Transilvania University of Brasov
FACULTY OF MECHANICAL ENGINEERING

The 7th International Conference on Computational Mechanics and Virtual Engineering
COMEC 2017
Brasov, ROMANIA, 16-17 November 2017

# THEORETICAL AND EXPERIMENTAL RESEARCHES ON THE SEPARATION PROCESS OF THE IMPURITIES FROM WASTE WATER THROUGH DECANTATION

**Daniela Zărnoianu**[1], **Simion Popescu**[2]
[1] Transilvania University of Brasov, Romania, e-mail: daniela.zarnoianu@yahoo.com
[2] Transilvania University of Brasov, Romania, e-mail: simipop38@yahoo.com

***Abstract:*** *After some theoretical considerations on the decantation process for water with suspensions, the paper presents the results obtained from the experimental research on the decantation processes for residual water (wastewater) on an experimental plant (pilot station) formed by two constructive varieties for the decanters with tangential inlet and spillway threshold: a) without a device for scraping (removing) decanted sludge (mud) and b) with device for scraping sludge (mud). The compared analysis of sediment separating efficiency for the two types of decanters was conducted by measuring the time variation of the concentration of suspensions at the entrance and exit from the two types of clarifiers and developing some comparative graphics for the concentration variation of the suspensions and the efficiency of decanters.*
***Keywords:*** *residual water sedimentation, impurity concentration, separating efficiency, decanter with tangential inlet, scraping equipment,*

## 1. INTRODUCTION

Industrially used water, also called „waste water" or „residual water" comes from different production and processing processes ad, from a physical point of view, they represent multiphase fluids (mixtures). When stopping, the phases are separated by gravity by a downward movement, due to the differences in specific mass of the particles in the suspension, thus achieving a *sedimentation* or *decantation* process [3]. The solid particles, which fall off to the bottom of the sedimentation vessel, form a solid – liquid mixture, more or less concentrated, in the form of a sediment called precipitate, slurry or sludge [1,3].
The equipment used the for gravimetric separation, caller *decanter* is composed by a sedimentation vessel, filled with suspension water that will be decanted, a device for recovering the decanted liquid (decanted water) that, usually, surpasses the basin surface and leaks above its level. Additionally, the decanter is equipped with a device for eliminating (extracting) the sediment (precipitate) from the bottom of the basin.
On the interior of the sedimentation vessel (fig. 1) are distinguished the following for areas [2]:
*Area I* – the superior layer of clear liquid or slightly turbid, whose thickness increases continuously along with the sedimentation speed;
*Area II* – layer of suspension with constant concentration equal or close to the initial concentration of the suspension, having a decreasing thickness over time;
*Area II* – intermediary layer, relatively thin, where the concentration of the solid phase increases in depth, having the thickness approximately constant until the disappearance of the suspension layer (layer II);
*Area IV* – layer of sediment particles, with high concentration in solid substances.
The thickness of the layer with high concentration in solid substances from Area IV increases continuously along with the sedimentation time, until the moment when the layer in the Area II disappears (fig. 2, d). Continuing the sedimentation process, the sediment layer decreases by the compaction of the precipitate, simultaneously with eliminating the liquid from the precipitate.
The real sedimentation speed $v_{sr}$ of particles with regular spherical shape for a concentration of slid suspension particles of 5...10% is determined using the relation:

$$v_{sr} = K.v_s \tag{1}$$

where:

$v_s$ is the theoretical sedimentation speed for particles with spherical shape (for a given sedimentation regime the sedimentation speed is determined on the basis of experimental researches or is calculated using analytical relations);
$K$ – dimensionless coefficient that takes into account the gravimetric concentration of solid suspension particles (from experimental researches, usually $K$= 0.5…0.6).

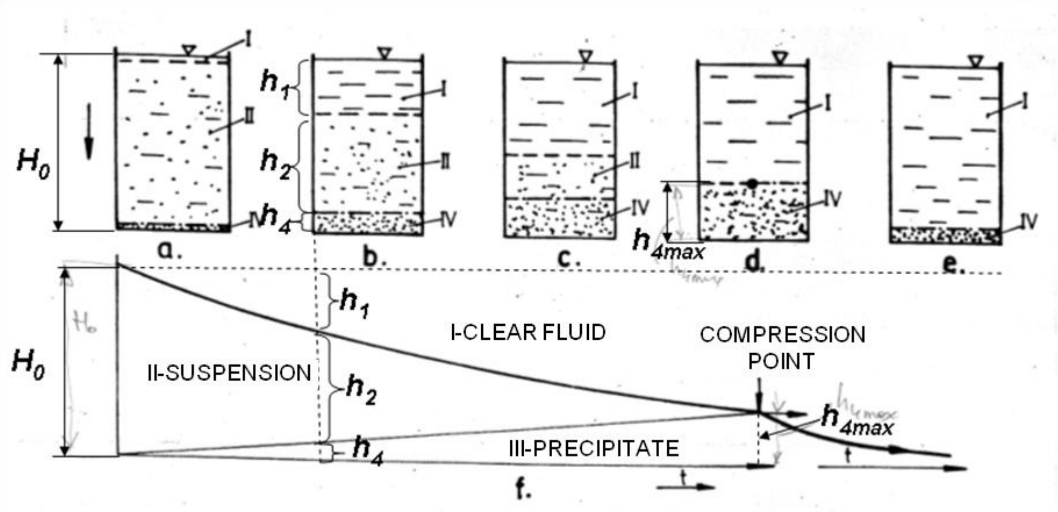


**Figure1**: Characteristic phases of the sedimentation process for water with suspensions

In the case of irregular shaped particles, the real sedimentation speed $v_{sr}$ is determined using the relation:

$$v_{sr} = \psi . K . v_s \tag{2}$$

where $\psi$ is a coefficient for the shape of the suspension particle (has values determined in experiments).
In reality, in the rectangular basin of a decanter, the mixture subjected to decantation (water with sediments) moves horizontally to that a particle situated in suspension in this environment performs a movement composed with the absolute speed $v_a$ (fig.2), resulted from summing up the two movements: the movement caused by the flowing of the mixture on a horizontal direction with the transport speed $v_m$ and the vertical sedimentation movement with the speed $v_s$ caused by the gravitational field.
From the constructive and functional point of view, a decanter can be defined by several distinctive areas: area of admission, area of sedimentation (decantation), area of accumulating sediments (sludge area) and area of evacuating clear water. The water-sediments mixture with a flow $Q$ enters the admission area in a turbulent flowing regime and is distributed, in a uniform horizontal movement, on the whole transversal section of the basin, with the same $v_m$ speed in all the points of the transversal section placed at the end the admission area (the mixture executes a piston type movement). It is considered that in the area of sedimentation, particles are set with the same $v_s$ speed as in the calm, static fluid.
In a rectangular basin, where the height of the suspension water layer is $H$ (fig. 2), the maximum time necessary for achieving the sedimentation of a particle with a given diameter is given by the relation:

$$t_s = \frac{H}{v_s} \tag{3}$$

From analyzing the relation above it is noticed that this time is larger as thickness of the suspension layer is bigger and the sedimentation speed is smaller.

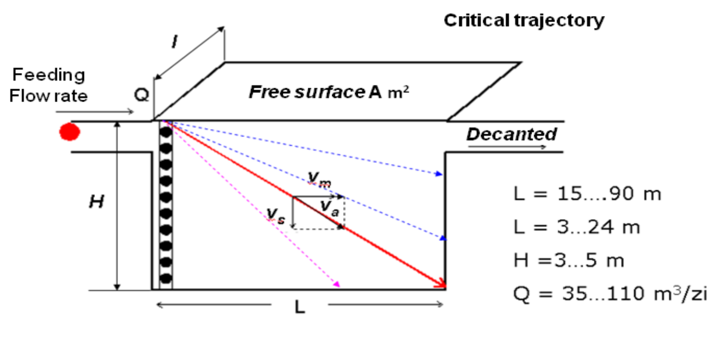


**Figure 2:** Diagram for particle movement for the sedimentation with transversal circulation (horizontal) of the mixture

If the useful length of the basin is $L$, the time for stationary movement of the fluid in the basin with a sedimentation speed $v_s$ is calculated using the relation:

$$t_0 = \frac{L}{v_m} \tag{4}$$

Due to the fact that a particle is considered sediment in the moment when it reaches the bottom of the vessel, in order to achieve the sedimentation of the particles in the moving suspension is necessary that the time of stationing in the basin is larger or at least equal to the time of particle sedimentation, meaning: $t_0 \geq t_s$.
Because, in general, the dimensions $L$ and $H$ of the basin are known and the value of the sedimentation speed $v_s$ for a certain type of suspension is also known, from relations (3) and (4) is obtained the relation through which is determined the limit value of the speed of movement $v_m$ of the mixture:

$$v_m \geq v_s \cdot \frac{L}{H} \tag{5}$$

Relation (5) emphasis the fact that by reducing height $H$ of the fluid layer in the decantation basin, $v_m$ speed of movement of the mixture can be increased. Height $H$ of the layer of fluid can't be reduced below a certain limit, because the situation may be reached where the separation of particles situated in suspension is done incompletely, the current of fluid also engaging a part of the particles laid on the bottom of the basin. Considering a rectangular shaped basin (s. fig. 2), it result that the width $l$ of the basin section depends on the value of the feeding flow $Q$, the height $H$ of the basin and the average speed of movement (transport) $v_m$ of the water in the basin section. From the known equation of continuity, namely $Q = H.l.v_m$, result the value of the basin width l given by the relation:

$$l = Q/\,H.v_m \tag{6}$$

and the free surface $A$ of the clarifier (fig. 2) is determined with the relation:

$$A = L.l. \tag{7}$$

The efficiency of a clarifier is assessed by the percentage coefficient $E$ of retaining impurities from used water, depending on the initial impurities concentration $c_0$ (mg/l) and the final impurities concentration $c_1$ (mg/l), defined by the relation [1]:

$$E = \frac{c_0 - c_1}{c_1} \cdot 100 = \left(1 - \frac{c_0}{c_1}\right) \cdot 100 \;\; [\%] \tag{8}$$

The value of the coefficient of separation $E$ depends on the clarifier type and on the installations that equip it and, usually, has values comprised in the limits $E$ = 35…65%

## 2. EXPERIMENTAL RESEARCHES

The main objective of experimental researches consists in the compared analysis of functional performances of a cylindrical decanter with tangential inlet and spillway threshold built in two models: clarifier with simple construction, meaning without an additional system for scraping sludge deposits (called scraper) and modernized clarifier, additionally equipped with device for interior scraping of sludge deposits. By installing the scraper was aimed to keep the volume of decantation constant by the contiguous removal of sludge deposits from the inferior walls of the decanter.
In order to establish the factors influencing the efficiency of the process of sedimentation in decanters for industrial waste water and finding the optimal constructive option for the decanter an experimental installation (pilot station) was built an experimental installation, which will allow to have a compared analysis between a model of cylindrical decanter without scraper and a model equipped with scraper.
The experimental installation (Fig. 3) consist of the feeding vessel (tank) 1 (V-1), fitted with a mechanical agitator for homogenizing the composition of the residual water subjected to experiments and a centrifuge pump 2 (P-1) for feeding decanters D-1 (without scraper) and D2 (with scraper). The temperature of the used water when entering in the clarifiers is measured with electromagnetic flow meters 4 and 12, mounted on the feeding pipe of decanter D-1 and, respectively, D-2. The evacuating flow of the sludge is measured with electromagnetic flow meters 6, respectively 14, mounted at the exit of sludge pipes of decanters D-1 and D-2. The adjustment of the feeding flow for clarifier D-1 is done by the regulating valve 5, connected to the flow meter 4, and in the case of clarifier D-2, adjustment of the feeding flow is done by the regulating valve 13, connected to the flow meter 12. The adjustment of the evacuating flow for decanters D-1 and D-2 is done by the regulating valve 7, connected to the flow meter 6, respectively with the regulating valve 15, connected to the flow meter 14. The scraping organ 11 of decanter D-2 is actuated mechanically from a driving device 9 situated in the exterior.

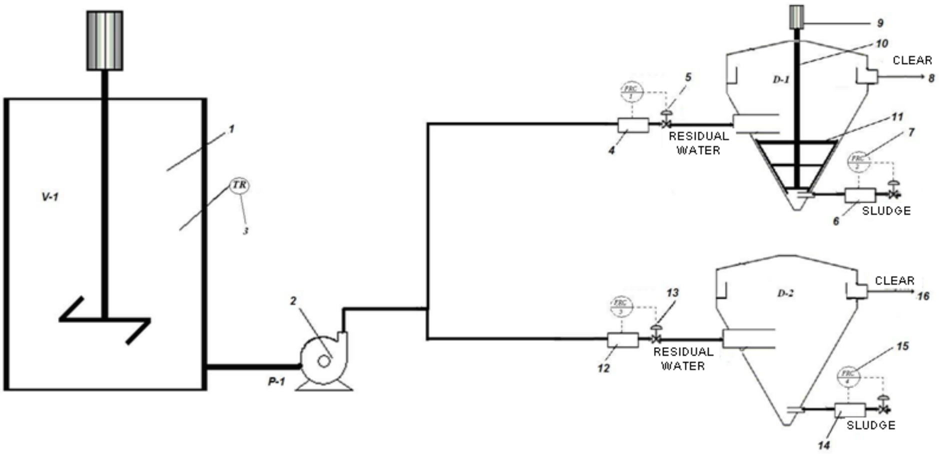


**Figure 3:** Diagram for the installation (pilot station) for conducting experiments on two options for decanters with tangential inlet and spillway threshold: D-1 - decanter with scraper; D-2-decanter without scraper

After filling vessel V-1 with used water subjected to testing, having a known initial concentration of impurities (determined by measuring), and pump 2 is started (P-1) for feeding decanter D-1, respectively D-2. In the process of filling decanter with used water, sludge in the inferior part is purged (eliminated) periodically in order to avoid the clogging of the system for evacuating clear water. In addition, after filling decanter D-2, the device for mechanical evacuation of sludge with scraping organ 11 enters into operation, driven by the driving system 9 through drive shaft 10.
For the tests conducted, samples of material were periodically collected and were measured the concentration of suspensions *c* (mg/l) from the used waters introduced in decanters, from the clear liquid evacuated and from the sludge evacuated from the decanter. Testing the operation of each option of experimental decanter was achieved by collecting of samples at a 24 hour interval. For each sample were determined by measures the values of concentration of impurities (in mg/l) at the entrance of waste water in the two clarifiers, from the clear water and at the exit from the decanter and from the sludge evacuated from clarifiers. By processing the data were determined by calculation the efficiency *E (%)* of the separation process for each periodical testing, using relation (9).

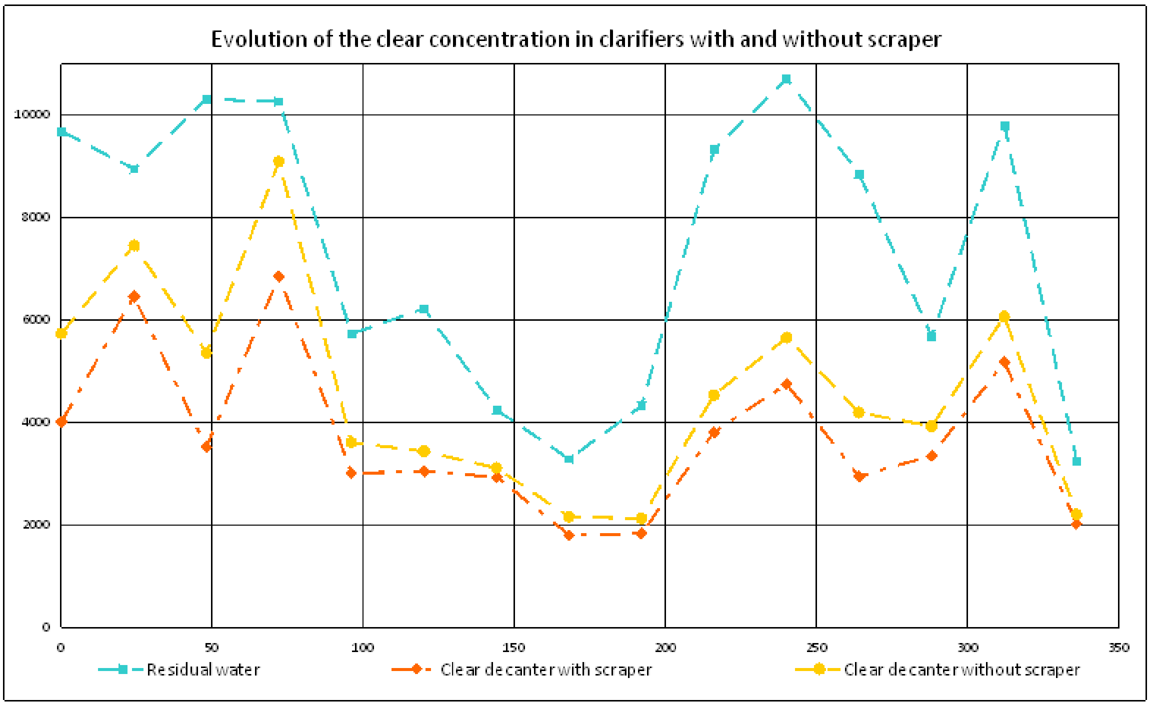


**Figura 4:** Variation in time of the concentration of the suspension (mg/l) in clear water for the two types of decanter (with scraper and , respecively, without scraper)

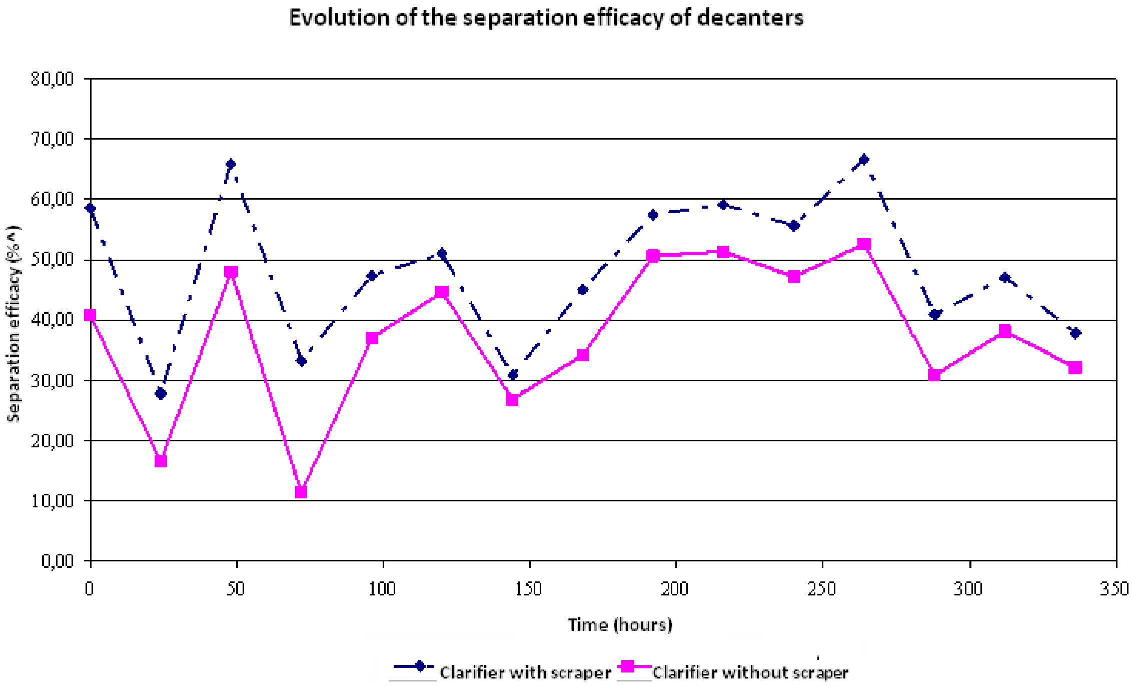


**Figure 5:** Variation in time of the efficiency of of impurities separating (%) for the two types of decanter (with scraper and , respecively, without scraper)

On the basis of experimental data were built graphics that represent the time variation of the suspension concentration *c* (mg/l) in clear water and in mud for the two types of decanters (Fig. 4) and the time variation of the efficiency of separation *E (%)* depending on the initial concentration of the solid in the residual (waste) water at the entrance in the decanters (Fig. 5). These graphics allow making a compared analysis of the separation process and the evolution in time of the separation efficiency for the for each type of decanters (decanters with scraper and , respecively, without scraper )

## 3. CONCLUSIONS

The efficiency of separating suspensions from residual waters is superior for the decanters with devices for scraping, compared to the one of the decanters without scraping devices, a fact leading to the reduction of solids concentration in the discharged (clear) water. Therefore, it is recommended to use decanters with tangential inlet and spillway threshold equipped devices for scraping the sludge, which come into operation automatically after filling the clarifier.

## REFERENCES

[1]. Robescu, Diana et al. Tehnici de epurare a apelor uzate, Editura Tehnica, Bucuresti, 2011
[2]. Rus F. Operaţii de separare în industria alimentară. Editura Universităţii Transilvania, Braşov, 2001
[3]. Techobanoglous, G., Burton, F.L. and Stensel, H.D. Wastewater Engineering. (4th Edition ed.). McGraw-Hill Book Company, 2003.