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Abstract

The main objective of this review was to analyze the effect on the separation of solids from wastewater with different conditions of aeration and mixing in order to compare their efficiency when both processes act simultaneously and find the most optimal conditions among the various variables.

Due to the effectiveness of a new additive provided by the company Norwegian Technology AS whose use in new experimental methods is being evaluated, it was decided to analyze its effectiveness of removal of total suspended solids and turbidity under different experimental conditions. Therefore, different variables were taken into account in the study: the use of different diffusers, the effect of different impellers, the result in the variation of mixing velocity and the response of solids to different designs of mixing tanks.

Obtaining that the design of the experimentation tank plays an important role in the results, when mixing and aeration act together, being in this case the 3-liter tank with a speed of 1200 RPM at a concentration of 2.75 g of N-sep per liter of water, with a pitched-blade impeller being the best conditions in all the experimentation processes obtaining a 92 – 96 % TSS removal and a turbidity range bewteen 5 – 9 FAU. To conclude it was founded that sintered tone diffuser has the best results for the two proposed tested tanks with a percentage removal of TSS between 85 - 95% in both tanks.

Nomenclature

DAF	Dissolved air flotation
ECF	Electrolytic Coagulation / Flotation
EF	Electrolytic Flotation
FAU	Formazin Attenuation Unit
gpm	Galloon per minute
IAF	Induced Air Flotation
MIAF	Modified Induced Air Flotation
NT	Norwegian Technology AS
NTU	Nephelometric Turbidity Unit
rpm	revolution per minute
SNJ	Sentralrenseanlegg Nord-Jæren
TSS	Total Suspended Solids
UiS	University of Stavanger

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Chapter 1. Introduction

"Flotation is a unit operation used to separate solid or liquid particles from a liquid phase where separation is brought about by introducing fine gas (usually air) bubbles into the liquid phase" (Burton et al., 2013).

Mainly, the flotation process began to be used in obtaining and processing minerals (ores). For later, be used in the treatment of wastewater. Its main focus is the elimination of solids in suspension, substances in solution, fibers, colloids, various microorganisms and oils and fats. In addition, its use is well known and used in a wide range of industries such as the paper, chemical or food industry (da Rosa & Rubio, 2005; L. K. Wang, 2010).

Due to the multiple and different applications of this method, the technological, scientific and chemical advances in the sector of wastewater treatment, at present, give way to research and innovation when looking for significant efficiency and effectiveness to obtain greater and better water quality.

In this case, not only the use of aeration processes is considered by itself, it goes a step further by simultaneously integrating the mixing operation and tries to use to a lesser extent, the addition of chemicals that facilitate the separation of unwished solids that cause an increasing in the operational cost.

For this reason, the main objective is to investigate how the conditions of aeration and mixing will influence the treatment of wastewater, thus prioritizing flotation techniques against sedimentation or filtration processes, whose function is similar: separation of solids in a liquid medium (L. K. Wang, 2010). For this, these conditions will be studied in the laboratory and whose results will be taken into account in the design of a future reactor for the company Norwegian Technology AS.

1.1 Role of Additive

As mentioned before, the use of chemicals is a fundamental part during the water treatment process. Its use is mainly due to the attempt to reduce to the maximum the substances and particles that do not guarantee a good quality and are present in the raw water. This process is usually called chemical treatment and includes processes such as coagulation, flocculation and precipitation mainly. Depending on what is intended to be eliminated in the influent, it is generally sought to eliminate smaller particles such as colloidal (of micrometric range) or particulate (larger) (Burton et al., 2013).

Therefore, generally depending on the type of chemical used, for example in the case of anionic polyelectrolytes, the recommended mixing time varies between 1 and 10 seconds (Burton et al., 2013). These recommended mixing times have been previously studied and nowadays they have been incorporated into the treatment plants, which stick to them in order to obtain the best conditions in the chemical reactions between the chemicals and the particles.

The challenge in this study case is due to the use of a patent belonging to the company Norwegian Technology AS (NT). The patent is called N-Sep, which is characterized as an additive and whose application is being investigated for the purpose of greater use of the product. Unlike other polymers, in this case, N-Sep has the advantage of acting as flocculant and coagulant with contact times of 5 – 10 seconds 40 (APPENDIX A), so its effectiveness is quite remarkable if we compare it with a conventional treatment using other chemicals .

The disadvantage in this case and therefore part of the importance in this investigation, is the fact of not having previous experiments and information with which to compare or start the research process.

Most polymers usually act either as flocculants or as coagulants, but not as both. This feature limited the study method to a small number of scientific articles focusing on flotation methods rather than mixing periods.

This objective gives us the possibility to study different hypotheses by allowing us to vary the different scenarios that take place in these processes.

1.2 Role of Mixing

To measure of mixing effectiveness, there is a unit that allows us to analyze the amount of energy dissipated in a reactor when using different types of mixing impellers. This measure is based on the concept that the higher the input power, the greater turbulence is created, resulting in a better mixing in the reactor (Burton et al., 2013).

Another matter that has to be considered is the flow rate, which will affect the hydraulic mixing as it alters the energy input, creating a non ideal mixing conditions due to low flow rates.

1.3 Wastewater at SNJ treatment plant

The experimental work of the thesis was done at the wastewater treatment plant "Sentralrenseanlegg Nord-Jæren (SNJ)" owned by IVAR IKS. SNJ is an advanced wastewater treatment plant, serving a population of about 300.000, and includes a primary filtration plant (0.1 µm pore size) as primary treatment and enhanced biological phosphorus removal as secondary treatment., where the sludge treatment consists of thickening, anaerobic digestion, dewatering, thermal drying and fertilizer production (SNJ) .

Different variables would be tested in order to understand and investigate the mixing and aeration conditions in the separation of solids. For this task, it is believed that the effect of different diffusers that produce smaller bubbles obtain a greater elimination of particles in the residual water; a higher mixing velocities, greater particle removal is obtained and the size and shape of the reactor and type of impeller, do influence the mixing conditions.

Chapter 2. Literature Review and Theory

2.1 Flotation Techniques

Several advantages must be taken into account compared to the rest of the techniques (sedimentation for example), since flotation uses shorter capture times, results in a greater elimination of substances and, lastly, also implies a lower cost, since they do not usually occupy a large volume of surface, nor are difficult to maintain (Burton et al., 2013; Rubio, Souza, & Smith, 2002).

In practice, the size of the bubble formation will be taken into account and, therefore, first of all the different types of flotation techniques should be differentiated, with special emphasis on injection by dissolved and dispersed air, since they are the most used currently (L. K. Wang, 2010).

2.1.1 Electroflotation (EF)

It is a method that uses the electrolysis of water through which a continuous electrical current circulates through the electrodes allowing the separation and formation of hydrogen at the cathode and O_2 at the anode. These gases and bubbles will allow the separation of particles and pollutants by flotation (Smith, 2005).

Regarding its advantages, the efficiency of the results depends mainly on the materials used and the size of the bubble obtained, other factors that influence are the energy capacity and the quality of the water. Some disadvantages are the formation of hydrogen bubbles and a large production of sludge, depending on the material used in the electrodes the cost may vary (G. Chen, 2004).

It has been observed a better performance with electrodes of reversible polarity, this process is known as Electrolytic coagulation / flocculation (ECF) (Rubio et al., 2002).

2.1.2 Dissolved (Pressure) Air Flotation (DAF)

DAF is a method widely used in most treatment plants, whose basis is Henry's Law, which depends on the temperature and pressure of gas and water. It consists in creating microbubbles by mixing supersaturated water with water to be treated, at atmospheric pressure; this will allow the contact of the bubbles with the colloidal substances and particles originating flocs. After this process has taken place, the mixture can be eliminated by different mechanical techniques (A. Chen, Wang, & Yang, 2016; P. Li, 2006).

Focusing on the advantages and disadvantages of this process, we can say that despite being one of the most used by treatment plants today, being a method that produces bubbles in a range between 0 and 100 micrometers, that is, a much lower range than most processes, thus facilitating the elimination process. Since, the smaller a bubble is, the more easily it can adhere and therefore a particle of the micrometric and even nanometric order come into contact (colloidal particles). However, this entails higher costs for equipment and materials and leads to larger equipment in terms of design and greater energy maintenance due to slow velocities of the bubbles (P. Li, 2006; Rubio, 2001).

There are two types of DAF; the first uses the vacuum technique after aeration, while the second one redirects part of the effluent, but saturated with air to create the bubbles in the tank with the water that will be treated later. In addition, generally, DAF is usually accompanied by a previous coagulation process which facilitates even more the agglomeration of the flocs (Smith, 2005).

Vacuum Flotation

This method, over time has become part of the DAF system because it also bases its operation by pressure changes. To do this, it uses air dissolved in water at atmospheric pressure and takes advantage of the variation in surface pressure, which releases it creating small bubbles and thus creating a change in pressure in both media, with the subsequent saturation of one of them (Packham & Richards, 1975; L. K. Wang, 2010).

The process of vacuum flotation is generally used in the paper industry but due to its cost and whose results depend mainly on the vacuum capacity that is created, it has been replaced by pressure flotation (Zabel, 1992).

2.1.3 Disperded (Induced) Air Flotation (IAF)

The procedure of induced air flotation differs from DAF mainly, in that the creation of bubbles have a larger size ($\geq 1\mu m$), therefore, the larger the size the higher the speed. This in turn implies a disadvantage, since it results in a lower collision between particle and bubble (Smith, 2005).

Another disadvantage to name is that to improve the union, surfactants are added; which gives rise to a greater production of sludge, whose treatment supposes an extra addition as much in cost as in effectiveness (P. Li, 2006).

Several advantages to mention are that generally, the equipment does not cover large areas, they are more compact, so they are more cost efficient. In this type of process, the air is injected through an induction system (a diffuser for example) or mechanical systems with holes of different sizes, which allow us to decide the ideal size and form of the aireators and the amount of air that we can use during the process (Burton et al., 2013; Romphophak, Chalermsinsuwan, Chawaloesphonsiya, & Painmanakul, 2016) .

2.1.4 Froth Flotation

During the process of flotation with foam, the aggregate of minerals from the ores or gangue minerals are crushed to form a kind of mass or paste called pulp. This technique also uses different types of agents, both foaming agents and flotation agents, making the most of the hydrophobic properties of valuable minerals (Deng & Zhu, 1999; S. S. Wang & Scanlon, 1983).

The pulp is aerated in a flotation cell or column and due to the foaming agents, the hydrophobic minerals will rise due to the interaction with the air bubbles in contact with the foam (which will be treated later) (L. Wang, 2017) .

Some advantages to mention are that this method allows the separation of a great majority of minerals, depending on the reagents used, the surface of the minerals can be modified and, in terms of the disadvantages, it is an expensive process and will depend on the slime of which it comes (Michaud, 2013) .

Chapter 3. Material and methods

3.1 Design approach

Several studies have been taken into account for the realization of this work. As already mentioned, due to the different way of acting of the N-Sep additive, with reference to the scientific articles, only the information regarding the flotation system was taken into account and a well thought-out methodology was selected to achieve our main objective.

On this occasion, NT proposed that the most appealing method to investigate would be IAF (due to its multiple advantages already mentioned above) allowing us to study a wide variety of air injection systems varying in size, shape and most importantly: bubble formation.

In this case six different types of diffusers, presented in Table 1, were studied:

Table 1

Different types of diffusers used and their main characteristics

Diffuser	Type	Characteristic
	Air stone bubble diffuser	– Ball / Golf shape (1.2" diameter); 1,5 - 5 l/min, with a recommended : Air Pump Power of 2 - 4 watts.
	Air stone bubble diffuser	– Cylinder , made from fused alumina with a bubble size of 1 – 2 mm.
	Air stone bubble diffuser	– Trapezoid Disc Diffuser, 6” (≈ 15cm) trapezoidal air stone
	O_2 Grow Dissolved Oxygen Emitter	– Nanobbuble technology using electrolysis, which increase in O_2 saturation in water. Works at 6 – 7 watts at 230 volts.
	Micron Sintered SS Oxygen Stone	– Stainless Steel Diffusion Stone, with a 2µm pore size and a pressure about 2 psi (≈ 0,14 bar) is required.
	Micro Bubble Air Diffuser	– Rubber hose (6” ≈ 15 cm) with a required air flow (appx) ≈ 120 l/h and a 5 – 10 kPa

Note. (Burton et al., 2013)

For the purpose of obtaining a good mixing between the polymer and the wastewater, a Hei-TORQUE Precision 100 overhead stirrer was used, whose main advantages were: its wide range of rotation speed (comprised between 10 and 2.000 rpm) and the ability to be able to exchange the impellers during the investigation (Heidolph, 2017).

In addition, to obtain better results, several characteristics were predetermined before the beginning of the study. For the overhead stirrer, flow, mixing speed and viscosity of the medium are key factors and in terms of impellers, its position and the design of the tank were taken into account to obtain ideal conditions during experimentation (Heidolph, 2017) .

3.1.1 Air Flow Rate

According to (Painmanakul, Sastaravet, Lersjintanakarn, & Khaodhiar) "it can be found at the gas flow rate equal to 5 ml/s which correspond to the QG value that provides the highest removal efficiency obtained with both IAF and Modified Induced Air Flotation (MIAF) processes", while for (Romphophak et al.) "it was observed that the efficiency slowly rises when the air flow rate increases and slightly drops after reaching its peak value at the flow rate of 0.3 l/min to 0.5 l/min" and finally for (Pan Li, Tsuge, & Ohnari) during the experimentation process "the induced air flow was at a constant value of 0.6 l/min".

During the first stage, four types of air flow were used according to the results of the scientific article experiments:

- 5 $ml/s = 0.3$ l/min = 18 l/h
- 0.4 l/min = 24 l/h
- 0.5 l/min = 30 l/h
- 0.6 l/min = 36 l/h

It should be noted that, regarding the O_2 grow diffuser, the flow parameter was predetermined at 0.50 gpm (gallon per minute) ≈ 113.14 l/h, so its value is always constant in all experiments (Oxygen Research Group, 2018) .

Meanwhile, in the final stage of the study, the air flow rate was maintained between 20 – 23 l/min ≈ 1.200 – 1.380 l/h, due to the use of the new compressor.

And as regards the mixing speed, four were evaluated: 600 rpm during the first and second stages and 800, 1200 and 1600 rpm in the final stage.

3.1.2 Impellers

One of the objectives in this investigation is to determine the performance of different impellers during the mixing, also counting on flotation as part of the system.

Therefore, 3 types of impellers, presented in *Table 2*, were tested:

Table 2

Different types of impellers

Impeller	**Type**	**Flow**	**Model**	**Name**
	Propeller-type impeller	*Axial*	PR 30	Pitched - Blade Impeller
	Propeller-type impeller	*Axial*	PR 32	Ringed Propeller
	Blade Impeller	*Radial*	BR 10	Cross -Blade Impeller

Note. (Heidolph, 2017)

In wastewater treatment there are different types of impellers whose choice varies depending on the function to be carried out. Those that favor the mixing of chemicals, are divided into two types: the ones that provide axial flow or those that provide a radial flow, the difference between them derives in the angle, design and number of blades (Burton et al., 2013).

Following the design criteria of Heidolph, the models PR30 and PR32 belong to the propeller-type impeller meanwhile the model BR10 belongs to the blade impeller type, but in this case, all of them favor the mixture and suspension of particles (*APPENDIX B)* .
In addition, giving rise to the following section in the study, the dimensions of these impellers were suitable for the designed reactors, thus supporting the decision of their use.

3.1.3 Microbubble generator design tank

For this project, in order to achieve the maximum levels of efficiency in the mixing period with the different impellers and diffusers and in turn not get much turbulence, two different types of tanks were designed at laboratory scale. In addition, it was possible to compare if the shape and size would be a factor that might influence in the results.

Following the recommendations of (Doran) in her book bioprocesses engineering principles: shape, volume, diameter of the tank, diameter of the mixer, height of the liquid in the tank, clearance and optimum width of baffles were considered in the design (Figure 3) .

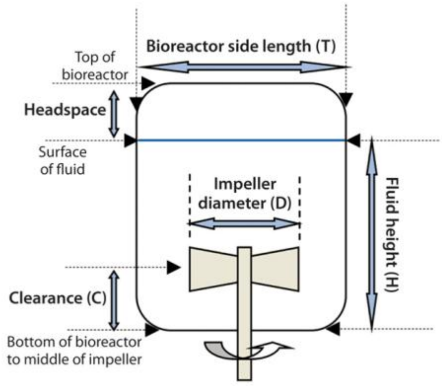

Figure 3. Different measurements impeller – reactor considered (Nienow, Isailovic, & Barrett, 2016)

According to (Burton et al.) baffles should be included in the design, as they are an important part in the mixing vessel tanks due to the fact that promote vertical mixing and greater turbulence. Usually between three and four baffles equally spaced are considered in the design for preventing vortex formation (Doran, 2013)

3.1.4 Bubble size

Bubble size was tested for all the different diffusers used throughout the development of the study case. Using a CANON PowerShot SX500IS camera which its configuration will be explained in the Data collection section in the experiment conditions.

As explained in the previous paragraph, eight photos per diffuser, at different mixing velocities and different types of impellers, were analyzed in each experiment. Compared in size due to the use of a millimeter rule, allowing to find out how the bubble size influences the conditions of the study and what also allowed to find out which diffuser provided the smallest, most suitable and least convenient bubble size.

Around 800 images were analyzed in the final stage, due to the evolution of the study, but only 1 of 8 pictures for each diffuser was chosen to be shown in the final results.

An overview of all laboratory variables in the experiments for one tank can be found in APPENDIX C.

3.2 Data collection

In this thesis, in order to investigate the effect of the conditions of aeration and mixing using different approaches in the study case, the evolution of the development in the methodology (figure 4) needs to be explained and understood firstly.

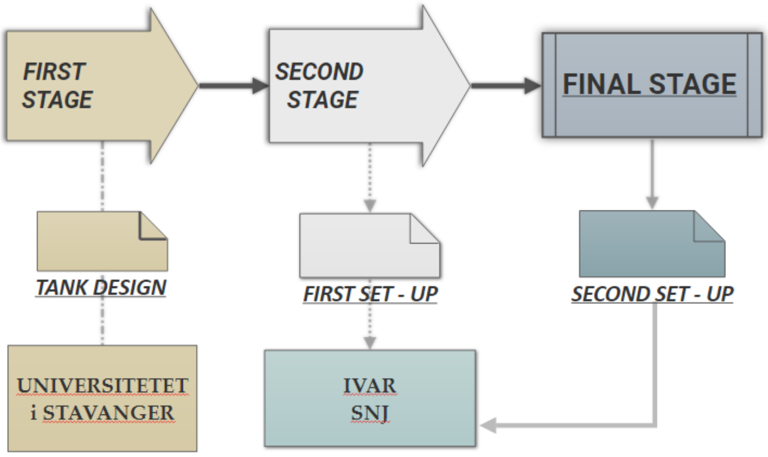

Figure 4. Development of the study case

3.2.1 FIRST STAGE (UiS)

From the beginning of January to the end of March, information was collected on theory, methodology and results and it was concluded that to obtain better results, the development of a new tank design would be optimal and for this task, various elements were considered.

In first place, the presence and number of baffles are key to avoid the swirl effect that is produced by the action of the mixer and the characteristic flow provided by the propeller (axial or radial), causing the particles in suspension to go to the bottom of the tank. As for the number refers, it is usually added from 1 to 4 baffles, with 3 and 4 being the most used (Doran, 2013).

The shape and size also affect the mixing process, so in order to test how these will contribute to the removal of TSS a low form (5-liter tank) and tall form (3-liter tank) beakers were chosen for these analysis (figure 5).

Figure 5. 5-liter and 3-liter tanks.

It was decided to opt for a model (figure 3) that reached the bottom of the tank, made of an acrilic plate sheet and following the recommended height and width ratios:

- Tank Diameter, D_T (mm): 170 mm (5-liter tank) and 135 mm (3-liter tank).
- Impeller diameter range, D_i : $\frac{1}{2} \sim \frac{1}{4} \times D_T$
- Height of liquid in the tank, H_L (mm): $1 \sim 1.25 \times D_T$
- Clearance, C_i: $\frac{1}{2} \sim \frac{1}{6} \times D_T$

Sampling

The first design allowed a capacity of five liters, meanwhile the second allowed a capacity of three liters. The conditions carried out in the experiment were the same as (Tjessem), since in turn, the best concentration to treat the wastewater was being investigated simultaneously, in order to be able to compare results of the aeration effect under the same conditions of experimentation..

In addition, in , it was observed that during her process of sample collection, which was done with a syringe, it contributed to the absorption of large flocs, influencing the subsequent analysis of TSS. Therefore, it was decided that the sampling point would become part of the tank, located at a distance of 2.5 cm, which also left space for the diffuser and mixer to perform their tasks.

Testing

Several tests were carried out first at the University of Stavanger (UiS), in which the wastewater was collected in a 10-liter plastic drums from SNJ wastewater treatment plant and stored in the cold room at a temperature of 7 degrees Celsius for a maximum of 2 days.

For this, the first requirements established were:

- with a concentration of 3g of dry N-sep per liter of water
- the use of a cross-blade impeller
- a constant air flow rate of 18 l/h
- a mixing speed of 600 rpm

The diffusers tested were: the O_2 grow diffuser and golf, cylindrical and trapezoid stone bubble diffusers.

Due to the incorporation of new impellers, new air flow rates, new diffusers and the need to use a greater amount of wastewater for the tests, it was stipulated that the study would be carried out in the SNJ wastewater treatment plant instead of UiS.

3.2.2 SECOND STAGE (SNJ wastewater treatment plant)

Due to the progressive evolution of the study during the analysis in the treatment plant and the definitive determination of the N-Sep concentration, the following changes were made:

Concentration of N-Sep

After the simultaneous experiments carried out by (Tjessem) it was concluded that the best results in terms of elimination of TSS with mixing by the cross-blade impeller and without aeration corresponded to 2.75g of dry N-Sep per liter of water. Therefore, this concentration was used in all tests performed at SNJ.

Impellers

After setting the concentration, it was decided to test other types of impellers to determine their effectiveness, so two more impellers were added: Pitched-blade Impeller and Ringed Propeller.

Both provided different mixing flux and whose dimensions fitted perfectly to the design of the reactors (Table 3), without affecting in this way the effectiveness of mixing in the process.

Table 3

Characteristics and impeller parameters included in the model tanks design

Tank	D_T (mm)	D_i (mm)	Adjust better	Impeller

5- liter Low form	170	***57*** 43 85	*PR 30* *(**58** mm Ø Impeller)*	
3-liter Tall form	135	***45*** 34 68	*PR 32* *(**45** mm Ø Impeller)*	

Note. (Heidolph, 2017)Where: D_T= Tank diameter; D_i= Impeller diameter range (Heidolph, 2017)

Diffusers and air flow

After the analysis of the diffusers it was found that the round stone diffuser provided the largest bubble size in comparison with the rest of the diffusers, eliminating the TSS to a lesser extent, so Micron Oxygen Stone diffuser was incorporated instead.

Unfortunately, this type of diffuser requires much higher air flows than the other diffusers, so the experiments performed with this diffuser at 18, 20, 24 and 32 l/h did not show the maximum power, so it was decided to change the type of compressor (Eheim Air Compressor 400 $l/h \approx 6{,}6\ l/min$) to a more powerful one (Meec Tools 200-070 Compressor), which was used in the final stage.

Same mixing velocity (600 rpm) was performed during this phase.

3.2.3 FINAL STAGE (SNJ treatment plant)

In the final stage, the same concentration and the same impellers were maintained to be able to compare them later with an increase in air flow.

Regarding the diffusers, it was agreed to introduce a new type of Micro Bubble Air diffuser with whose shape that provides microbubbles and whose design was created so that it was wound on itself in the form of a thread, thus providing a greater quantity of bubbles.

Focusing on the air flow, as mentioned above, the new compressor operated at a continuous flow of 26 l/min. In addition, three new speeds were available: 800, 1200 and 1600 rpm, in order to check whether the increase in speed improved the results obtained at 600 rpm.

And finally, it was decided to incorporate a second reactor design in which the size and shape changed. With a capacity of 3-liter and low form beaker, it was also designed following the criteria of (Doran).

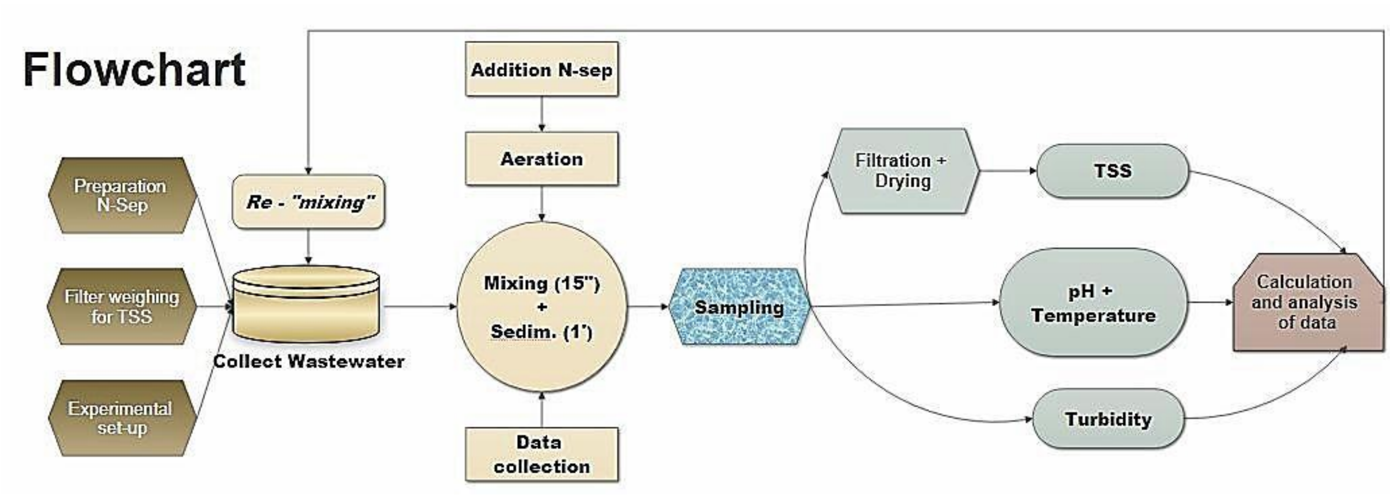

Figure 6. Final procedure flowchart.

Before collecting the wastewater, the required materials must be prepared in advance:

The concentration of additive, the arrangement of the materials (experiment set-up and vacuum filtration system), mark the sampling containers, fill in the laboratory data sheet (APPENDIX D) with the basic information and the weighing (Sartorius Basic B120S Analytical Balance) of the filters (GF/C Glass Microfiber Filter, 47 mm, 1.2 µm) for their subsequent filtration.

After that, an approximate amount of about 190 liters is collected at the SNJ treatment plant. The water was always collected at the same point of the influent: after the screening process (pre-treatment) in charge of removing large solids such as plastics, napkins, stones… Without affecting the particles and solids in suspension.

The water was collected manually with the help of a 10 liter bucket and stored in a 200 liter capacity barrel. In addition, it was always collected between 9 - 11 o'clock in the morning, allowing us to have the same quality of water throughout the experiment. This factor is very important, since the quality of the wastewater varies from one hour to another and this affects the results when performing the tests.

Once collected and taken to the laboratory, the wastewater used in the second 3-liter tank is refrigerated, in order to avoid any alteration that may affect the properties of the wastewater treatment.

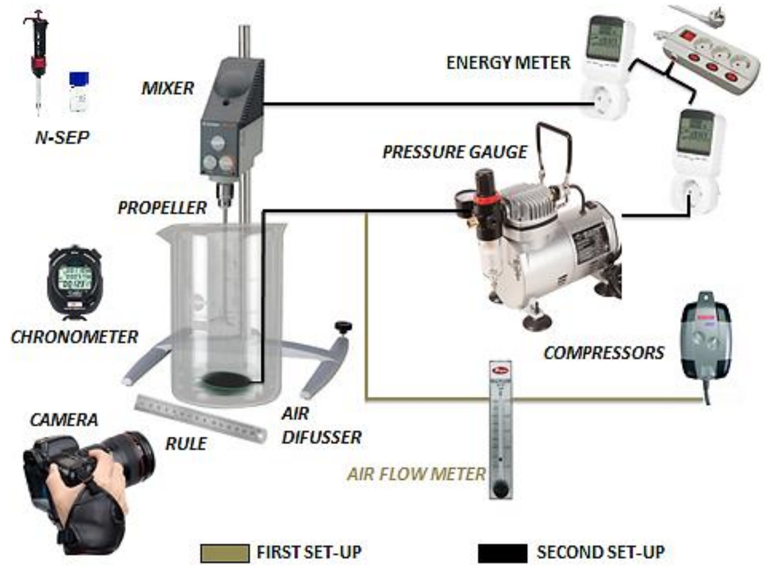

Figure 7. Experimental set-up

In the laboratory and before the procedure, the configuration (Figure 7) has to consider the following:

- The amount of polymer to be tested must be prepared, in this case a concentration of using a solution of 2.75g of dry N-Sep per liter of water, whose efficiency has been tested in parallel (Tjessem, 2018), resulting to be the best concentration. To do this, a Thermo Scientific ™ Finnpipette ™ F2 (1-10 ml) was used with 8 ml N-Sep to 4 liter wastewater for the 5-liter reactor and 4 ml N-Sep to 2 liter wastewater for the 3-liter reactor.

- The electric power meters (EMG-1 model) must be connected to the power strip, in which the mixer and the compressor (Meec Tools 200-070 Compressor) will be connected in order to measure the power and power factor of both, which will allow us to monitor the progress of the study.

- The impeller to be tested must be adjusted in the mixer (Hei-TORQUE precision 100) and always placed at a height of ≈ 16 cm, thus guaranteeing a mixture at the same distance in all processes.

- The mixing speed to be examined is previously fixed, to avoid possible confusion with the speeds used throughout the analysis.

- The camera (CANON PowerShot SX500 IS) serves the following configuration: manual mode, with adjustment of 17 cm distance from the millimeter rule to the lens, capture of eight images per second and tripod support, which allows the capture of images always at the same distance.

- Chronometer at zero.

- Each diffuser is coupled to an air exhaust hose. Which is connected to the compressor and adhered to the reactor with industrial adhesive tape, which prevents the impact of the diffuser with the impeller.

Once everything is arranged and organized, we proceed to 1 minute of vigorous mixing of the raw wastewater in the 200 liters drum, to activate the recirculation in the water of the solids in suspension and avoid sedimentation. After that, 4 of 5 liters of water collected, are added to the tank (for efficiency reasons in the design).

Showing up next the process of rapid mixing (15 '') and sedimentation (1 '):

1. Start at the same time aeration and mixing.
2. Right after and simultaneously; we add the polymer and start the chronometer.
3. Start capturing images.
4. Check the compressor pressure and note the power and power factor of the impeller.
5. Turn off the power strip at 15” and let it settle for 1 minute.
6. We collect the samples: 1 glass beaker of 250 ml for filtration, 1 sampler wide mouth bottle of 50 ml to measure the turbidity and finally 1 glass beaker of 150 ml to measure pH and temperature.

To measure TSS, the procedure of filtering and drying follows the Standard Methods (2005) with a filtering volume sample of 200 ml.

The pHenomenal® pH 1100L was used to measure both pH and temperature as a control measure of the experiment.

And finally, Spectroquant ® Spectrophotometer Prove 300 determined the turbidity of the wastewater following the procedure of (Merck, 2017)

For the 5-liter tank, this experiment tests the 5 types of diffusers and for each one the procedure is repeated three times changing the mixing speed, without forgetting the blank sample that indicates the initial quality of the water without adding polymer and the same happens with the 3-liter tank.

3.3 Data analysis

Due to the ability of the additive to form large flocs and separate suspended solids APPENDIX A, three parameters were taken into account to determine the efficacy of the air diffusers, impellers and mixing variables: determination of total suspended solids (TSS) removal, turbidity and velocity gradient.

The TSS analysis will determine the amount of suspended solids that have reacted with the polymer and thus created larger flocs, leading to an appearance of clean water due to the agglomeration of these particles. The procedure used follows Standard Methods (2005).

$$mg\ total\ suspended\ solids/L = \frac{(A - B) \times 1000}{sample\ volume, mL}$$

Where: A = weight of filter+dried residue (mg), and
B = weight of filter (mg)

To determine the turbidity of the wastewater, the Spectroquant ® Spectrophotometer Prove 300 was used and its measurement at 550 nm provides a total range between 1 - 100 FAU (Formazin Attenuation Unit) , following the procedure of (Merck, 2017) .

When measuring turbidity, the ability of light to scatter in wastewater is analyzed, the greater the presence of suspended solids and particles, the less amount of light can pass through. (Burton et al., 2013).

Using FAU equals to NTU values, due to the fact that both are scattered ligh units. Its main difference lies in the angle of measurement, “180-degrees to the incident light for FAU and 90-degree from the incident light for NTU” (Hach, 2018) .

4.1 Effect of diffusers on particle separation

In the data analyses, we find that the diffusers that produce smaller bubbles obtain a greater elimination of particles in the wastewater in the tests carried out with air flows between 18 - 36 l/h. It was obtained that the diffuser that provided the smallest bubble size (FIGURE 8), in this case the O_2 grow diffuser, did remove more particles in the wastewater in comparison of the rest of diffusers.

Figure 8. Bubble size with O_2 grow diffuser a milimetric scale

For the crossed - blade impeller, with a total of 114 $mg\ TSS/l$ in the raw wastewater, the elimination with the O_2 diffuser had a 66% TSS removal compared to a 42% on average for the rest of the diffusers (Figure 9).

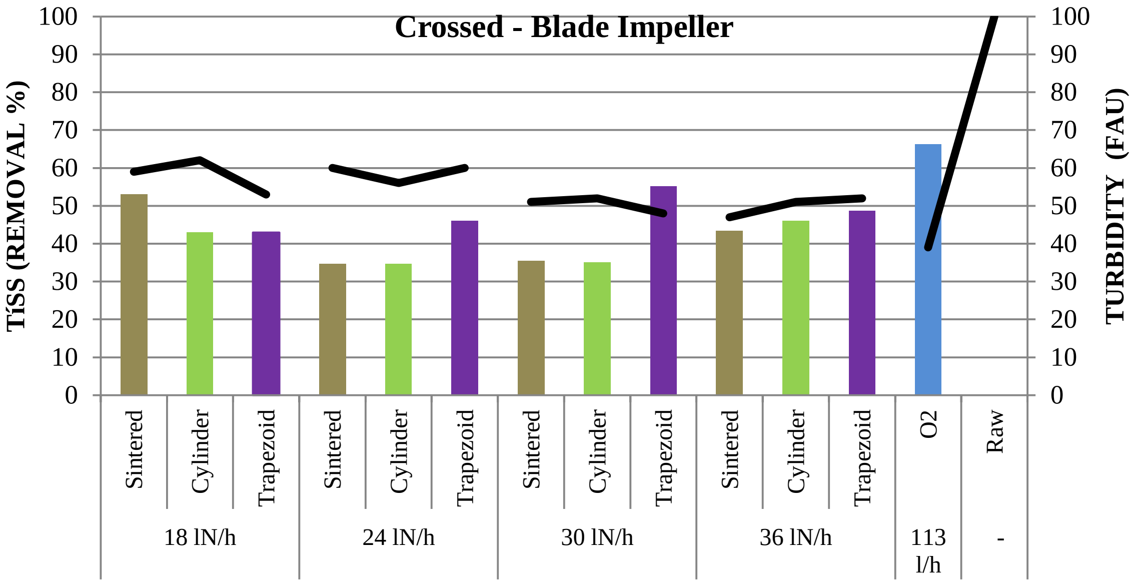

Figure 9. Different aeration flow rates tested with the crossed - blade impeller in the 5-liter tank at 600 rpm

In the case of the pitched - blade impeller, with a total of 91 $mg\,TSS/l$ present in the raw wastewater, a 67 % TSS removal with the O_2 diffuser compared to a 48% on average for the rest of the diffusers (Figure 10).

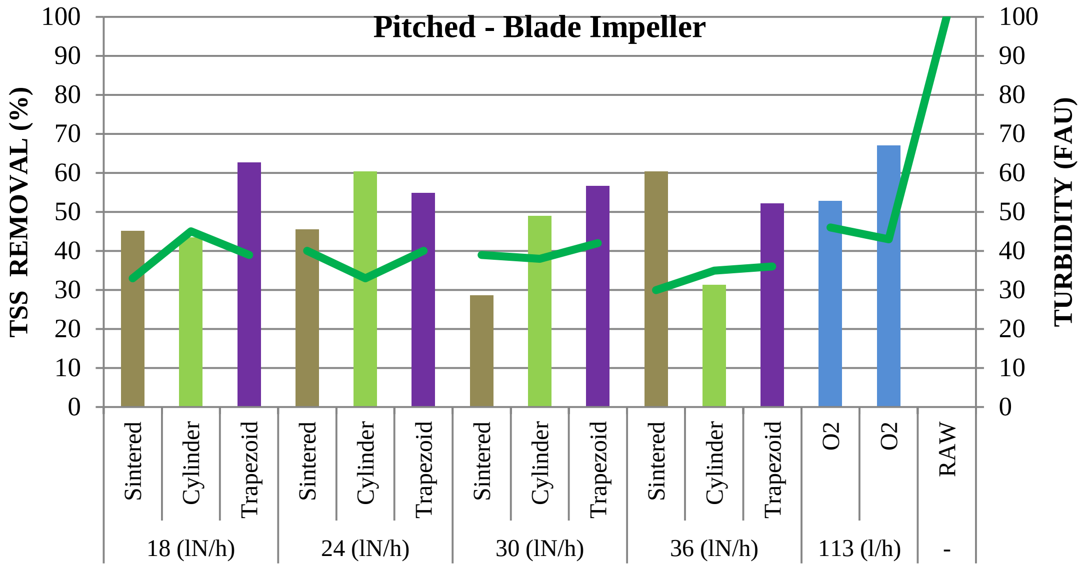

Figure 10. Different aeration flow rates tested with the pitched - blade impeller in the 5-liter tank at 600 rpm

And for the ringed propeller, with a total of 415 $mg\,TSS/l$ in the raw wastewater, the elimination with the O_2 grow diffuser had a 87% removal on average, compared to the 76% removal on average for the rest of the diffusers (Figure 11).

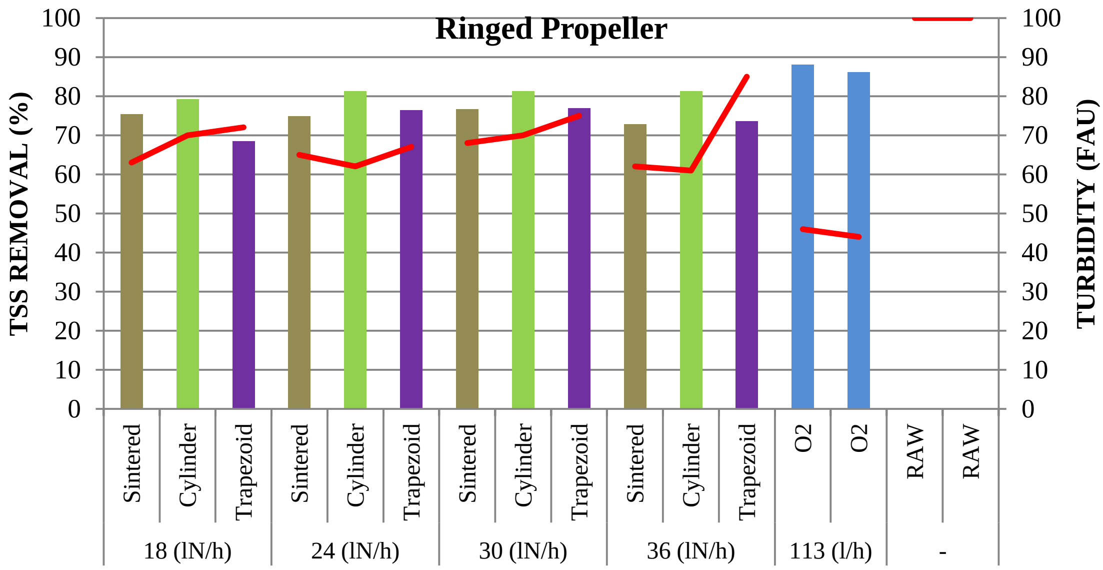

Figure 11. Different aeration rates tested with the impeller ringed propeller in the 5-leter tank at 600 rpm

The figures below (figure 12 and 13) show a summary of TSS removal percentage on the Y axis on the left and turbidity of the sample on the right. In which for five different types of diffusers, which were analyzed each with three unequal types of impeller and each impeller tested at three different mixing velocities. The first figure corresponds to the 5-liter tank desing and the second figure to the 3-liter tank.

With regard to analysing the tests carried out with an air flow between 1200 - 1330 l/h, it was obtained that the diffuser that provided the smallest bubbles was the O_2 grow diffuser too, but whose flow formation of bubbles (113 l/h) differs completely from this range of air flow.

However, it was used in the study to check its effectiveness, but in general it did not produce the best results compared to the rest of the diffusers being mostly under 80% TSS removal in the 5-liter tank (Figure 14) and on average a 88% TSS removal for the 3-liter tank, excluding the 21% TSS removal value for the Pitched-blade impeller due to in this analysis the mixer suffered a setback which affected the result. On the contrary, with this diffuser the lowest levels of elimination of TSS were obtained if we compare the general tendency of the elimination percentage of the other diffusers.

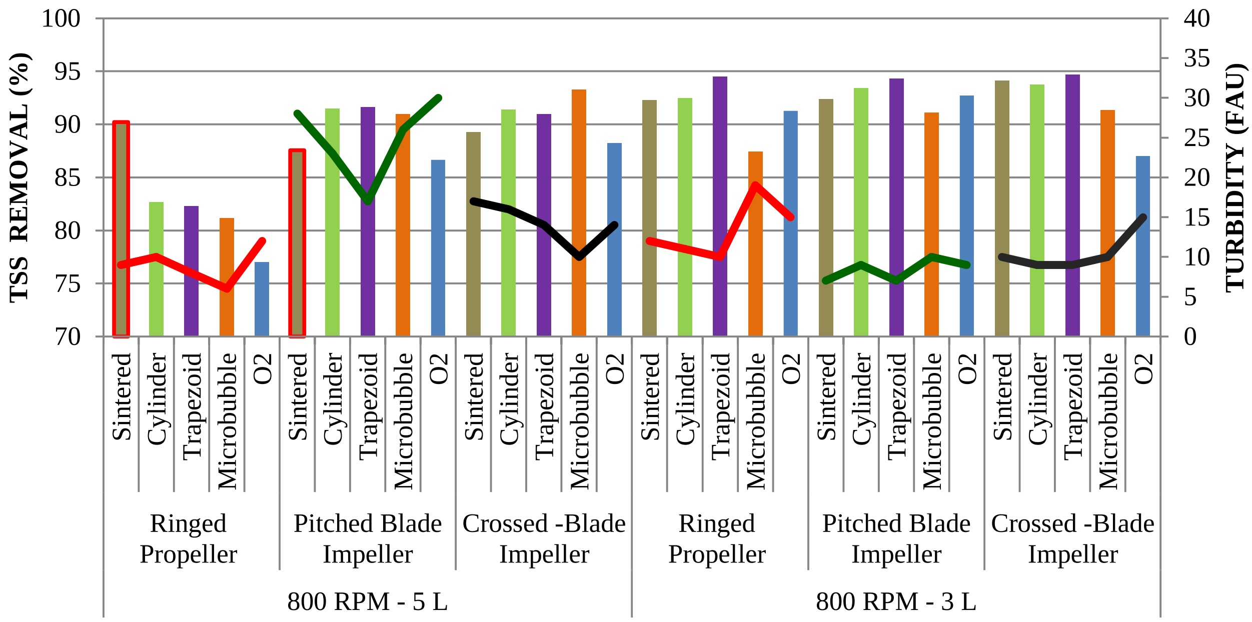

Figure 14. Different aeration rates tested with the impeller ringed propeller in the 5-leter tank at 600 rpm

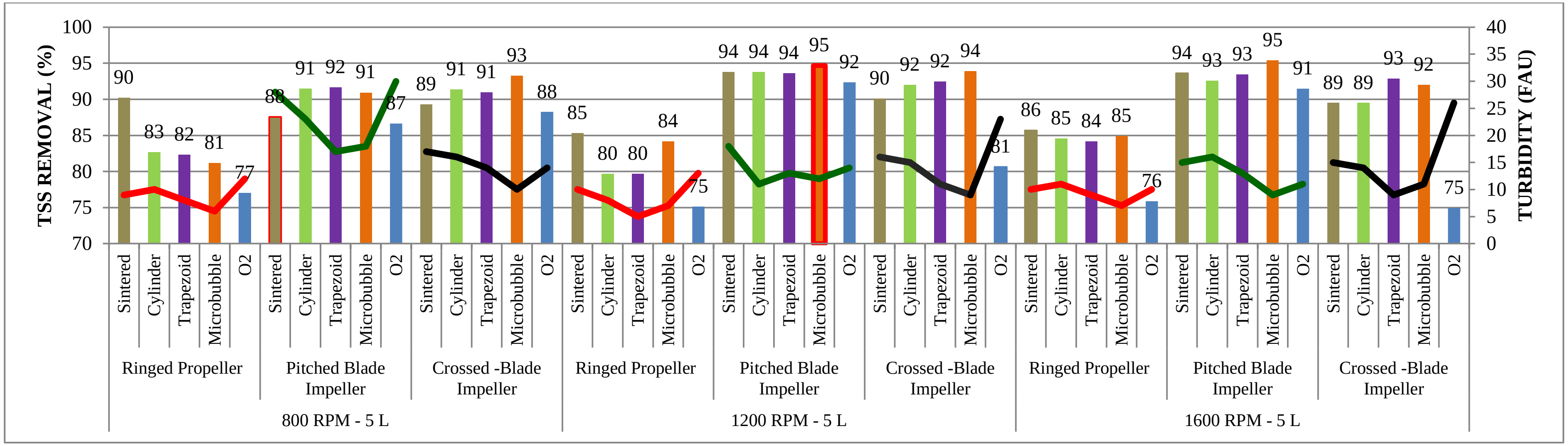

Figure 12. Summary of all the variables for the 5-liter tank test. Colors in turbidity means: red= ringed; green=pitched; black=crossed-blade impellers.

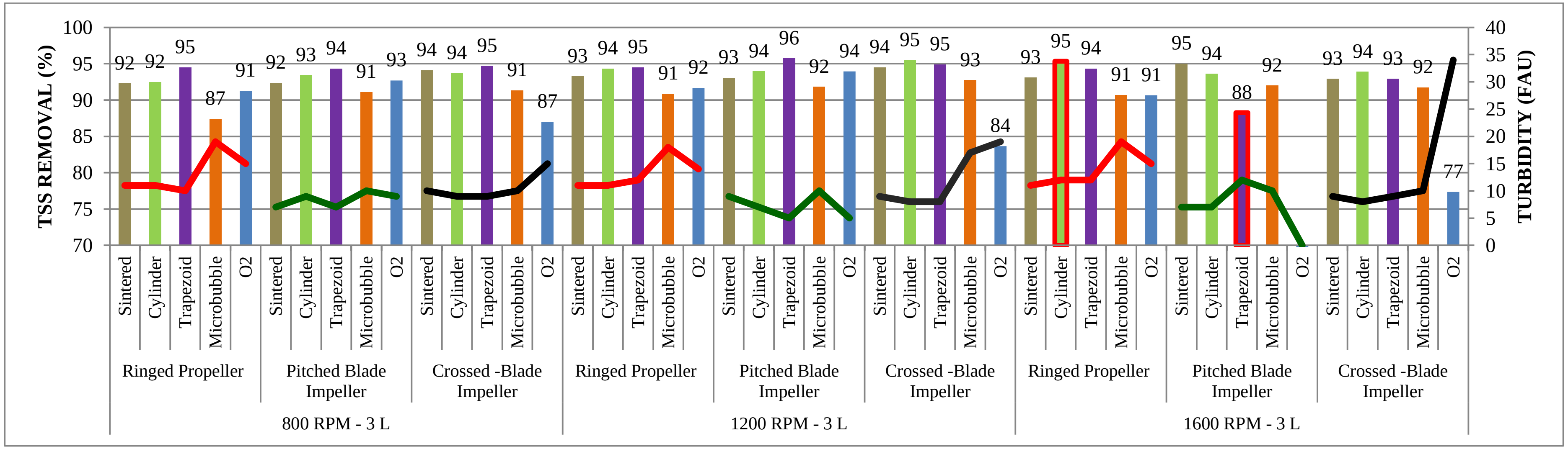

Figure 13. Summary of all the variables for the 3-liter tank test. Colors in turbidity means: red= ringed; green=pitched; black=crossed-blade impellers.

Therefore, it was decided to analyze the performance of the other diffusers; First with reference to the **sintered diffuser** (*Figure 15*), a removal range between 85 - 94% of TSS was obtained in the 5 liter tank between the 3 mixing speeds tested and a turbidity rate between 9 - 28 FAU and in contrast to the 3 liter tank. the elimination percentage rate is between 92 - 95%, with a turbidity rate of 7 – 11 and very

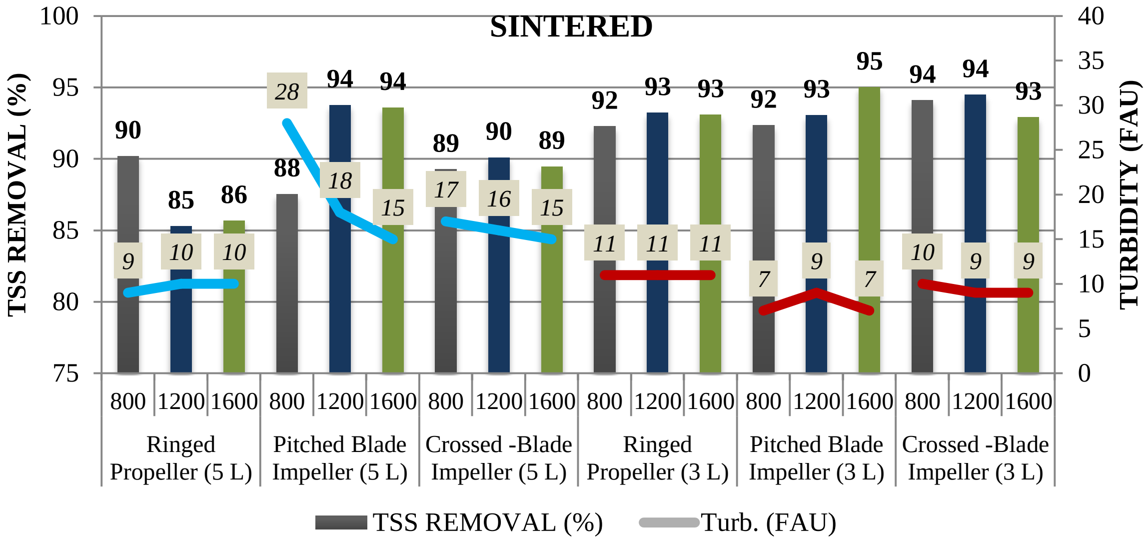

Figure 16. Results for the Sintered diffuser for both tanks.

Considering these results, the following values (table 4) has been reached for all the different diffusers (APPENDIX E):

Table 4

Summary of the results obtained with the different diffusers

	5-LITER TANK		3-LITER TANK	
	Removal TSS (%)	Turbidity (FAU)	Removal TSS (%)	Turbidity (FAU)
Sintered	85 – 94	*9 – 28*	92 – 95	*7 – 11*
Microbubble	81 – 95	*6 – 18*	87 – 93	*10 – 19*
Trapezoid	80 – 94	*5 – 17*	88 – 96	*5 – 12*
Cylindrical	80 – 94	*8 – 23*	92 – 95	*7 – 12*
O_2	75 – 92	*10 - 30*	77 – 94	*5 – 34*

Notes. Diffusers ordered from highest to lowest efficiency.

4.2 Effect of impellers on solids removal

The **ringed propeller** impeller (FIGURE 17) produces a removal range between 75 – 90 % of TSS in the 5-liter tank between the 3 mixing velocities tested and a turbidity rate between 5 - 13 FAU and in contrast to the 3-liter tank, the removal percentage rate is between 91 – 95 %, with a 10 - 12 turbidity rate, not being considered in this case the value of 19 FAU of the microbubble diffuser (previously analyzed in the section 4.1).

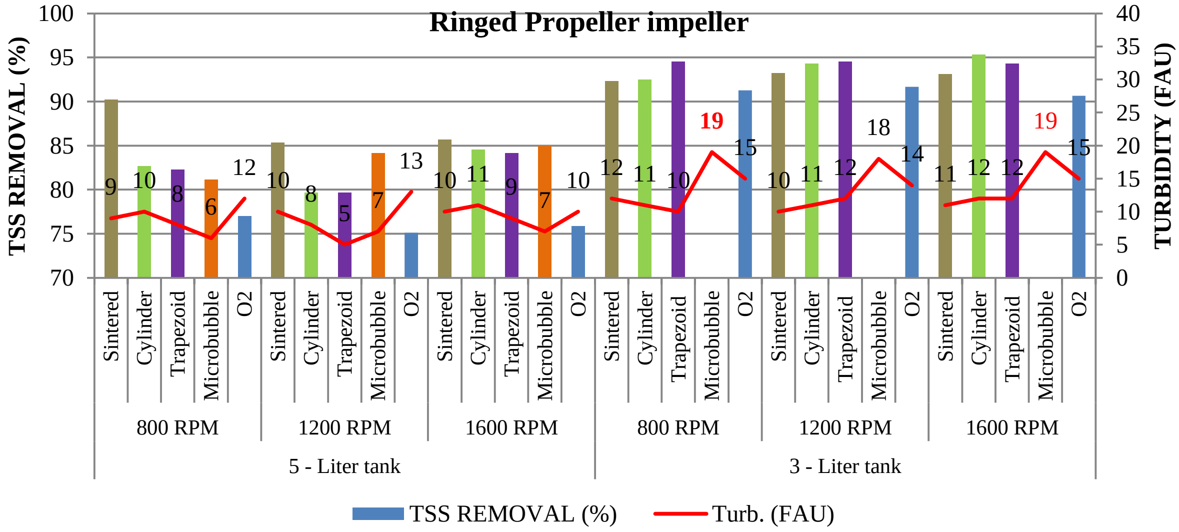

Figure 17. Ringed propeller impeller tests. Microbubble diffuser is not considered for the the 3-liter tank

The **pitched-blade** impeller (FIGURE X) produces a removal range between 87 – 95 % of TSS in the 5-liter tank between the 3 mixing velocities tested and a turbidity rate of 11 to 30 FAU and in contrast to the 3-liter tank, the removal percentage rate is between 88 – 96 %, with a 5 - 12 turbidity rate, not being considered in this case the value of 0 FAU of the O_2 grow diffuser at 1600 rpm (previously analyzed in the section 4.1).

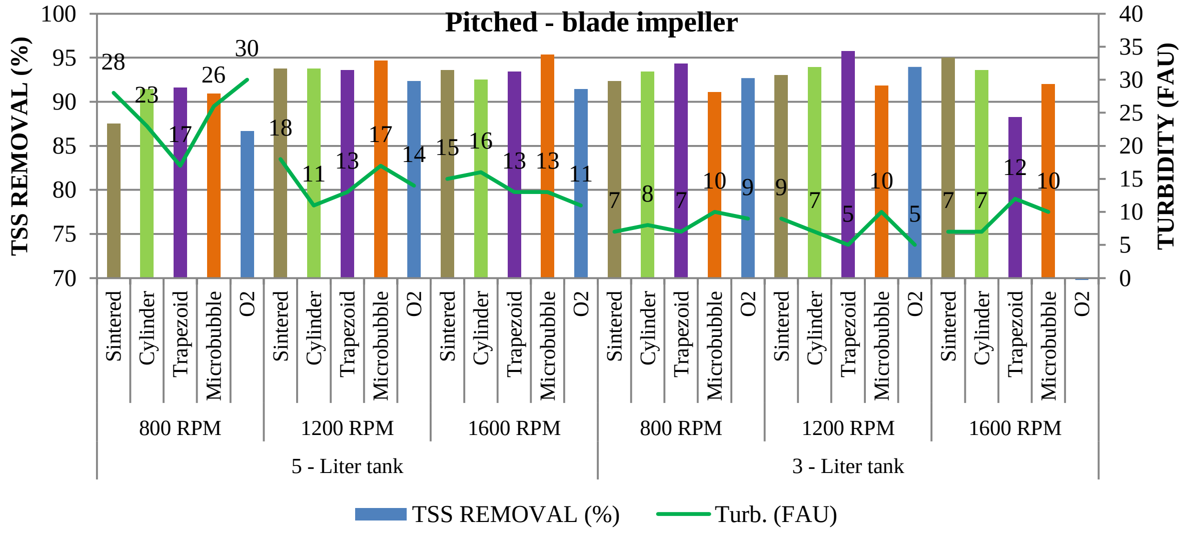

Figure 18. Pitched-blade impeller tests. Last value (21% TSS removal) in the O_2 grow diffuser is not considered for the turbidity in the 3-liter tank

The **crossed-blade** impeller (FIGURE 19) produces an elimination range between 75 – 94 % of TSS in the 5-liter tank between the 3 mixing velocities tested and a turbidity rate of 9 to 26 FAU and in contrast to the 3-liter tank, the removal percentage rate is between 77 – 95 %, with a 8 - 34 turbidity rate.

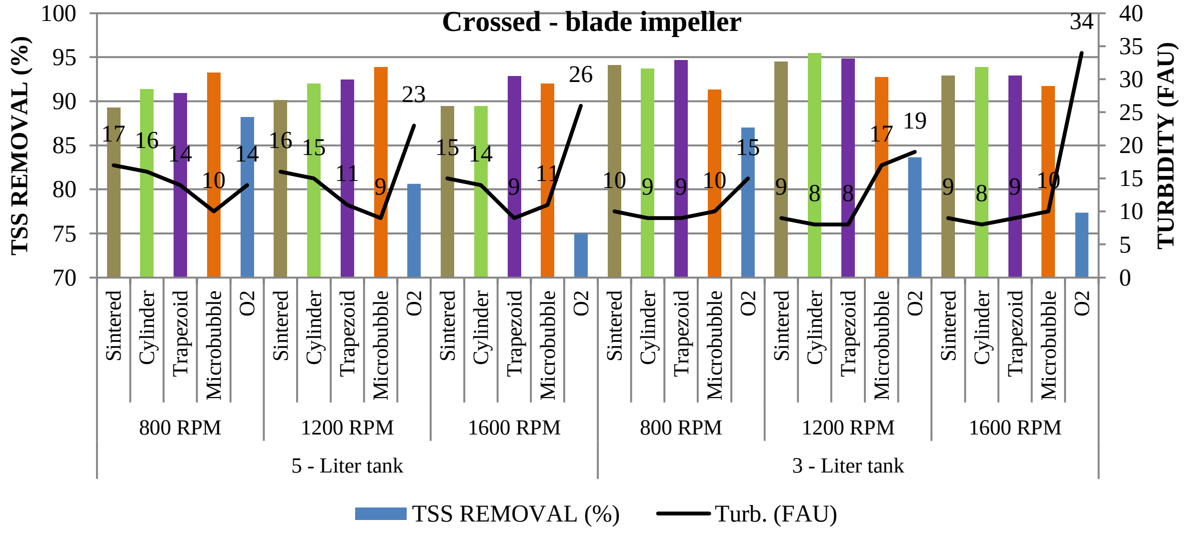

Figure 19. Crossed-blade impeller tests

4.3 Effect of mixing velocity on solids removal

In the 5-liter reactor, it can be seen (FIGURE 20) that in a generalized manner in the diffusers, a greater reduction of the particles in the wastewater can be obtained at a higher mixing velocities. Diminishing, in turn, the turbidity of the medium too.

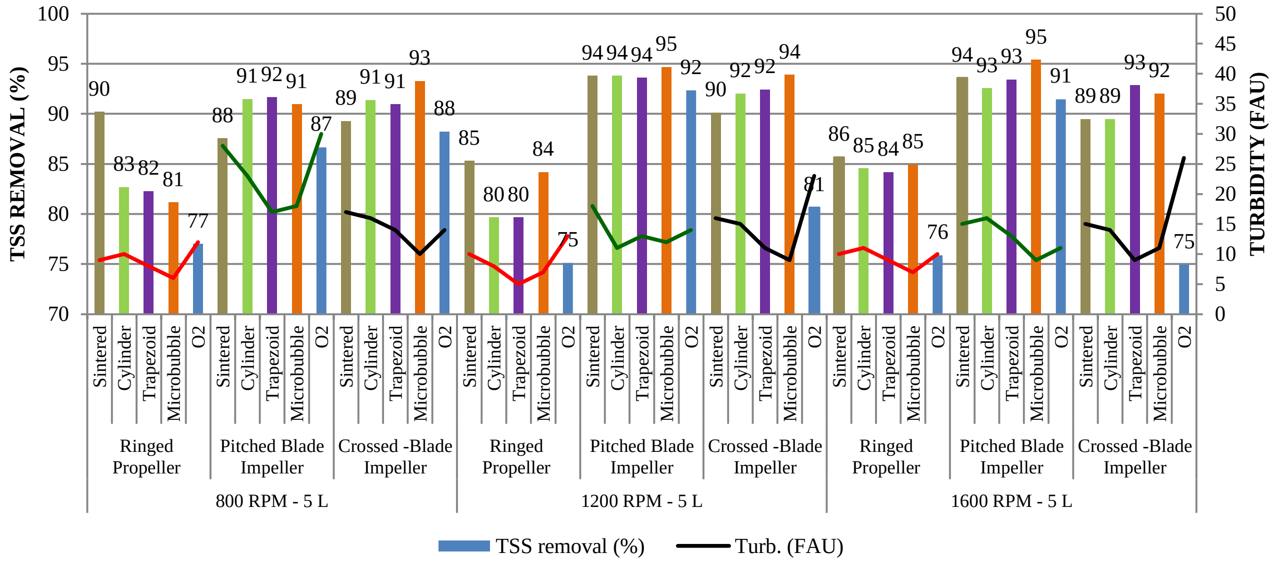

Figure 20. Overview of the three mixing velocities result in the 5-liter tank

In the 3-liter reactor, it can be seen (FIGURE 21) in a generalized manner in the mixing velocities a slightly equitable removal percentage of the particles in the wastewater finding more constant values at 1200 rpm.

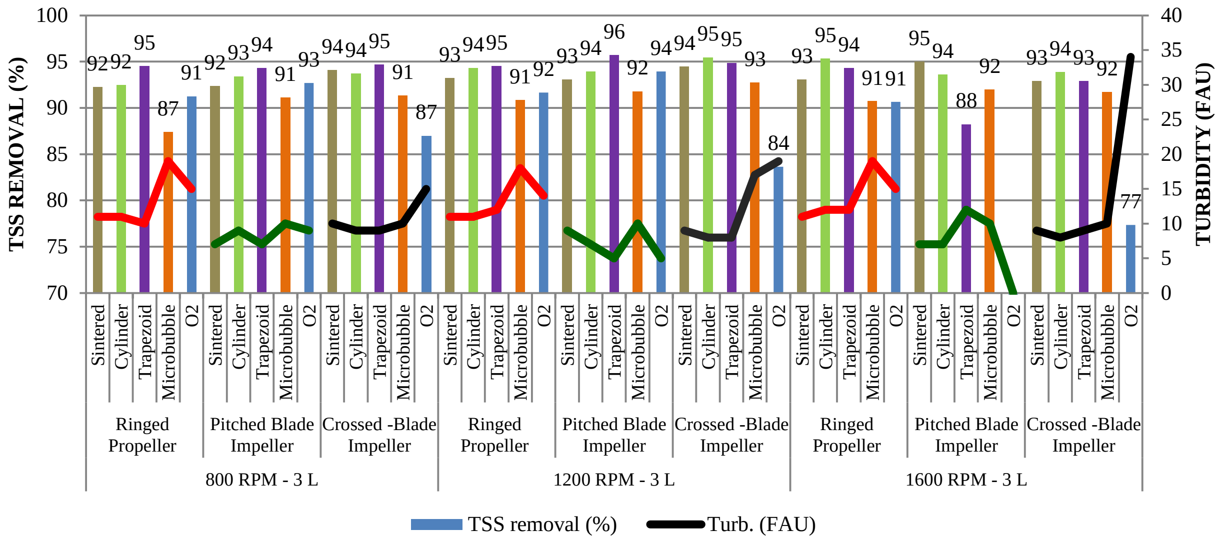

Figure 21. Overview of the three mixing velocities in the 3-liter tank

Regardless of the O_2 grow diffuser, at **1600 rpm** (FIGURE 22), the percentage removal of TSS in the 5-liter tank is between *84 - 95%* among the 3 types of impellers and a turbidity rate between 7 – 16 FAU , meanwhile for the 3-liter tank the percentage removal rate is between *88 – 95%* and a 7 – 12 FAU turbidity in this case, if we do not include the value of 19 FAU of the microbubble diffuser with the ringed propeller (previously analysed in the 4.1 and 4.2 sections).

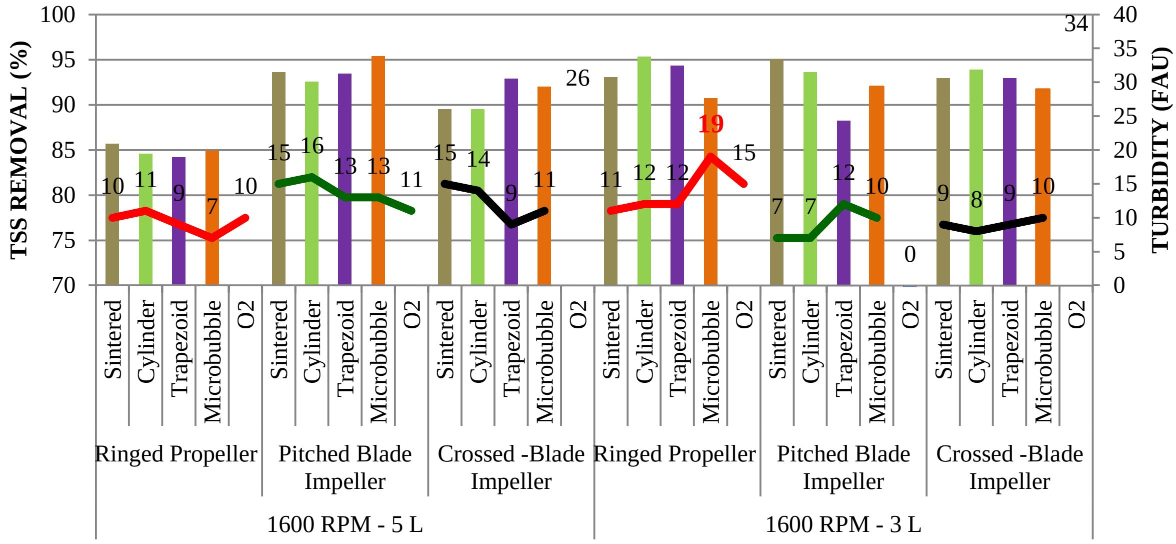

Figure 22. 1600 rpm tests where the O_2 grow diffuser is not considered and the turbidity number values are showed for both tanks

Consequently at 1200 rpm (FIGURE 23), the percentage removal of TSS in the 5-liter tank is between *80-95%* among the 3 types of impellers but not taking into consideration the O_2 grow diffuser, moreover the turbidity rate between 5 – 18 FAU , meanwhile for the 3-liter tank the percentage removal rate is between *91– 96%* and a 5 – 12 FAU turbidity in this case, if we do not include the value of 17-18 FAU of the microbubble diffusers with the ringed propeller (previously analysed in the 4.1 section).

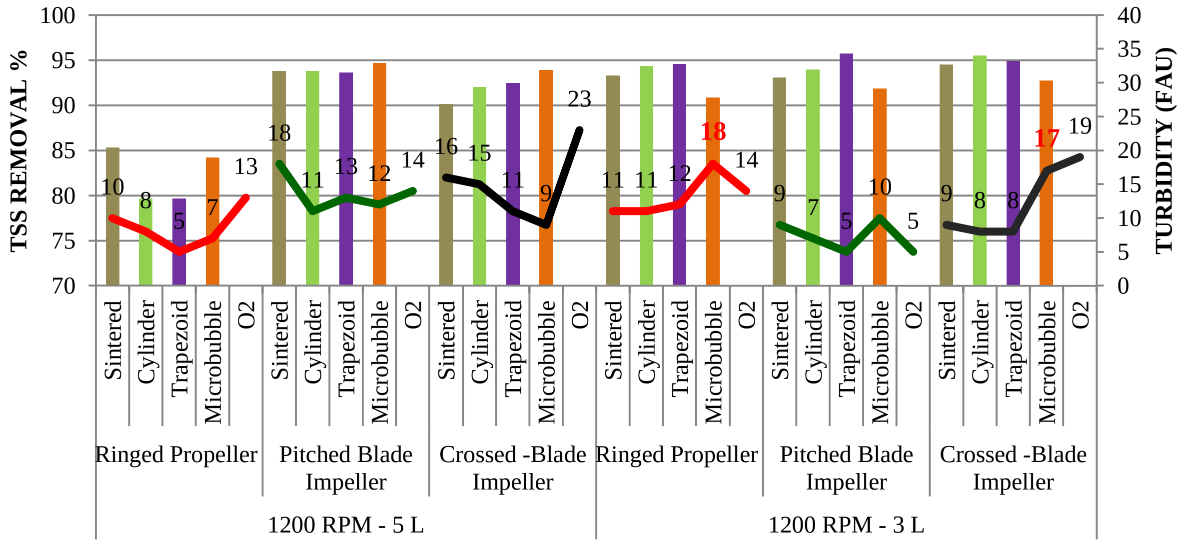

Figure 23. 1200 rpm tests where O_2 grow diffuser is not considered and the turbidity number values are showed for both tanks

While for the 800 rpm (FIGURE 24), the percentage removal of TSS in the 5-liter tank is between *0-95%* among the 3 types of mixers and a turbidity rate between 6 – 26 FAU , meanwhile for the 3-liter tank the percentage removal rate is between *91– 96%* and a 7 – 12 FAU turbidity in this case, if we do not include the value of 19 - 15 FAU of the microbubble diffusers with the ringed propeller (previously analysed in the 4.1 section).

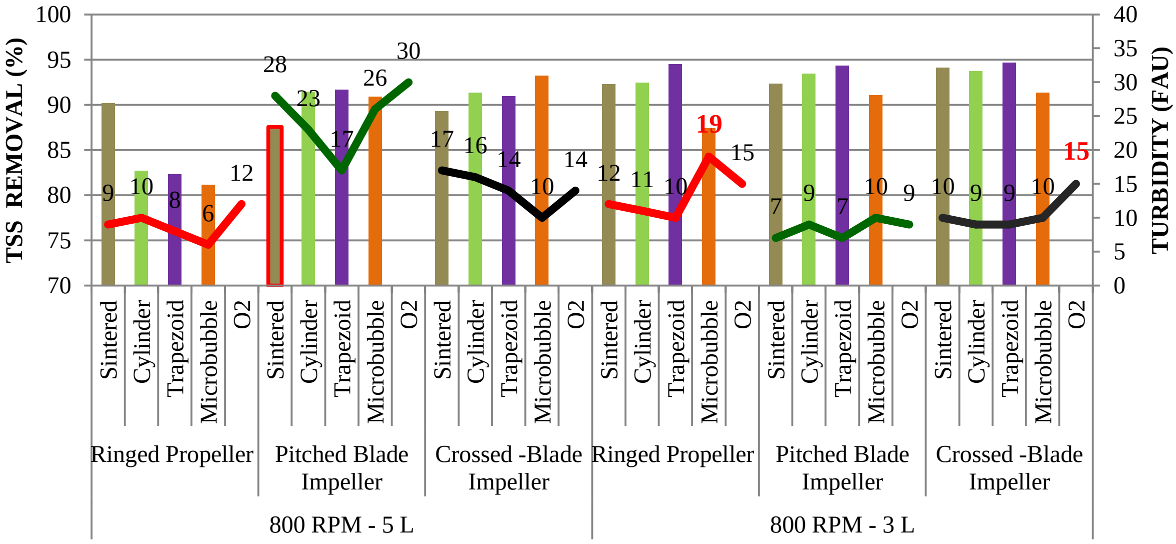

Figure 24. 800 rpm tests where O_2 grow diffuser is not considered and the turbidity number values are showed for both tanks

4.4 Solids removal response in different size and shape of reactors

Size and shape of the reactor and type of propeller, do influence the mixing conditions. In the previous sections, the influence of the suspended solids in both reactors has been explained in a general manner according to the type of diffuser, type of impeller and mixing speed and following the analysis of FIGURES 12 and 13 of the previous section, it can be observed in the tank of 5-liter a percentage of elimination comprised between 75 and 95%, with an average of 88% while in the tank of 3-liter with an average of 90% of elimination of TSS, it reaches a range comprised between 84% and 95%.
Turbidity refers to a range of 5 - 28 FAU in the 5-liter tank with an average of 12 FAU, while in the 3-liter tank with an average of 10 FAU, the range is between 5 - 19 FAU, if we exclude the last O_2 value of 34 FAU since it is an atypical data.

4.5 Error

During the experiment, an attempt was made in order to use the same wastewater for both tanks since, as mentioned above, the presence of solids and substances may vary with the passage of the day, due to greater or lesser discharges and its use in different communities. This guarantees us, the same concentration of TSS in the wastewater allowing the comparison between both tanks.

An example of this situation, was the experiment with the ringed propeller impeller. Since the experiment with the 3L tank was carried out another day and in which the presence of TSS in the wastewater was 246 $mg\ TSS/l$ compared to the 133 $mg\ TSS/l$ of the 5-liter tank, the results may vary due to higher concentration in the 3-liter tank.

Due to a mechanical problem with the inclined blade impeller and the mixer during the tests carried out with the 3-liter tank at speeds of 1200 and 1600 rpm, the influence of this fact on the results has been verified. So it would be advisable to repeat this experiment with this impeller.

Random errors may occur but they are not represented in the study.

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Chapter 5. Discussion

5.1 Effect of diffusers on particle separation

In the data analysis, we found that in relation to the effect of the diffusers in the separation of particles, it was obtained that for low air flows, the O_2 grow diffuser provided a 66% elimination of TSS being the best diffuser in this first tests. Could be mainly due to the size of bubbles that this diffuser provides (nanobubbles), since when bubbles of smaller size are formed, a larger gas surface is created that improves the flotation process (Escudero, Tavera, & Espinoza, 2013).

Regarding the increase in air flow in the final phase of the project, it has been concluded and based on the data obtained, that the best diffuser for both tanks is the sintered diffuser. Whose percentage of solids removal (TABLE 5) shows better values than the rest of diffusers in both tanks. In order of effectiveness they have been clasified as follows: the microbubble diffuser, followed by the trapezoid and cylindrical, since they have very similar values as they belonged to the same type of diffuser (air stone) but with a different shape, being from my point of view the trapezoid diffuser better than the cylindrical and finally the O_2 grow diffuser.

Table 5

Summary of the results obtained with the different diffusers

	5-LITER TANK		3-LITER TANK	
	Removal TSS (%)	Turbidity (FAU)	Removal TSS (%)	Turbidity (FAU)
Sintered	85 – 94	*9 – 28*	92 – 95	*7 – 11*
Microbubble	81 – 95	*6 – 18*	87 – 93	*10 – 19*
Trapezoid	80 – 94	*5 – 17*	88 – 96	*5 – 12*
Cylindrical	80 – 94	*8 – 23*	92 – 95	*7 – 12*
O_2	75 – 92	*10 - 30*	77 – 94	*5 – 34*

Notes. Diffusers ordered from highest to lowest efficiency.

In my opinion, better results could have been obtained in relation to the microbubble diffuser for the 3 liter tank, since the material from which this diffuser (rubber hose) comes, allowed us to give it a snail shape, rolling it on itself, covering in this way a greater surface than the rest of diffusers. This design provided a greater number of bubbles (Figure 25), but the inconvenience in this case was due to being connected with a hose that supplemented air to the diffuser and although if it fitted in size in the tank, the free space between the bottom and the impeller (clearance) could be seen affected since the hose came in contact with the impeller affecting its normal mixing flow.

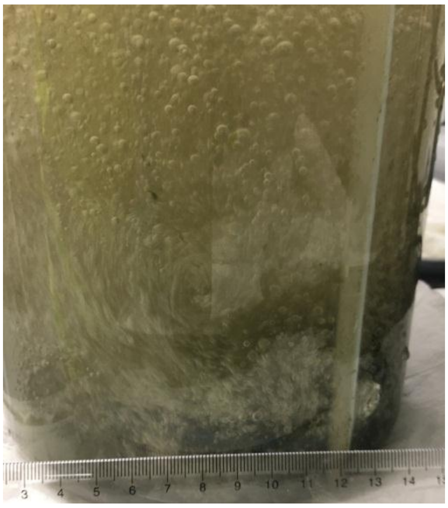

Figure 25. Ringed impeller at 1600 rpm testing the Microbbuble diffuser in a 5-liter tank

Consequently, the diffuser was arranged vertically instead of horizontally (Figure 26), affecting the design of the tank, the mixing conditions and therefore the results of the experiment.

Figure 26. Ringed impeller at 1600 rpm testing the Microbbuble diffuser in a 3-liter tank

The theory that supports these results explained that “another aspect of vessel geometry influencing mixing efficiency is the clearance C_i between the impeller and the lowest point of the tank floor FIGURE 3 . This clearance affects solids suspension, gas bubble dispersion, and hydrodynamic stability” (Doran, 2013) and in this case this requirement has been broken leading to not so effective mixing results and conditions as high shear was formed and the solids did not have the proper environment to mix and react with the additive.

In addition, we conclude that one reason for a greater elimination of particles with the ringed propeller than the other impellers, may be due to the fact that the N-Sep additive works better at high concentrations of TSS than at low concentrations in the first air flows rates (18 – 36 l/h) and secondly, this test was carried out last, after previously studying the other two impellers, so that lower error capacity and greater speed and agility in the process, are factors that favor obtaining better results.

5.2 Effect of impellers in solid removal

At the beginning of the study, the predictions made in the efficiency design of the tank (Figure 3) in relation to the impellers and the results compiled from TABLE 6, have been able to demonstrate that for the 5-liter tank, the pitched blade impeller was the impeller that best suited the characteristics and dimensions of the tank, providing the best results of particle removal reaching levels up to 95% and a minimum of 87%.

Table 6

Summary of the results depending on the impellers type in the 5-liter tank

	RINGED PROPELLER	**PITCHED-BLADE**	**CROSSED-BLADE**
Removal TSS (%)	75 - 90	**87 - 95**	75 - 94
Turbidity (FAU)	5 - 13	11 – 30	9 – 26

With reference to the 3 liter tank, it has been observed that excluding the microbubble diffuser for not complying with the design standards and therefore, as can be seen in table 7, it produces the lowest results in the removal of solids, it is obtained a range of 91 - 95%, thus fulfilling the prediction made.

Table 7

Summary of the results depending on the impellers type in the 3-liter tank

	RINGED PROPELLER	PITCHED-BLADE	CROSSED-BLADE
Removal TSS (%)	**91 - 95**	88 – 96	77 – 95
Turbidity (FAU)	10 - 12	5 - 12	8 - 34

In addition, the performance of the rest of the impellers in the 3-liter tank has been analyzed, to corroborate the statement and despite excluding the microbubble diffuser, this fact did not modify their percentage removal range.

On the other hand it has also been observed that with the O_2 diffuser, which provided the best removal results at low air flows rates, with the ringed propeller impeller and a constant air flow of 20 – 23 $l\ /\ min$ the best results have been obtained compared to the rest of the impellers and tests. Removal rates of 91 – 92 % has been reached (table 7), comparing the 77 – 87% TSS removal with the crossed blade impeller which as it was predicted was the impeller that worked with less efficiency.

The first test that was carried out in the final phase was with the ringed propeller impeller. This may have led to better removal at 800 rpm with the first diffusers than the rest of the propellers, due to the lack of practice and longer reaction times with the new methodology, but it has been seen clearly an increasing in the evolution of the removal efficiency as the velocity had risen (FIGURE 11).

It is possible that the best results have been obtained with the 3-liter tank and the ringed propeller because this impeller provides an axial flow, which improves the formation of vertical currents in the tank (Doran). This tank, having a diameter of less width than the other desing, is characterized by its elongated shape, which together with the aforementioned and whose design is limited to the desired proportions of efficiency, have been positive factors in the analysis obtained. Not forgetting to mention, the flotation process and the operation of the additive as complementary qualities.

Regarding the design of the pitched-blade impeller whose dimensions were certainly suitable for both designs, it has been possible to verify that the removal percentage of TSS obtained similar values for both tanks, but special mention has the range at 1200 rpm so it can be used if we want to compare more variables in future experiments between both tanks.

5.3 Effect of mixing velocity on solids removal

Considering the results for the velocity mixing table 8 we can observed that with relation the 5-Liter tank the best mixing velocity was at 1600 rpm where we found a 84 – 95 % of TSS removal and lower turbidity values.

Table 8

Summary of the results in velocity mixing in the 5-Liter tank

	800 RPM	**1200 RPM**	**1600 RPM**
Removal TSS (%)	81 – 93	80 – 95	**84 – 95**
Turbidity (FAU)	*6 – 28*	***5 – 18***	*7 – 15*

As shown in Table 9, for the 3-Liter tank better values were achieved at 1200 rpm with a 91 – 96 % TSS removal and a 5 – 12 FAU in turbidity measurements.

Table 9

Summary of the results in velocity mixing in the 3-Liter tank

	800 RPM	**1200 RPM**	**1600 RPM**
Removal TSS (%)	87 – 95	**91 – 96**	88 – 95
Turbidity (FAU)	*7 – 12*	***5 – 12***	*7 – 12*

When the air flow increases, the properties that determine the diameter of the bubbles will depend on the conditions and interactions with the medium and the additive, therefore increasing the mixing speed in the 5-liter tank taking into account the reactor design, this produces an improvement in the mixing conditions, allowing the particles to remain in suspension for a longer time (Painmanakul et al., 2010).

The same happens with the 3 liter tank but with the difference in that its diameter is smaller, with smaller volumes. The vigorous mixture in this tank together with the rapid action of the additive, generated quantities of foam causing the opposite effect at 1600 rpm, with 1200 rpm being the best mixing speed in this case.

5.4 Solids removal response in different size and shape of reactors

In this part, it can be noted despite the range of 75 – 95 % of TSS removal being a good result comparing with the first tests performed, which was about 66 – 67 % TSS removal in the 5-liter tank. The achieved values in the 3-liter tank supposed an important change from 75% to 84%, being this tank reactor much more efficient in long terms. The justification for these results can be explained in view of longer contact times between the bubbles and the fluid can be reached as the elongated form in the 3-liter tank facilitated this interaction when aeration needed (Doran).

There are some general aspects that I could observed during the investigation process that I would like to point:

During the development of this experiment, it has been valued the fact of being able to include different materials that went on the market as new components of innovation in the area, being a clear example the new matter designed for diffusers; resulting in the easy adaptation of the experimentation process, to these brand-new components.

In second place, the fact of starting this project from scratch, without much literature with which to compare previous experiments and results, since the use of the additive is partially new in this type of research, favored the project to develop little by little and with frequent trial and error tests.

For future experiments, I propose that NTU (Nephelometric Turbidity Unit) should be used instead of FAU as a measure unit of turbidity, since it is currently more accepted and there are studies that relate it to the removal of total solids in suspension in the second effluent (Burton et al., 2013).

Chapter 6. Conclusion

We therefore conclude that the O_2 grow diffuser provides the smallest bubbles based on the tests carried out during the first phase, but with a view to the future it would not be beneficial since its gas flow is constant and can not be modified and its optimum functioning capacity is limited between 2 to 3 hours per day (Oxygen Research Group, 2018).

It was founded that the Micron Sintered SS Oxygen Stone has the best results for the two proposed tested tanks with a percentage removal of TSS between 85 – 94 % for the 5- Liter tank and 92 – 95% for the 3-liter tank at a flow rate of 20 – 23 l / min with a buble pore size of 2 µm.

As the removal of 81 – 95 % of TSS with low turbidity values of 6 – 18 FAU suggests, the microbubble diffuser obtained the second best results regarding the 5-liter tank. Meanwhile, in order to investigate and compare the evolution in the results for the 3-Liter tank due to average removal range (87 – 93 % TSS) compared with the rest of the diffusers, a new model design of smaller size or shape could be proposed to improve the performance of the diffuser.

The performance of the pitched – blade impeller suits the requirements for both tanks, making it more suitable in future experiments. Another fact to point is that avoiding the mechanical problems at the end of the tests with this impeller, at a 1200 rpm a removal percentage of TSS range from 92 – 96 % was reached with very low values of turbidity and a 92 – 95 % removal of TSS for the 5 – liter tank with a little higher turbidity values than the others.

From the results it was observed that a higher mixing velocities, the better removal of total suspended solids was achieved, regardless of the O_2 grow diffuser, at 1600 rpm the percentage removal in the 5-liter tank is between 84 - 95% meanwhile for the 3-Liter tank better values were achieved at 1200 rpm with a 91 – 96 % TSS removal.

The shape and size of the reactor clearly influenced the way of how particles are distributed, the longer and elongated the tank, the more recirculation takes place in the mixing process and longer contact times between the bubble and the liquid occur, consequently, better percentages of TSS removal were obtained with the 3-liter tank (84 - 95% TSS removal) than the 5-liter (75 – 95 % of TSS removal).

It has been demonstrated that the design of the experimentation tank plays an important role in the results, when mixing and aeration act together, being in this case the 3-liter tank with a speed of 1200 RPM at a concentration of 2.75 g of N-sep per liter of water, with a pitched-blade impeller being the best conditions in all the experimentation processes.

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Appendix

A. N-Sep Additives
B. Types of impellers
C. Experiments summary
D. Data sheet laboratory
E. Diffusers summary data

N-Sep additives

Considerable cost savings - increased efficiency

The N-Sep additives are used both in the industrial and municipal wastewater treatment plants.

The use of N-Sep in the coagulation and flocculation stages increases the degree of separation of the suspended solids.

Norwegian Technology has developed a new simple method to advance the treatment of wastewater. The adoption of N-Sep improves the solids removal efficiency in the wastewater treatment plants, both industrial and municipal. N-Sep additives have short reaction time, handle large variations in the wastewater chemical characteristics and can easily be used in the existing treatment plants without the need for modifications. The efficiency of the separation of the suspended solids is above 90%.


IVAR – Grødaland treatment plant – Utilizing air flotation in combination with N-Sep 438. Photo: IVAR

Cost savings with N-Sep

GIVE NEW LIFE TO OLD EQUIPMENT

Mixing N-Sep to wastewater improves the separation of the suspended solids, so that the plant meets emission requirements without the need for major modifications, thus extending the life of the facilities.

LOWER INVESTMENTS IN NEW FACILITIES

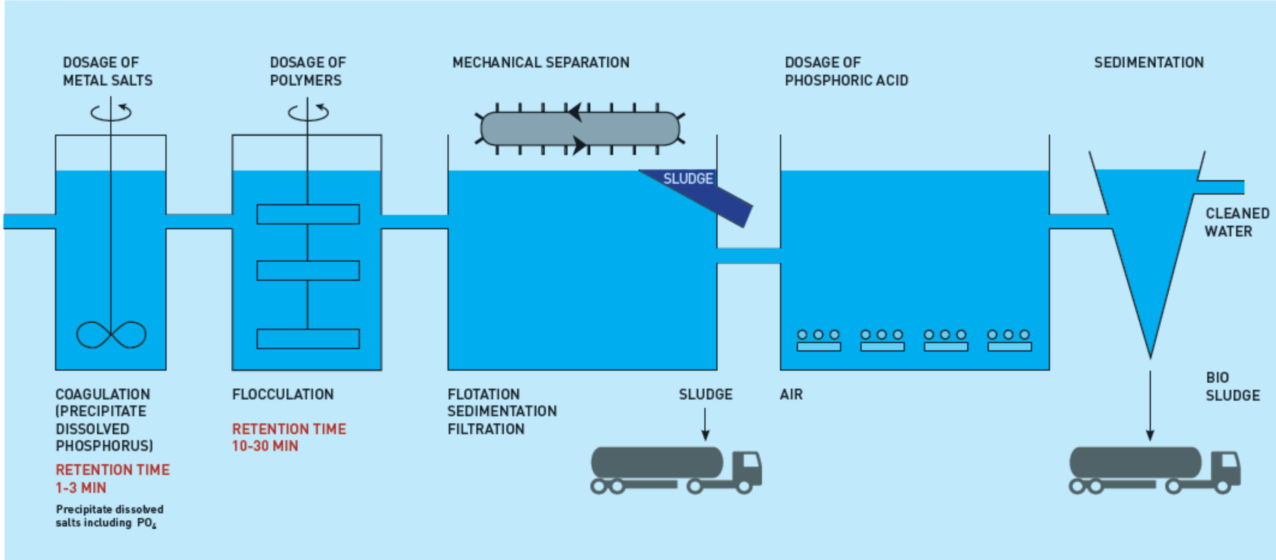
Conventional treatment using metal salts in combination with polymers requires in mixing and time for retention. Quick stirring and retention time of 1-3 min. are common procedures in the coagulation with metal salts. Flocculation occurs during slow stirring with typical retention time of 10-30 minutes.

With N-Sep both coagulation and flocculation happen in the duct, contact time of 5 to 10 seconds is enough to separate the suspended solids.

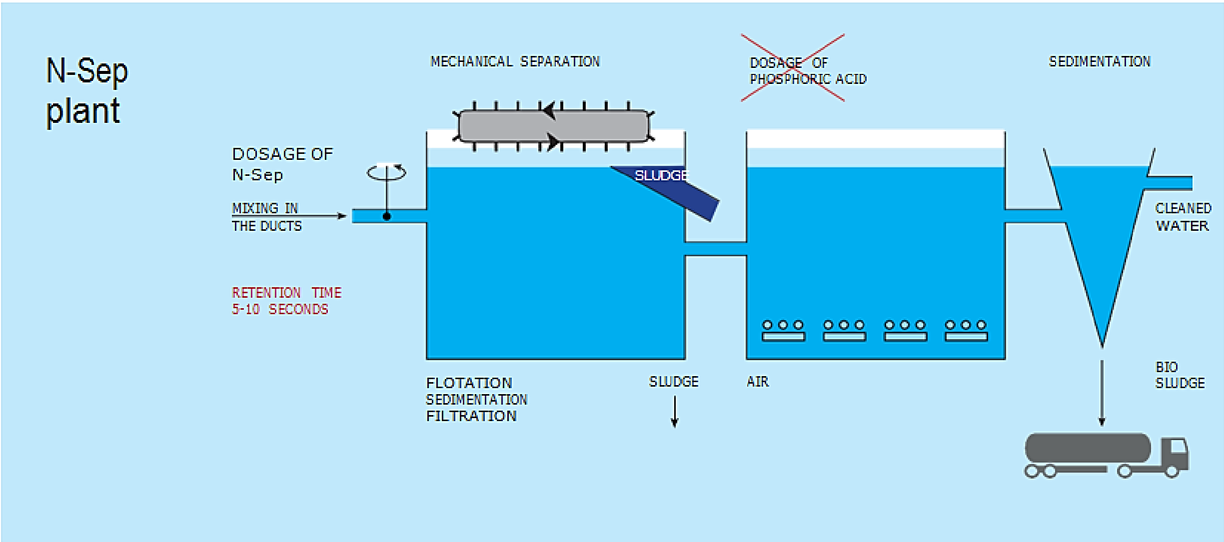
SEPARATION OF FLOCCULANTS

N-Sep generates large and stable flocs that can withstand high shear forces, and can therefore be utilized together with conventional filter types adopted in the municipal treatment plants. Experience shows increased water flow through the filters in addition to increased separation of the suspended solids. Flotation characteristics allow significantly higher surface load, both by the induced air and dissolved air flotation.

CONVENTIONAL TREATMENT



TREATMENT WITH N-SEP



N-Sep

- Works efficiently in the pH range 3-11, so that acids and bases are neutralized,
- Does not separate dissolved PO_4,
- Reduced sludge production results in less logistic costs,
- Reduced plant size without the need for coagulation and flocculation pools,
- Produced sludge has less organic fraction, is therefore excellent for biogas production,
- N-Sep does not influence the pH of the water.

Norwegian Technology offers customized solutions for the treatment of wastewater. Research and development are carried out in close cooperation with the Customer.

JAR TESTING

The jar test is intended to simulate the coagulation/flocculation process in a water treatment plant. The results that it produces are used to help optimize the performance of the plant. Norwegian Technology can run the jar testing of your wastewater and provide you with all the data and information about the most advisable treatment solution for your project.

Contact us for more information:
www.norwegiantech.com

APPENDIX B. TYPES OF IMPELLERS

Table 10

Classification and characteristics of the impellers

	Impeller	**Flow**	**Type**	**Ø Impeller (mm)**		**Length (mm)**	**Ø shaft (mm)**	**Maximum speed (rpm)**	**3L Tall form**	**5L Low form**
				Length (mm)	**Width (mm)**					
	Propeller-Type impeller	*Axial*	PR 32 Ringed Propeller	45		400	8	2000	√	χ
	Blade Impeller	*Radial*	BR 10 Cross - Blade Impeller	50	12	400	8	2000	≈	≈
	Propeller-Type impeller	*Axial*	PR 30 Pitched - Blade Impeller	58		400	8	2000	χ	√

Notes. Retrieved from *(America, 2013)*

APPENDIX C. LABORATORY EXPERIMENTS SUMMARY

Table 11

Laboratory experiments summary for one tank

Diffuser /Impeller			
	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm
	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm
	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm
	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm
	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm
	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm	800 rpm 1200 rpm 1600 rpm

APPENDIX D. DATA SHEET LABORATORY

Table 12

A. *Data sheet laboratory*

Test Nº	C_{N-Sep}	**RPM**	**Diffuser**	**Pressure (bar)**	**A**		**B**				**pH**	**Temp (ºC)**	**Turb. (FAU)**	**POWER (W)**	**POWER FACTOR**
					Filter (g)	Filter (mg)	Filter (g)	Filter (mg)	Vol. (mL)	TSS					

B. Date: Impeller: Tank:

APPENDIX E. DIFFUSERS SUMMARY DATA

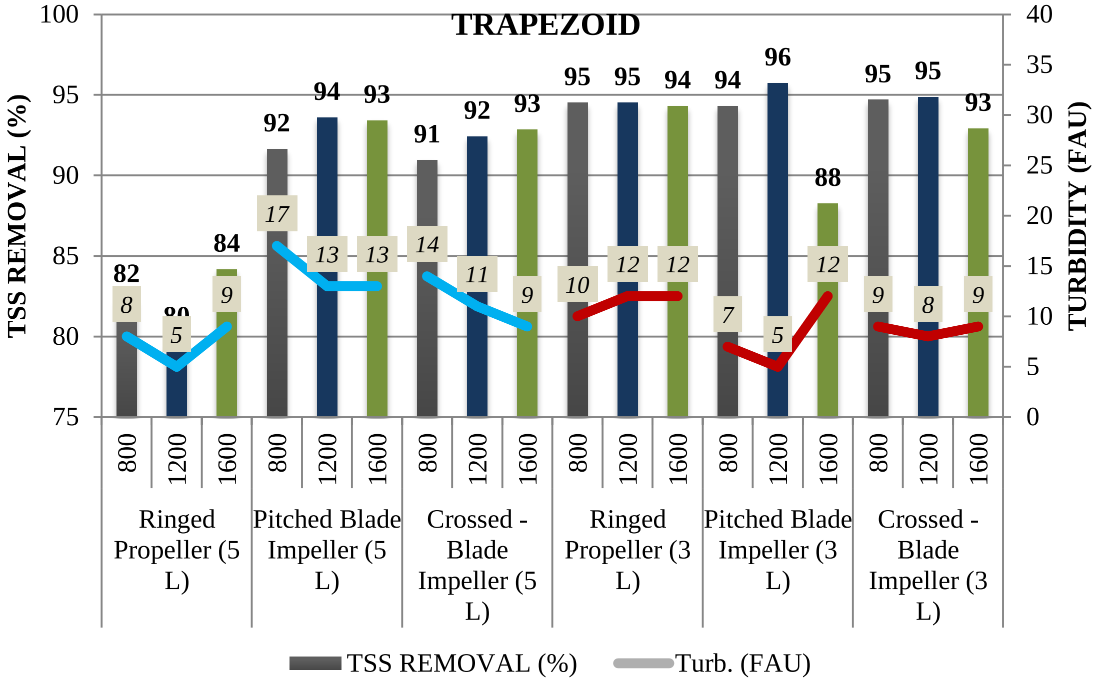


Figure 27 . Trapezoid summary data results

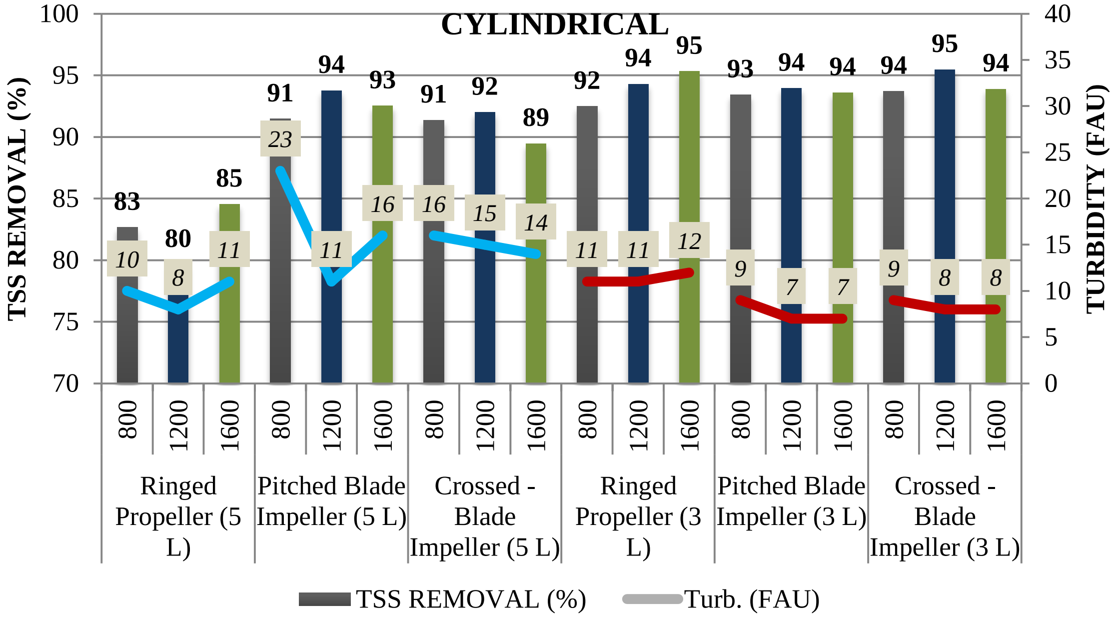


Figure 28. Cylindrical summary data results

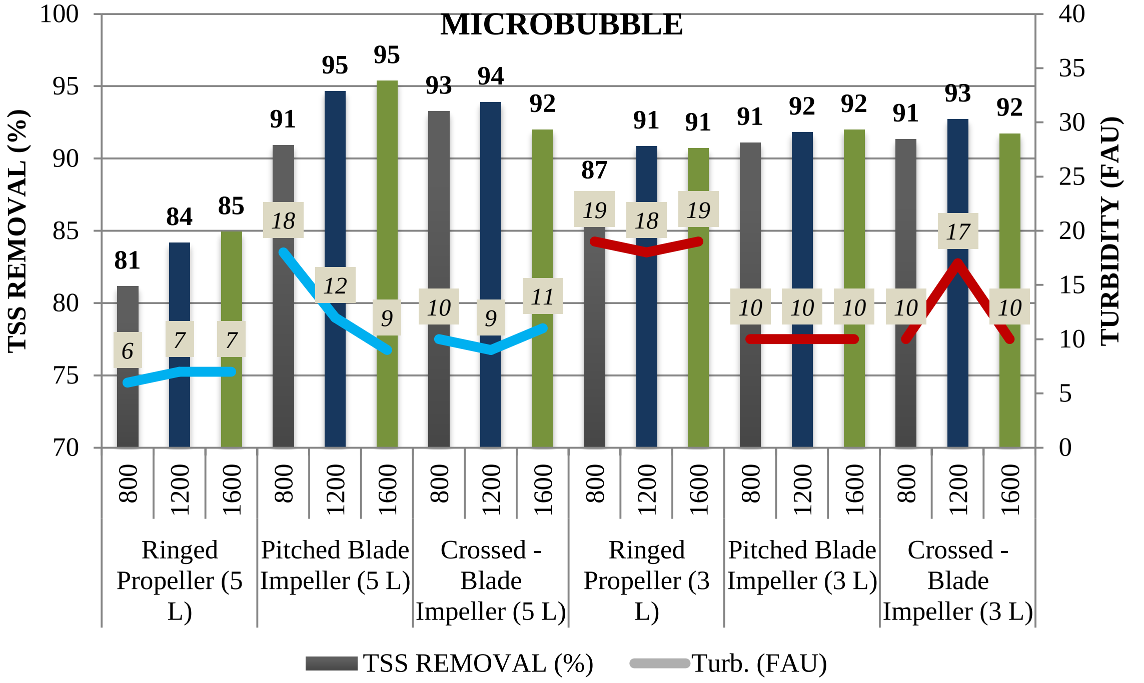


Figure 29. Microbubble summary data results

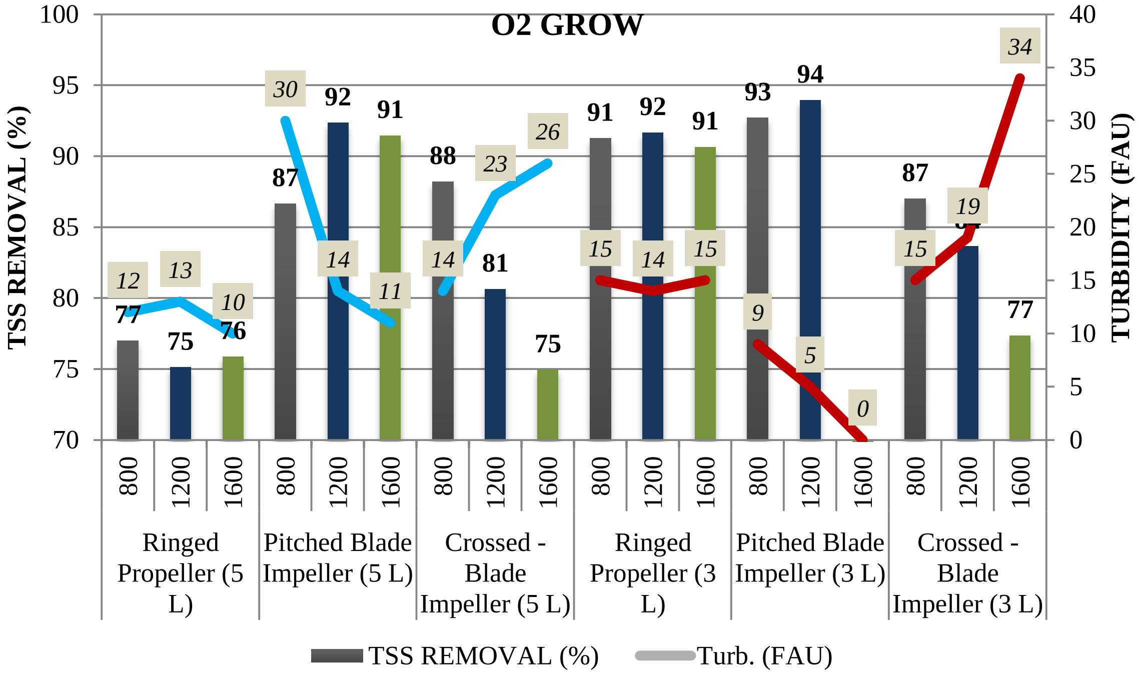


Figure 30. O2 Grow summary data results