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EXPERIMENTAL RESEARCH ON WASTEWATER TREATMENT PROCESSES FROM SUGAR BEET PROCESSING TECHNOLOGY BY SEDIMENTATION

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Abstract

Wastewater from the food industry is characterized by major changes in quality indicators, and their discharge into the natural water cycle causes contamination of the receiving basin. The most important categories of wastewater from sugar beet processing technology (in terms of quantity and quality) are represented by: wastewater resulting from the transport and washing of raw materials; wastewater resulting from the diffusion and pressing process; condensation water. Wastewater from the diffusion and pressing process is characterized by a high nutrient content.

The discharge of these wastewaters into a receiving river can cause its rapid siltation, followed by rapid oxygen consumption. Due to the high temperatures specific to this category of wastewater, the discharge area in particular is likely to be completely devoid of oxygen. This process can also be accompanied by anaerobic fermentations (generating a specific unpleasant smell), as well as the development of biocenoses specific to dirty water. A first step in the treatment of wastewater from sugar beet processing technology consists of its decantation (in order to remove suspended matter). with or without coagulation. The process is carried out using decanters which can be: horizontal, vertical, radial or multi-stage. As a rule, vertical or radial decanters are used, which require a smaller installation space.

***Key words**: decanters, wastewater, food industry*

INTRODUCTION

The process of extracting sugar, or cell juice, from the noodles involves ensuring the necessary conditions for the process of cellular plasmolysis (denaturation of the cellular protoplasm and its withdrawal towards the centre of the cell, along with the destruction of the ectoplasmic membrane), in order to favour diffusion.

Plasmolysis is achieved by heating the noodles in the diffusion water. The diffusion temperature is an important factor in achieving plasmolysis of sugar beet cuttings cells

The indicated temperature in a diffusion installation is approx. 75…85 ^{0}C. The plasmolysis process is completely completed at approx. 85 ^{0}C. The duration of the diffusion process is approx. 60…100 min.

The diffusion process can be achieved by two methods:

- diffusion by washing the material with clean water; the disadvantage of this process is the high water consumption, extended over a long period of time (https://zahar.ro/wp-content/uploads/2021/04/Tehnologia-zaharului.pdf).
- counter current diffusion; in this case the beet pulp enters through one end of the installation, and the exhausted material is

discharged through the opposite end (in the opposite direction of the water circulation).

The advantage of this process is the use of a significantly smaller amount of water, compared to the first process (approximately equal to the amount of beet pulp subjected to the extraction process).

Also, with the help of the counter current diffusion process, a higher concentration of the diffusion juice is obtained, with lower heat consumption (https://zahar.ro/wp-content/uploads/2021/04/Tehnologia-zaharului.pdf).

In the case of this category of wastewater, the biochemical oxygen content varies from several hundred mg/l to several thousand (depending on the degree of recirculation) (Banu C., 2002; Negulescu M., 1989; Negulescu M. and colab.,1978).

The diffusion and pressing waters are very rich in dissolved and colloidal organic matter. These waters can reach loads of several tens of thousands of mg/l CBO_5 (in which sugar may also be present in concentrations of 0.15...0.30%). Thus, nitrogen can reach very high values (even hundreds of mg/l), and total phosphorus up to 250 mg/l (Oneț C., 2011; Rojanschi, V., and colab.,1997).

The primary treatment process of wastewater from sugar beet processing technology is carried out using decanters which can be: horizontal, vertical, radial or multi-stage (Antoniu R., 1987; Glodeanu M., 2003; Trofin P., 1987).

MATERIALS AND METHODS

The main objective of the experimental research on the analysis of industrial wastewater decantation processes from sugar beet processing technology was achieved by determining the efficiency of impurity separation, using different constructive types of vertical decanters.

Also, another objective of the experimental research was to establish factors that influence the decantation efficiency, such as: the temperature of the wastewater subjected to decantation, the decantation time, the value of the feed flow of the decanter under study.

Thus, within the experimental research on the decantation processes of industrial wastewater originating from the sugar beet processing technology, three constructive types of vertical decanters were used:

- decanter with a lateral compartment for wastewater supply and free discharge of clarified water (without a discharge spillway wall) (Jumanca V., 1996);
- decanter with wastewater supply through a central tube with a deflector and a spillway wall for the discharge of clarified water;
- radial decanter (Dorr) equipped with a scraping system with blades fixed solidly to a central drive shaft and a central compartment for wastewater supply.

In the experimental research, wastewater from the water diffusion process of sugar beet pulp was used.

Given that temperatures higher than approx. 80 ^{0}C are required to achieve plasmolysis of pulp cells and increase sugar diffusion, the experiments were carried out for 5 distinct values of the inlet temperature (T_i) of the wastewater in the decanter (75 ^{0}C, 80 ^{0}C, 85 ^{0}C, 90 ^{0}C and 95 ^{0}C). Also, experimental research on the evolution of the decantation efficiency of the constructive types of decanters studied was carried out for different plant feed flows (Qi), with values ranging between 0.5…8.0 m^3/h. For each experimental work variant, the duration of the sedimentation cycle was approx. 15 hours.

The determination of the impurity concentration (in mg/l) for the wastewater samples from the diffusion process (used to feed the experimental decanters) was carried out by the gravimetric method, using the relationship (https://www.unitbv.ro/documente/cercetare/doctorat-postdoctorat/sustinere-teza/2019/zarnoianu-daniela/REZUMAT%20TEZA%20ZD.pdf):

$$C=(m_2-m_1)\cdot 1000/V \ \text{(mg/l)} \quad (1)$$

where: m_1 is the mass of the vial with the filter paper, in mg; m_2 - mass of the vial with the filter paper with impurities, in mg.

The degree of retention, or impurity separation efficiency E (%) achieved by the experimental decanters (during the sedimentation process) was calculated using the relationship:

$$E=(C_i-C_e)\cdot1000/C_e\ (\%) \quad (2)$$

Where: C_i is the impurity concentration at the water inlet to the decanter, in mg/l; C_e - impurity concentration at the water outlet from the decanter, in mg/l.

Experimental testing of the types of decanters studied was carried out by creating three installation variants, which include the decantation equipment presented previously. Figures 1, 2 and 3 present the construction diagrams of the settling facilities used in the work variants.

The analysis of the results obtained will be done for different values of the wastewater supply flow rate (values obtained by changing the position of the control valve), and their measurement by means of an electromagnetic flowmeter with turbine.

The measurement of the wastewater temperature is done at the entrance to the decanter, using a thermometer (mounted on the decanter supply circuit).

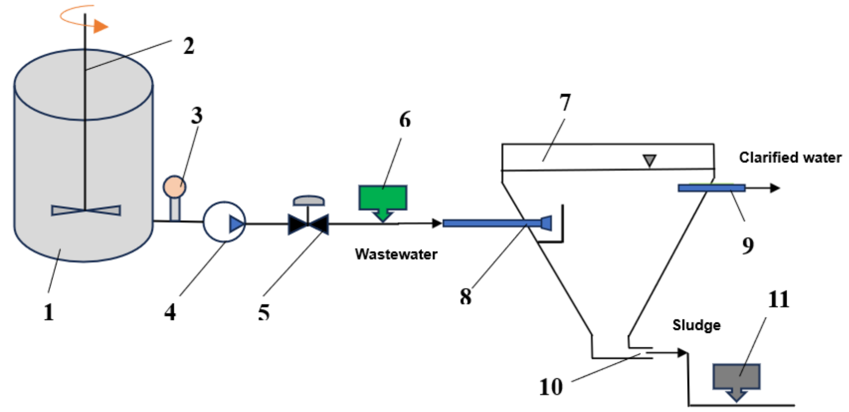

Figure 1. Construction diagram of the settling plant used in the first working variant (V1): 1- wastewater supply tank; 2 – agitator; 3 – thermometer; 4 - centrifugal pump; 5 – wastewater supply flow control valve; 6 - electromagnetic flowmeter for measuring the wastewater supply flow; 7 - decanter; 8 – wastewater supply pipe to the decanter side compartment; 9 - clarified water discharge pipe; 10 - sludge discharge pipe; 11 - electromagnetic flowmeter for measuring the sludge flow.

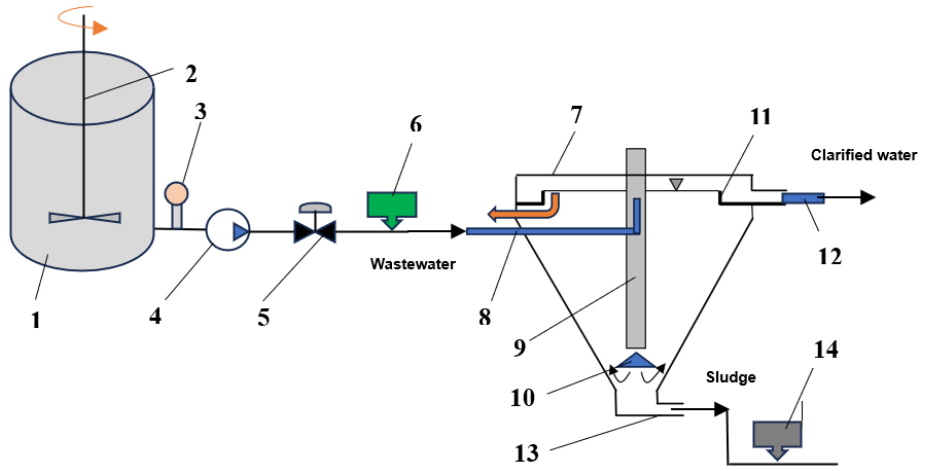

Figure 2. Construction diagram of the settling plant used in the 2nd working variant (V2): 1- wastewater supply tank; 2 - agitator; 3 - thermometer; 4 - centrifugal pump; 5 - wastewater supply flow control valve; 6 - electromagnetic flowmeter for measuring the wastewater supply flow; 7 - decanter; 8 - wastewater supply pipe; 9 - decanter supply central tube; 10 - deflector; 11 - circular spillway; 12 - clarified water discharge pipe; 13 - sludge discharge pipe; 14 - electromagnetic flowmeter for measuring the sludge flow.

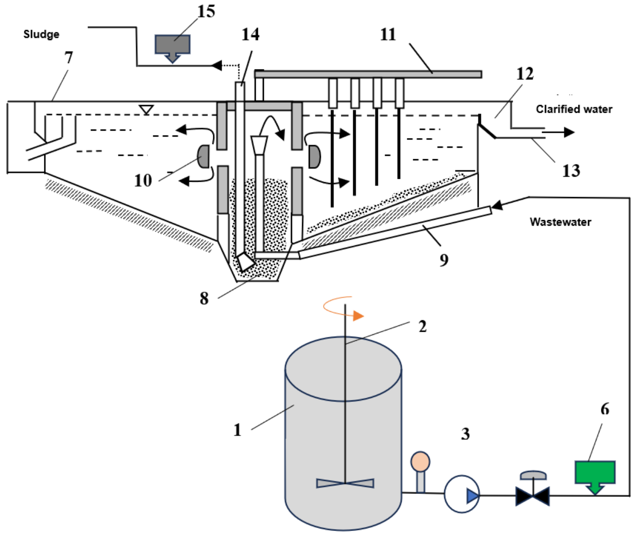

Figure 3. Construction diagram of the settling plant used in the 3rd working variant (V3): 1- wastewater supply tank; 2 – agitator; 3 – thermometer; 4 - centrifugal pump; 5 – wastewater supply flow control valve; 6 - electromagnetic flowmeter for measuring the wastewater supply flow; 7- radial decanter; 8 – central decanter supply cylinder; 9 – wastewater supply pipe; 10 – deflector; 11 – scraping system; 12 – lateral gutter; 13 - clarified water discharge pipe; 14 - sludge discharge pipe; 15 - electromagnetic flowmeter for measuring the sludge flow.

RESULTS AND DISCUSSIONS

Based on the measured parameter values (wastewater feed flow rate Qi, respectively its temperature at the decanter inlet T_i), the separation efficiency values E(%) were calculated, specific to each constructive type of decanter tested. Based on these values, the graphs corresponding to the separation efficiency were drawn depending on the feed flow rate values, respectively the wastewater temperature at the decanter inlet, $E=f(Q_i, T_i)$ (fig. 4, 5, 6).

In order to select the most efficient decanter, the evolution of separation efficiency (for the three types of decanters used in the experiments) was analysed comparatively and separately, for each value of the wastewater inlet temperature.

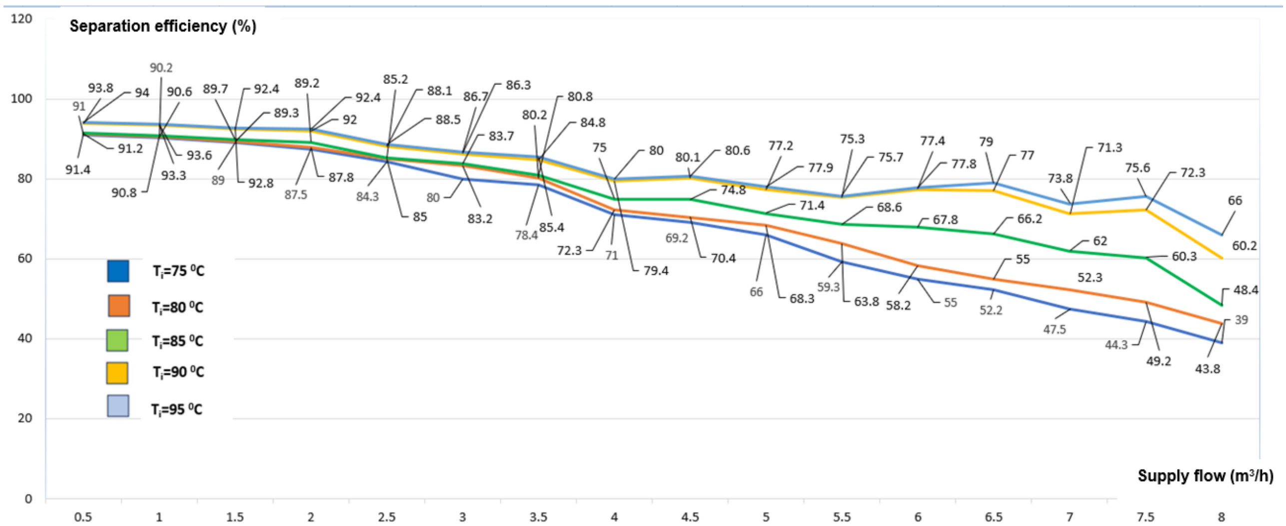

Figure 4. Evolution of separation efficiency E(%) as a function of feed flow rate Q_i, in the case of a decanter with a lateral compartment for free feed and discharge of clarified water (without spillway wall) (variant 1), for different wastewater temperatures T_i.

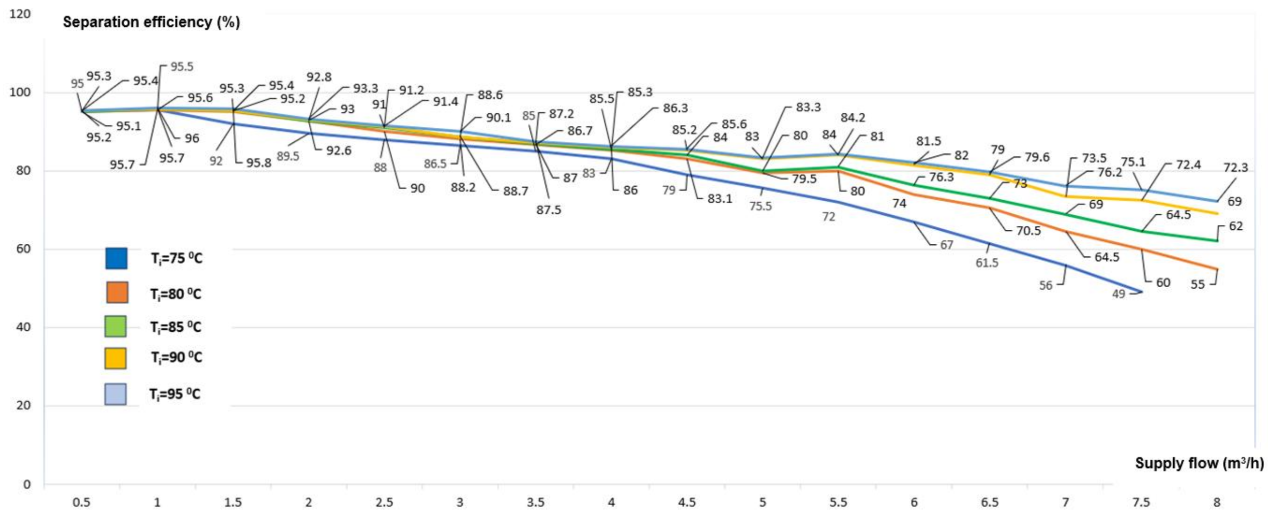

Figure 5. Evolution of separation efficiency E(%) as a function of feed flow rate Q_i, in the case of a decanter with feed through a central tube with deflector and circular spillway wall for the discharge of clarified water (variant 2), for different wastewater temperatures T_i.

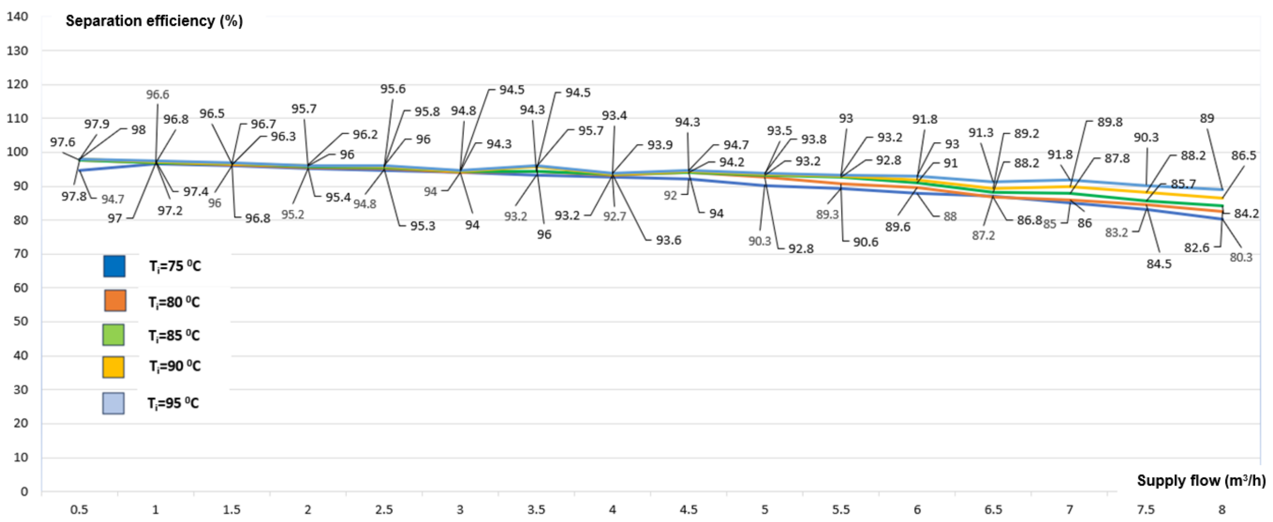

Figure 6. Evolution of separation efficiency E(%) as a function of feed flow rate Q_i, in the case of the Dorr radial decanter equipped with a sludge scraping system (variant 3), for different wastewater temperatures T_i.

The analysis of the evolution of the separation efficiency E(%) depending on the feed flow rate Q_i, respectively the initial temperature T_i of the wastewater (for the types of decanters tested) highlights the following:

- the separation efficiency (E) decreases as the feed flow rate (Q_i) increases for all types of decanters tested; also, the separation efficiency (E) is higher for higher values of the inlet temperature T_i of the wastewater (for all types of decanters tested):
- for the first working variant (V1), which uses a decanter equipped with a lateral compartment for feeding wastewater, the separation efficiency (E) has values between: 39.0% and 91.0% for the inlet temperature T_i of 75 ^{0}C; 43.8% and 91.2% for the inlet temperature T_i of 80 ^{0}C; 48.4% and 91.4% for the inlet temperature T_i of 85 ^{0}C; 60.2% and 93.8% for the inlet temperature T_i of 90 ^{0}C; 66.0% and 94.0% for the inlet temperature T_i of 95 ^{0}C;
- for the 2nd working variant (V2), which uses a decanter equipped with a central tube with a deflector (for the supply of

wastewater) and a spillway wall for the discharge of clarified water, the separation efficiency (E) has values between: 49.0% and 95.0% for the inlet temperature T_i of 75 ^{0}C; 55.0% and 95.1% for the inlet temperature T_i of 80 ^{0}C; 62.0% and 95.2% for the inlet temperature T_i of 85 ^{0}C; 69.0% and 95.3% for the inlet temperature T_i of 90 ^{0}C; 72.3% and 95.4% for the inlet temperature T_i of 95 ^{0}C;

- for the 3rd working variant (V3), which uses a Dorr redial decanter, equipped with a decanted sludge scraping system, the separation efficiency (E) has values between: 80.3% and 97.4% for the inlet temperature T_i of 75 ^{0}C; 82.6% and 97.6% for the inlet temperature T_i of 80 ^{0}C; 84.2% and 97.8% for the inlet temperature T_i of 85 ^{0}C; 86.5% and 97.9% for the inlet temperature T_i of 90 ^{0}C; 89.0% and 98.0% for the inlet temperature T_i of 95 ^{0}C;

- the analysis of the results obtained highlights the fact that the highest value (98%) of the separation efficiency (E) was obtained in the 3rd working variant (which uses a Dorr redial decanter, equipped with a decanted sludge scraping system);

- also, an important aspect is that when the inlet temperature of the wastewater (T_i) has higher values, the separation efficiency increases significantly even in the case of high feed flows (Q_i) with wastewater (situation when low values of this parameter were obtained):

- ➢ thus (at temperature T_i=75 ^{0}C) for low values of feed flows between 0.5 m^3/h and approx. 4.0 m^3/h, the separation efficiency (E) has similar values for variants V1 and V2 (values between 69.2% and approx. 91%, for variant V1, respectively between 85% and approx. 95%, for variant V2), in the case of variant V3 these values are higher (between 92.7% and approx. 97.4%);
- ➢ compared to the situation in which the inlet temperature of the wastewater T_i=75^{0}C, it is observed that for higher values of it (for example T_i=95 ^{0}C), as well as for the feed flow rates (Q_i) with wastewater (between 5 and 8 m^3/h), the separation efficiency increases significantly: for a feed flow rate Q_i=8 m^3/h, from 39% to 66% for variant V1; for a feed flow rate Q_i=8 m^3/h, from 49% to 72.3% for variant V2; for a feed flow rate Q_i=8 m^3/h, from 80.3% to 89% for variant V3, where significant increases in this working parameter are observed, compared to the first two variants studied.

Also, in order to be able to carry out a comparative study on the separation efficiency for the types of decanters experimented and to be able to select the most efficient decanter from this point of view, the evolution of the separation efficiency (for the three types of decanters used in the experiments) was analysed comparatively and separately, for each value of the wastewater inlet temperature (fig. 7, 8, 9, 10, 11).

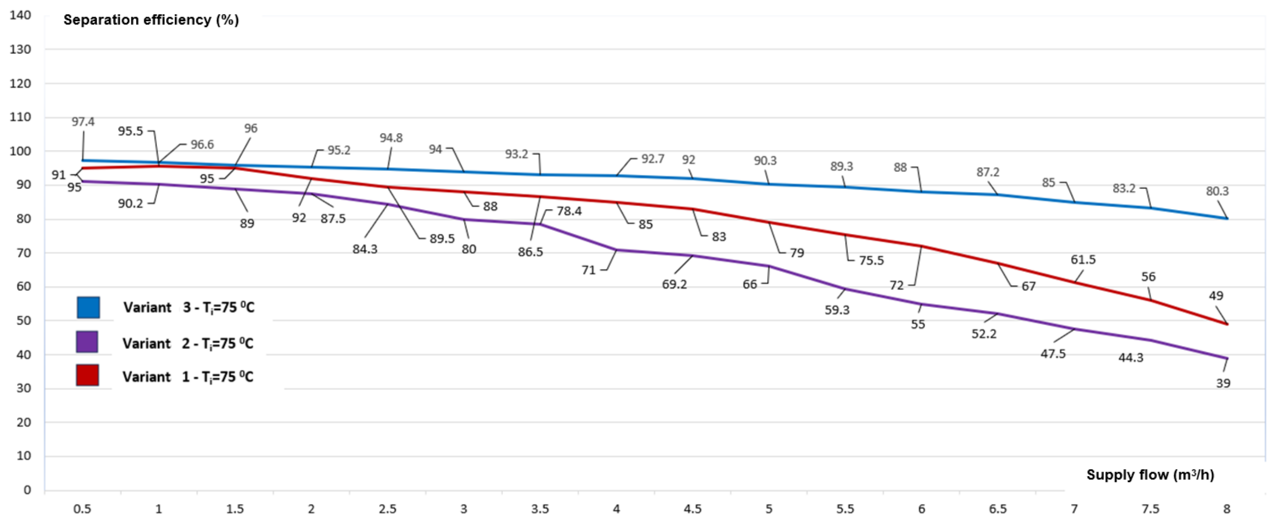

Figure 7. Evolution of separation efficiency E(%) as a function of feed flow rate Qi for the three types of decanters used in the experiments, for wastewater inlet temperature T_i=75 ^{0}C.

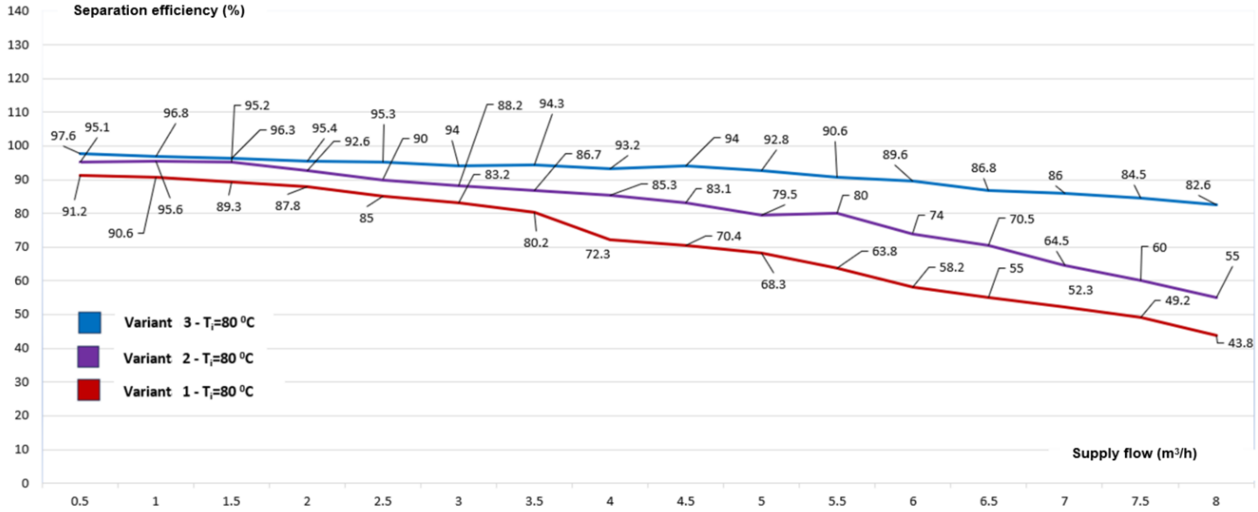

Figure 8. Evolution of separation efficiency E(%) as a function of feed flow rate Qi for the three types of decanters used in the experiments, for wastewater inlet temperature T_i=80 ^{0}C.

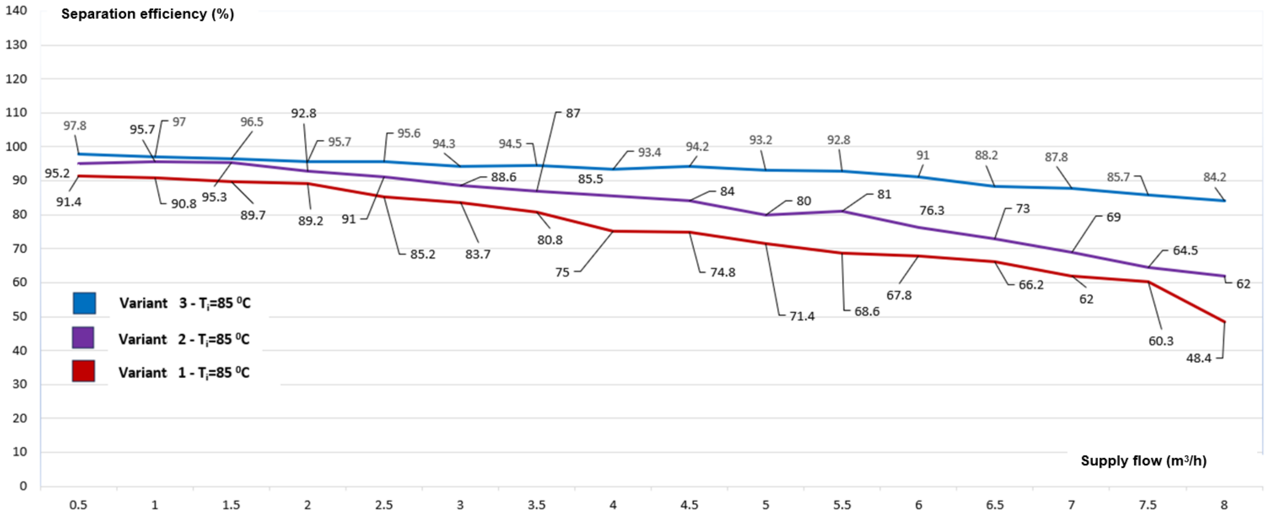

Figure 9. Evolution of separation efficiency E(%) as a function of feed flow rate Qi for the three types of decanters used in the experiments, for wastewater inlet temperature T_i=85 ^{0}C.

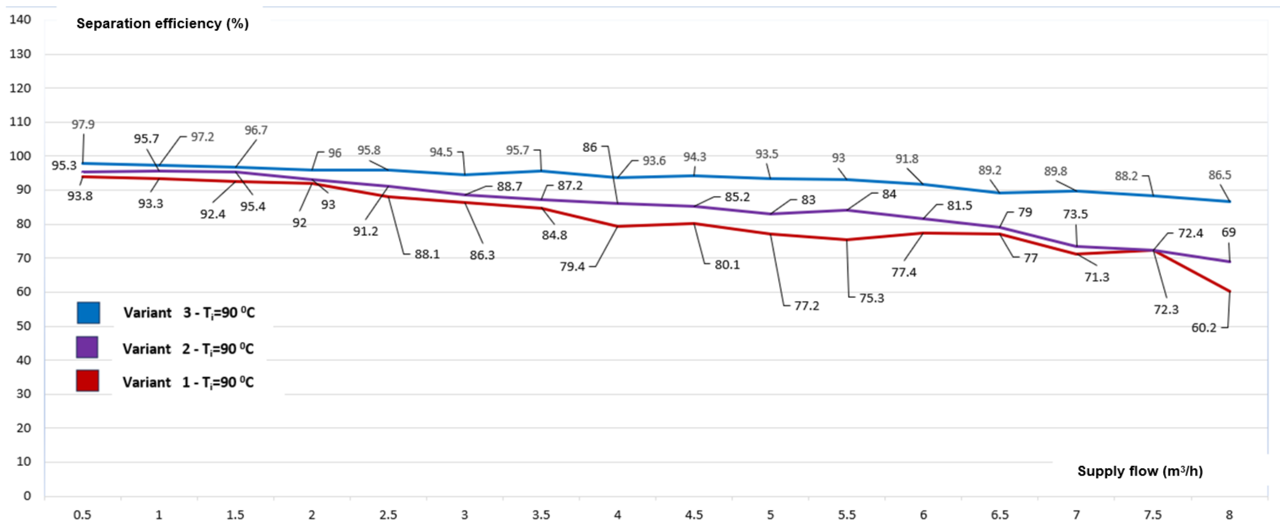

Figure 10. Evolution of separation efficiency E(%) as a function of feed flow rate Qi for the three types of decanters used in the experiments, for wastewater inlet temperature T_i=90 ^{0}C.

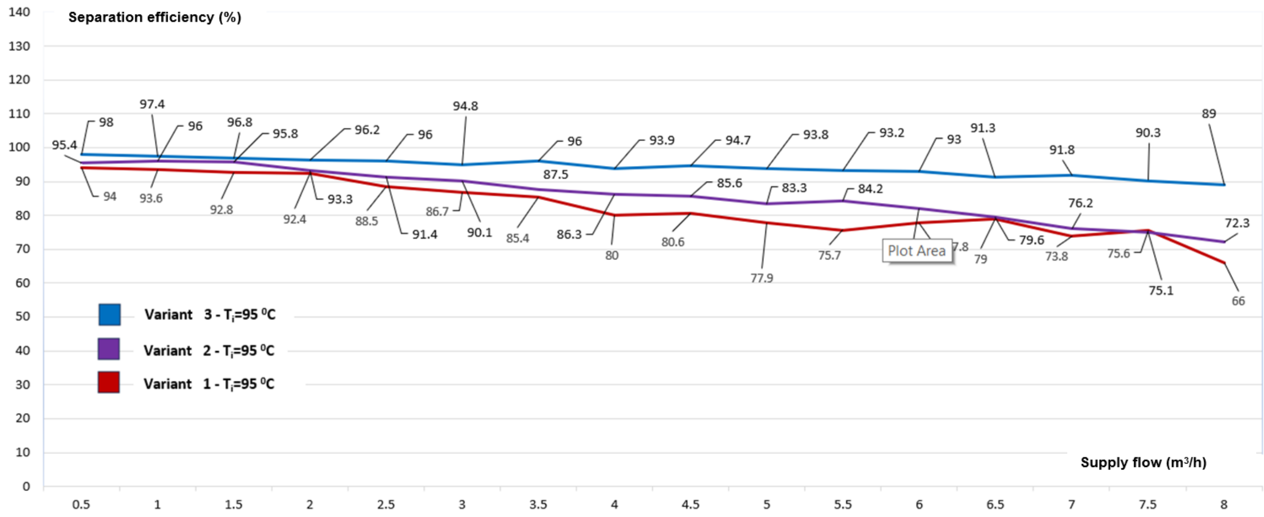

Figure 11. Evolution of separation efficiency E(%) as a function of feed flow rate Q_i for the three types of decanters used in the experiments, for wastewater inlet temperature T_i=95 ^{0}C.

The comparative analysis regarding the variation of the separation efficiency depending on the feed flow rate Qi and the inlet temperature of the wastewater Ti, for the three types of decanters tested, in order to select the most efficient equipment highlights the following:

- the separation efficiency has low values in the case of working variants 1 and 2 (which use a decanter equipped with a lateral compartment for feeding wastewater and a free discharge pipe for the clarified water (without a spillway wall), respectively a decanter to which the wastewater is fed through a central tube, provided at the bottom with a deflector-type device), at values of 75 ^{0}C and 80 ^{0}C of the inlet temperature of the wastewater and for values of feed flows (Q_i) higher than approx. 4 m^3/h;
- for higher wastewater inlet temperatures (T_i=85 ^{0}C, T_i=90 ^{0}C, T_i=95 ^{0}C) and feed flow rates lower than approx. 3.5 m^3/h, the decanters used in working variants 1 and 2 ensure appropriate separation efficiency values (especially the decanter with central tube and baffle plate feed);
- compared to the first two working variants, the separation efficiency is superior in the case of the decanter used in variant 3 (decanter equipped with scraping system), both for lower wastewater inlet temperatures and for higher equipment feed flow rates.

CONCLUSIONS

1. The experimental research carried out to establish the efficiency of the sedimentation process for the three constructive types of decanters tested was based on determining the values of the impurity concentration, both at the inlet of the wastewater and at the outlet of the clarified water from the decanter; based on the values obtained, the separation efficiency graphs were drawn, which establish the variation in time of the impurity concentrations.
2. The evolution of the separation efficiency E was analysed for different values of the inlet temperature of the wastewater in the decanter (T_i=75 ^{0}C, T_i=80 ^{0}C, T_i=85 ^{0}C, T_i=90 ^{0}C, T_i=95 ^{0}C), as well as for values of the water supply flow rate ranging between 0.5 m^3/h…8.0 m^3/h.
3. The analysis of the evolution of the separation efficiency E depending on the feed flow rate Q_i, respectively the initial temperature T_i of the wastewater (for the types of decanters tested) highlights the following:

- the separation efficiency (E) decreases as the feed flow rate (Q_i) increases for all types of decanters tested; also, the separation efficiency (E) is higher for higher values of the input temperature T_i of the wastewater (for all types of decanters tested):

➢ so (at temperature T_i=75 ^{0}C) for small values of the feed flow rates between 0.5 m^3/h and approx. 4.0 m^3/h, the separation efficiency (E) has similar values for variants V1 and V2 (values between 69.2% and approx. 91%, for variant V1, respectively between 85% and approx. 95%, for variant V2), in the case of variant V3 these values are higher (between 92.7% and approx. 97.4%);

➢ compared to the situation in which the inlet temperature of the wastewater T_i=75 ^{0}C, it is observed that for higher values of it (for example T_i=95 ^{0}C), as well as for the feed flow rates (Q_i) with wastewater (between 5 and 8 m^3/h), the separation efficiency increases significantly: for a feed flow rate Q_i=8 m^3/h, from 39% to 66% for variant V1; for a feed flow rate Q_i=8 m3/h, from 49% to 72.3% for variant V2; for a feed flow rate Q_i=8 m^3/h, from 80.3% to 89% for variant V3, where significant increases in this working parameter are observed, compared to the first two variants studied.

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