The purpose of this research was to visualize the fouling process of a flat-sheet polymeric membrane into a flow cell, using particles to study their deposition onto the membrane surface. This set of experiments was analyzed from an imagistic point of view, designing for this purpose a measuring installation where hydrodynamic surface evaluation was carried out with an image processing concerning to the reverse osmosis operation. To ensure the measurements accuracy, calculations, logical approximation, and comparisons were made with existing and verified models, revealing that the differences were insignificant.

Keywords: filtration, fouling membrane, reverse osmosis, imaging analysis
of the fouling over time of the membrane. For this, a closed frame was built for optimal viewing, using the cold light of a lamp. Also, recordings during the operation of the installation were made using a Nikon camcorder D5200 [27].

The flat membranes used in these researches have a flat configuration and are mainly rectangular. The membrane used in the present research is a polymeric membrane of RO (reverse osmosis), ULP model 1812-50 (VONTRON) (fig. 2a). From this membrane were performed analysis models for flow cell experiments (Fig. 2b) [27].

**Designing experiments**
These experiments refer to the use of imaging analysis in order to highlight the fouling process of the filter membrane. This group of experiments was organized following a bifactorial form equation [27]:

\[ A_3 \times B_3 \times C_2 \]

where: A3 is the input pressure factor (2.5, 4.0 and 6.0 bar); B3 - factor representing the amount of nanoparticles (5, 10 and 25 g).

**Methodology for fouling membrane analysis**
In order to analyze the fouling process of the membrane during the filtering process, a visual analysis of this process was chosen. For this purpose, a flow cell, especially made of Plexiglas’s, was used in order to monitor the manner of deposition of solid suspensions on the surface of the filter membrane. Because this method was chosen, the flow cell, the film chamber, the light source, was placed in an aluminum foil lined enclosure to achieve the following conditions [27]:
- Eliminating external light intensity variations that may influence experimental results;
- Create a uniform dispersion of light generated by the light source within the enclosure;

- In order to highlight the manner of deposition of solid particles on the filtering surface, solid particles with dimensions ranging from 44.6 - 115.5 µm were chosen. Measurements were performed using an MTM-1A metallographic electronic microscope, the average color-associated value of which is 155.9 (figs. 3a and 3b). This value was obtained using the GIMP program.
Because video analysis of the filtration process is not possible, it was chosen to analyze certain frames. These were chosen so that there is the same amount of time between the frames, respectively the frames were taken at a time interval of 1 min. This process was accomplished with Virtual Dub program;

The photos thus obtained were imported into the Mathcad program where they were analyzed. The image processing steps are described below:

The images were inserted into the program using the READ.IMAGINE read function;

The histogram of the image was created using the following steps (Mathcad work code):

\[
\begin{align*}
H &:= \text{inhist}(A, 256) \\
k &:= 0 \ldots \text{rows}(H)-1 \\
k\_range &:= k \\
HK\_k &:= H_k
\end{align*}
\]

where: \(A\) represents the analyzed file or image; \(H\) - the new file conversion using the inhist function that creates the histogram, using all the color spectrum, respectively 256 (fig. 4b); \(k\) - represents a new function to transform files \(A\) and \(H\) into matrix files; \(HK\) - The final form of the file under analysis. For example, choose the solid particle mass file to be used within this experiment batch (fig. 4).

The flow cell system in which a cut-out membrane was mounted from the commercial reverse osmosis polymeric membrane, ULP type 1812-50.

After analyzing the films and frames corresponding to each minute, a series of graphical representations were made, which aimed at highlighting the color spectrum, respectively the fouling of the filter material by deposition of solid colored particles on the filtering surface [27].

The analysis of the images in figure 4 shows that there is no difference between the two methods and the average value, which in the GIMP program is 155.9 (marked red) can be determined in the Mathcad program with the help of the function mean. So, all images processing of membrane fouling can be accomplished using MathCAD and the mean function without any errors [27].

Results and discussions

In order to analyze the membrane fouling process during the filtration process, a visual analysis of this process was chosen. For this purpose, the methodology presented above was used. The flow cell system in which a cut-out membrane was mounted from the commercial reverse osmosis polymeric membrane, ULP type 1812-50.

For the beginning, a set of images was taken at 5-minute intervals in order to achieve for them the histogram representation, which was performed for a feed pressure of 2.5 bar and for a quantity of solid particles of 5 g. From the analysis of the histograms thus obtained (fig. 5) it is observed that there are differences between the graph alloy but also between the values included in these types of graphic representations [27].

Taking into account the working methodology presented above, the results obtained, respectively the variations in time of the average values of the color spectrum, are presented as follows [27]:

- for a pressure of 2.5 bar - figure 6:

- for a pressure of 4 bar - figure 7:
- the experiments were carried out for a period of 30 min, which proved to be insufficient to carry out the total fouling process;
- the method of obtaining data necessary to highlight the fouling process used a technical software, Mathcad, in which more images could be analyzed consecutively and the histogram and variation of the mean value of the color spectrum over time could be made;
- regardless of the operating parameters of the equipment used or the quantity of material used, it is found that the average value of the color spectrum has a decreasing trend over time, indicating that the solid particles are deposited on the filtering surface, leading to its fouling.

Conclusions
Based on the results obtained in the imaging analysis of the membrane fouling process, it can be concluded that the use of this method cannot determine the quantity of a component, but it may indicate its existence [27].

At the same time, the fouling process was highlighted by color spectrum values in color units (0 uc - for black color and 255 uc - for white color) [27].

Also, the important advantages of this method are:
- highlighting the variation of a parameter in our case of the mean spectral value over time;
- determination of the average spectral value with accessible equipment, such as a camera, a well-lit enclosure and a computer with an imaging program;
- use in industrial processes to control fouling of filter membranes.

References
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