the mechanical mandrel (8).

In order to analyze the mixing process it was chosen a heterogeneous mixture of liquid-solid type, mixture frequently met within the wastewater treatment processes resulted both from industry and those obtained from household consumers. The mixture is composed of:
- water - respectively one volume of water of 0.00353 m^3;
- solid particles - whose diameter is of 7 mm and a density of 1800 kg/m^3.

The experimental study aimed to determine and to identify the behavior of the dispersed phase, in this case, the solid particles, during the mixing process. For this, we chose three speed working (400, 500 and 650 respectively rotations/minute) to the mixing device. Speed control of the mixing device was performed with a three-phase frequency converter equipped with a variable voltage and a digital display for reading speeds of the mixer. The height of the positioning of the mixing device in relation to the bottom of the vessel was 100 mm.



a) b)

Fig. 1. The completely equipped laboratory stand:
a) adjacent components used in the experiments:
a - the completely equipped laboratory stand; b - the frequency converter; c - the high speed camera; laptop adjustment and high-speed camera by control and storage of films;
b) laboratory stand.

The whole mixing process was recorded using a High Speed camera. The number of frames used for recording the mixing process was of 500 frames per second, the speed that allowed us to follow the behavior of the solid particle. For the processing of films were used the next software:
- SyntEyes, used for tracking an object, generating a series of coordinates which can then be used in order to achieve its trajectory;
- Gimp, used to make the measurements;
- Mathcad, used for experimental data processing and to obtain the real coordinates.

3. THE PROCESSING METHOD OF THE DATA

For the experimental data processing we used the following scheme of work (Figure 2).

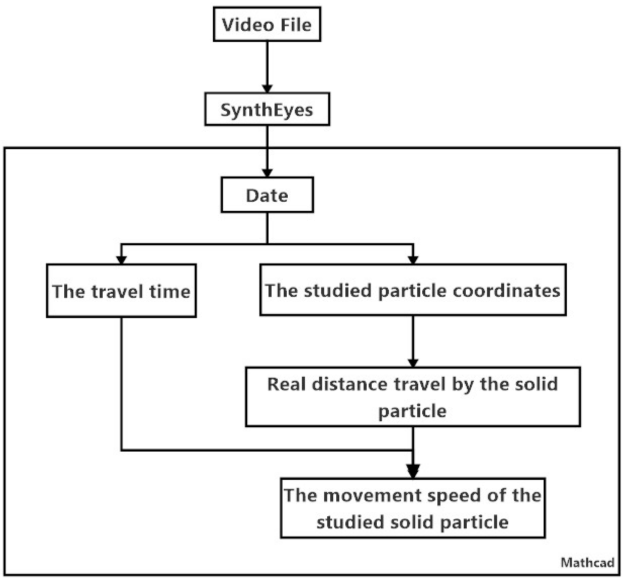


Fig. 2. The steps of experimental data processing.

In order to obtain data that coincide with the actual trajectory of movement of the solid particle in the liquid-solid heterogeneous mixture, during the mixing process must be respected the following steps of processing of the experimental data:

1. Before filming with the High-Speed camera, the following parameters must be known: the recording speed of the speed camera and resolution at which the film is achieved;

2. The obtained video will be imported into SynthEyes software that has tracking function and after exporting data obtained, are resulting values which correspond as location, to the pursued point. The values are expressed in pixels;
3. The file type "* .txt" generated by the software SynthEyes is imported into Mathcad software which will convert the pixel data in mm. For the conversion it must undertake an equivalence of some benchmarks which are in the videos, respectively, it was chosen for OX axis (horizontal) the diameter of the mixing vessel and for OY axis (vertical) was selected the height of liquid in the vessel on idle. Thus, the obtained values will coincide with the real dimensions;
4. In order to achieve a three-dimensional model of the trajectory of the solid particle, it was opted for measuring the solid particle in various fixed positions in the vessel with liquid, thus being achieved a strong correlation between particle size and the distance between it and the objective of camera. The next step consists in Print Screen-ing of different frameworks and measuring the particle size using Gimp software. Then, it will be created a mathematical model that most closely correspond to the variation of the particle size and to the filming frame number;
5. After determining the distance traveled by the solid particle during the process of mixing, knowing the time between two processed frames, it can determine the velocity of the particle;
6. Since in the graph of speed variation of the movement of the solid particle during the process of mixing, there is a number of fluctuations (Figure 3 parameter v1), which is error-processing data, it must be used the smoothing function of the results (Figure 3 parameter v2).

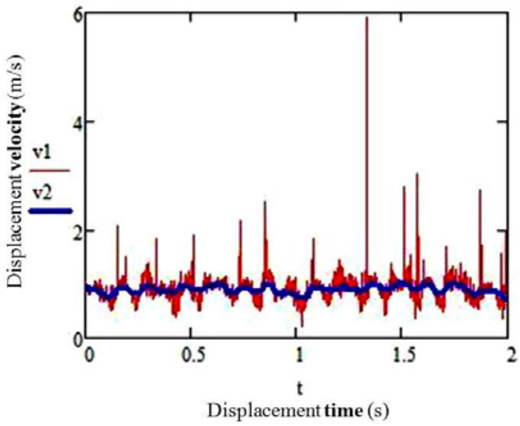


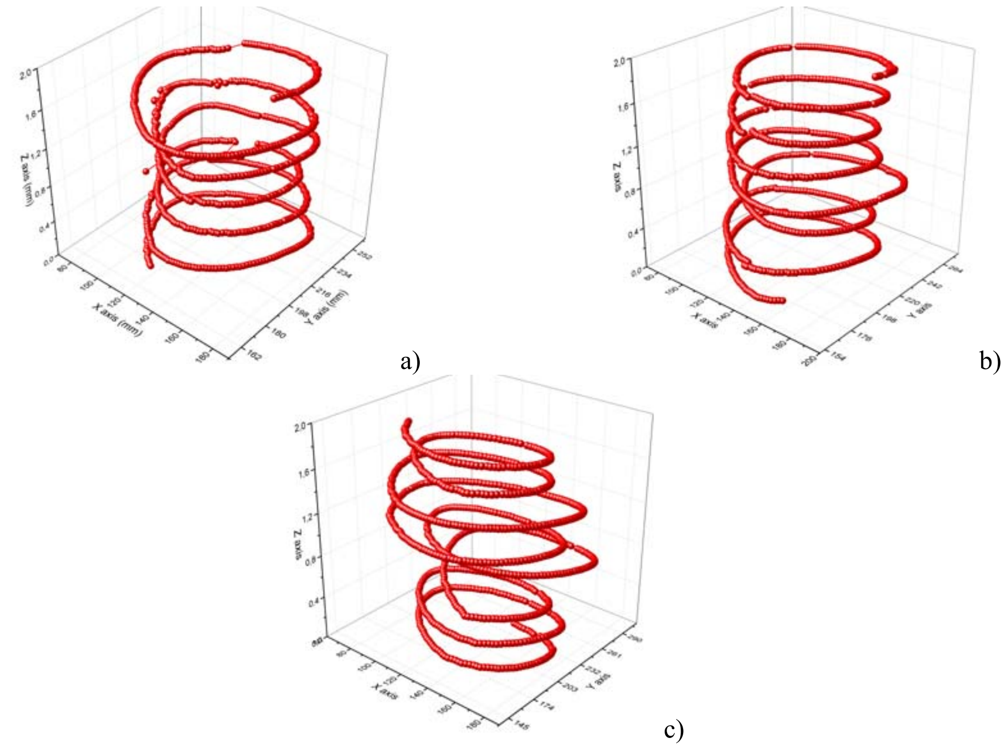
Fig. 3. The graphical representation of the particle speed depending of time.

4. RESULTS AND DISCUSSION

Following the studies on the laboratory bench work and using the methodology outlined above have been realized the graphical representation which:
- presented the trajectory of the solid particle during the process of mixing;
- the distance traveled by the solid particle during the process of mixing;
- the variation of the movement speed of the solid particle during the process of mixing.

In the graphic representations of the Figure 4 are presented the trajectories described by the solid particle during the mixing process. In the following graphics it notes that the particle describes an upward almost circular motion.

The shape described by the trajectory of the particle differ from one experiment to another. If at the rotation speed of the mixing device of 400 rot/min the trajectory described by the particle is arranged around an axis of symmetry, once with the increase in speed, the trajectory of the particle does not comply with the rule given above. This is due to the increasing speed of the mixing device respectively the increase of the flow regime thus increasing the turbulence leading to a chaotic behavior of the solid particle.

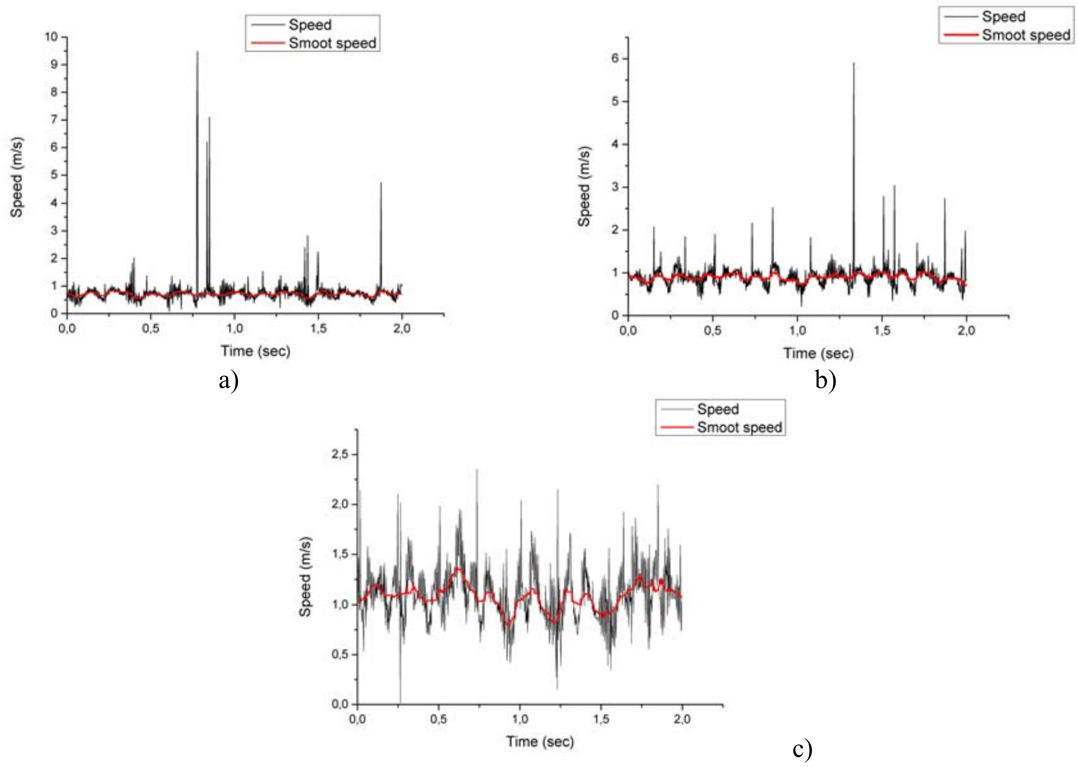


a) b)

c)

Fig. 4. The trajectory of the particle at a height of 100 mm: a) 400 rot/min; b) 500 rot/min; c) 650 rot/min.

Considering the distance covered by the solid particle and knowing the time interval in which it performs the trajectory it can be determined the respective displacement speed (Figure 5).



a) b)

c)

Fig. 5. The distance traveled by particle between the frameworks at 100 mm: a) 400 rot/min; b) 500 rot/min; c) 650 rot/min.

From the analysis of the graphs represented in Figure 6 it is shown that the solid particle velocity increases with the increasing rotation speed of the mixing device. This is evidenced in Figure 7 which presents the variation of this parameter for the 3 analyzed cases.

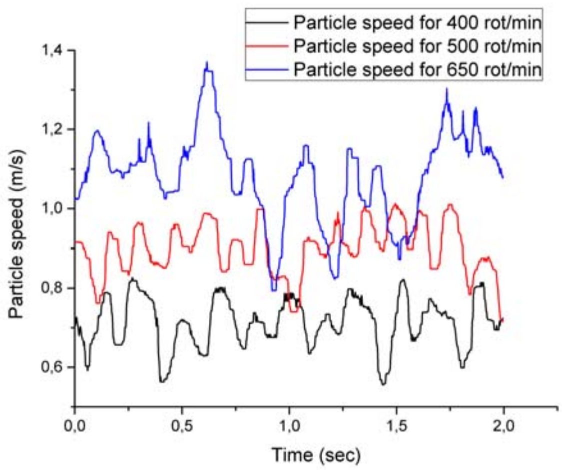


Fig. 6. The variation of the solid particle speed depending on the engine speed of the mixing device.

By combining the graphical representations of Figure 4 and Figure 5 it is obtained a distribution of the particle speed in the mixing process based on the position of particle in relation to the objective of the camera (Figure 7).

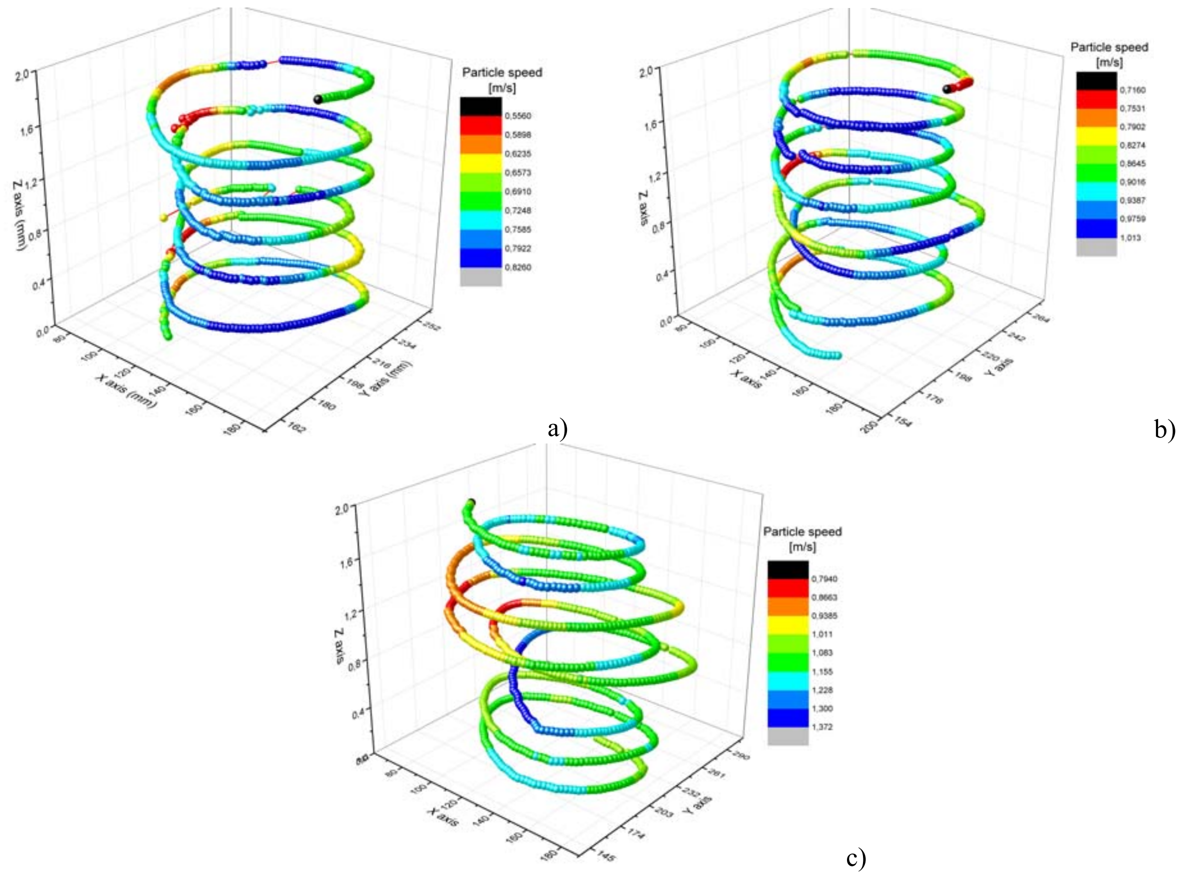


Fig. 7. The variation of the particle speed depending on the position of solids at different speeds of the mixing device: a) 400 rot/min; b) 500 rot/min; c) 650 rot/min.

With this type of graphical representation it can be drawn the following conclusions:

- the difference between the maximum speed and the minimum speed of movement of the solid particle within the process of mixing is:
  - 0.27 m/s for the rotation speed of 400 rot/min;
  - 0.29 m/s for the rotation speed of 500 rot/min;
  - 0.57 m/s for the rotation speed of 650 rot/min.

5. CONCLUSIONS

The experimental results which were conducted on laboratory stand have highlighted the mixing operation, respectively the distribution of the velocity of the solid particles in the mixing process based on the particle position relative to the objective of camera.

After the conducted experiment it was observed that the speed movement of the solid particle increases along with the increasing of the rotation speed of the mixing device. The vertical movement distance of the solid particle during the process of mixing being of approximately 2 mm. It was also observed that the distribution of the movement speed of the solid particle isn´t preferentially in a particular area, which demonstrates that the method used to process the data is correct.

This type of application can be a beginning for future research in order to optimize the mixing operation of the wastewater treatment process, in the stages of coagulation - flocculation.

Optimization of coagulation - flocculation process is necessary because it influences the efficiency of the quality of treated water regarding obtaining more profitable production costs.

REFERENCES

[1] Nedeff, V., Raveica, C., Procedee si tehnici de protectia mediului in agricultura si industria alimentara, Ed. Tehnica Chisinau, 1998.
[2] Savin, C., Panainte, M., Mosneguţu, E., Nedeff, V., Amestecarea produselor agroalimentare, Ed. Tehnopress, Iasi, 2006.
[3] Folescu, E., Distribution of mixing intensity of oxygen-vector dispersions in aerated simulated broths for stirred bioreactors, Environmental Engineering and Management Journal, vol. 10, no. 3, 2011, p. 435-444.
[4] Bârsan, N., Moşneguţu, E., Lazăr, G., Nedeff, V., Procedee şi tehnici pentru protecţia mediului. Epurarea apelor uzate menajere în staţii de epurare de capacitate mică, Ed. Alama Mater Bacău, 2012.
[5] Mavros, P., Flow visualization in stirred vessels. A review of experimental techniques, Chemical Engineering Research and Design, vol. 79, no. 2, 2001, p. 113–127.
[6] Coagularea şi flocularea, SNF FLOERGER, http://www.floerger.ro/certificate/COAGULAREA%20si%20FLOCULAREA.pdf (25.03.2015).
[7] Ramphal, S., Muzi Sibiya, A., Optimization of time requirement for rapid mixing during coagulation using a photometric dispersion analyzer, Procedia Engineering, vol. 70, 2014, p. 1401–1410.
[8] Păun, V.D., Studii și cercetări privind modernizarea proceselor de coagulare-floculare în producția de apă potabilă, Universitatea Tehnică de Construcții, Facultatea de Hidrotehnică, Catedra de Inginerie Sanitară și Protecția Apelor, Bucuresti, 2011.