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# Hydrodynamic Cavitation as a Clean Technology in Textile Industrial Wastewater Treatment

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The textile industry, according to world reports, is one of the industries that most pollutes water resources in its production process. It is estimated that a large amount of water is used in the production of a pair of jeans for dyeing, washing and finishing. This wastewater, when discharged into the receiving body without treatment, causes a negative environmental impact on ecosystems, especially humans. In the search for the treatment of these wastewater, the "hydrodynamic cavitation" method was applied with the aim of reducing the pollutants present and improving the physical-chemical parameters of these effluents. After 60 minutes of treatment, the pH was reduced by 23.95%, the total suspended solids by 82.82%, the biological oxygen demand was reduced to 64.77%, the chemical oxygen demand was reduced by 63.05%, in terms of the presence of oils and fats (O and F), the reduction was 93%, these parameters being within the established by the Peruvian regulations of maximum admissible values of wastewater discharge to the sewer. In addition, with regard to microbiological parameters, the application of hydrodynamic cavitation through the analysis of the *Escherichia Coli* parameter obtained a 100% reduction. Therefore, it is concluded that hydrodynamic cavitation is an efficient alternative method with the advantage of a clean technology in the treatment of wastewater due to low energy consumption and the non-use of polluting products.

Keywords: hydrodynamic cavitation, wastewater treatment, textile industry, reduction of physico-chemical parameters.

## 1. Introduction

The consumption of water is vital for the life of living beings, as well as for developing many activities and transformation processes in the industry. This generates an increasing amount of wastewater with a high level of pollutant load as a result of the inefficiency of the processes (Romero, 2016), which negatively impacts the environment, altering ecosystems. The use of water for dyeing in the production of jeans in the textile industry requires approximately 42 liters of water, originating wastewater with characteristics of variations in pH, chemical and biochemical oxygen demand, color, among others. On the other hand, chemical substances are incorporated that are then also discharged with the effluents where they can remain for a long time, as is the case of the hydrolyzed reagent blue 19 with approximately 46 years to degrade (Villegas and Gonzales, 2013). Given the forecasts that in coming years the consumption of water will be higher, which will cause a greater amount of wastewater in the industry, including textiles, it forces to look at solutions to the environmental problem for the efficient treatment and purification of pollutants present in wastewater (Bráñez et al., 2018). The use of water for dyeing in the production of jeans in the textile industry requires approximately 42 liters of water, originating wastewater with characteristics of variations in pH, chemical and biochemical oxygen demand, color, among others. On the other hand, chemical substances are incorporated that are then also discharged with the effluents where they can remain for a long time, as is the case of the hydrolyzed reagent blue 19 with approximately 46 years to degrade (Villegas and Gonzales, 2013).

There are several methods in the purpose of treating wastewater; However, in recent times, research has been carried out using the physical phenomenon of hydrodynamic cavitation, which consists of the process of generation and implosion of cavities (bubbles) that occur in a flowing liquid as a result of a decrease and subsequent increase in the pressure by a cavitating element, example orifice plate (Oualha et al, 2019). This phenomenon was used with the same purpose, it was tested creating cavitation by means of rotational fluxes with a vortex diode and comparing them with linear fluxes by means of an orifice plate, obtaining a 60% decrease in Gram negative microbial strains at the beginning. This was improved by achieving 90% when the pressure drop was increased by means of an orifice plate (10 bar), reaching cell destruction due to oxidative damage and DNA denaturation, including gram-positive microbial strains (Jain P, et. to, 2019. Orifice plate configurations have been compared to find the most efficient in the removal of contaminants, as well as the pressure conditions, number of cavitation and efficiency in the removal of *chlorpyrifos*, finding that the 1.5 mm configuration plate with 17 holes had better efficiency in reducing COD with 60% and 98% *chlorpyrifos* removal, compared to a plate with 2 mm holes, in 2 hours of hydrodynamic cavitation (Randhavane, 2019). The generation of micro-bubbles to reduce coliforms and heavy metals is another of the eco-efficient alternatives (Abate and Valverde, 2017; Valenzuela and Valverde, 2018).

Hydrodynamic cavitation can also be applied in a combined treatment with other methods as it was done with an induced hybrid fenton process, using hydrodynamic cavitation-$H_2O_2$-metals, obtaining good results for the treatment of the azo dye methyl orange at 20 ° C, with 4 bar inlet pressure with a discoloration of approximately 32% only with cavitation process, 50% with cavitation-$H_2O_2$, and 90% when cavitation-$H_2O_2$-metal ions was made (Innocenzi V., et al., 2019). In another investigation for the treatment of water contaminated with diazo Orange II (OR2) dye (10 mg / L) with hydrodynamic cavitation combined with hydrogen peroxide (H2O2) and monovalent zero iron (nZVI), achieving 99% degradation of the colorant in a time of 1 hour, a result that has to do with the mineralization of the azo dye (Badmus et al., 2020). Also, with the combination of hydrodynamic cavitation, fenton and oxygen, the efficiency to reduce COD was 63% in 180 minutes in wastewater treatment at a cost of $ 398 / m3 (Joishi and Gorgate, 2019. In another case, the application of cavitation combined with an electrocatalytic membrane was used for the degradation of oil pollutants in water, initially, dispersion and dissolution occur, then subjected to an electrolytic membrane the concentration of the oil decreases, stirring up to 98.81% (Deng et al., 2018).

The objective of the research was to determine the level of reduction of physicochemical parameters (SST, pH, O and F, $BOD_5$, COD) and microbiological (*Escherichia Coli*) in effluents from the textile industry with hydrodynamic cavitation (HC) in order to improve their quality to be disposed of in the recipient body and can reduce its danger and impacts to the environment.

## 2. Materials and methods

It was carried out following the following stages:

### 2.1. Obtaining sample

The wastewater was collected following the monitoring protocol for liquid effluents and atmospheric emissions (R.M. N ° 026-2000-ITINCI-DM). 120 liters of wastewater from the textile industry was collected to perform four treatments (coded with: TT1, TT2, TT3 and TT4), being characterized in the field and also analyzed in a laboratory duly accredited by a certifying entity. The results were compared with maximum admissible values regulated by the D.S. 003-2002-PRODUCE and D. S. 010-2019-HOUSING for water from industrial activities.

### 2.2. Parameter analysis methods

- Biochemical oxygen demand (BOD5): Method: APHA - AWWA - WEF (2012), 5220 - D
- Chemical Oxygen Demand (COD): Method: EPA 410.4 (Colorimetry)
- Analysis of oils and fats (O and F): STANDARD: NMX-AA-005-SCFI-2000
- *Escherichia Coli*: By dilution and culture

### 2.3. Hydrodynamic cavitation process

The cavitating system with a stainless-steel orifice plate with 25 holes of 2 mm diameter was used. The operating conditions were at an inlet pressure of 4 bar and for a time of 1 hour, with an average of 33.33 recirculation every 15 minutes for 30 liters of sample being treated. Samples were taken after 15, 30, 45 and 60 minutes of treatment, monitoring the temperature, pH, total suspended solids (TSS), BOD, COD, Oils and fats (O and F), *Escherichia Coli*. This process was repeated in three textile samples of the same nature.

The cavitation equipment was provided by the company PROMEC INGENIEROS. The cavitation equipment was provided by the company PROMEC INGENIEROS, which consists of: An effluent storage tank, an effluent flow tube along the path of which are: filter, centrifugal pump, pressure gauge, thermometer before entering the cavitating device (orifice plate), pressure gauges at the inlet and outlet of the orifice plate, orifice plate, to return to the storage tank. It also has a pass line to stabilize the process. See figure 1.

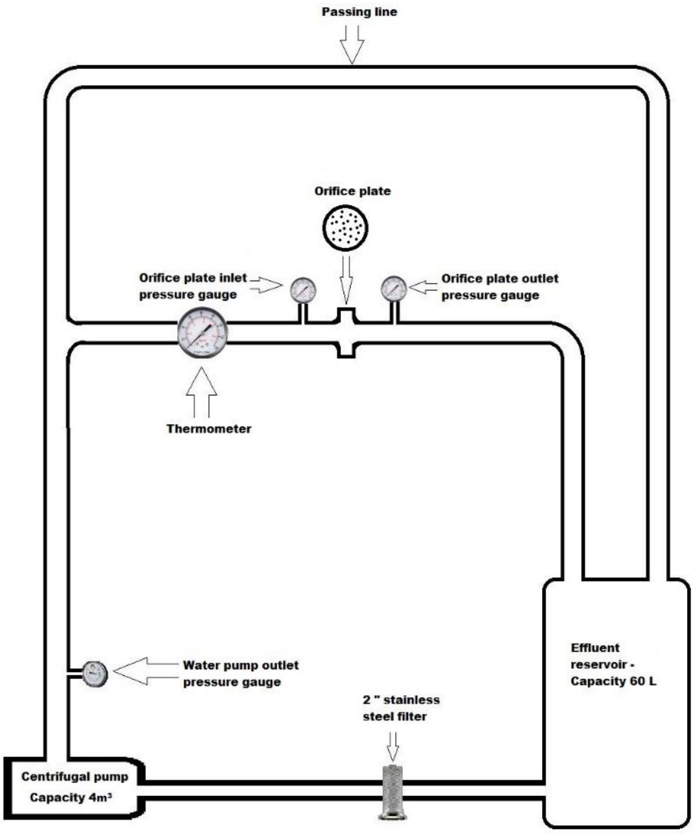


*Figure 1: Diagram of the hydrodynamic cavitation equipment*

## 3. Results and discussion

### 3.1. Physical and chemical parameters

The temperature increased as the treatment time progressed from 20.3 to 53.5 ° C, this is because the cooling system was not put into operation in the system. due to the implosion of the cavities (bubbles) in their compression phase releasing a large amount of energy that in turn favors the performance of chemical reactions that may occur. (Molina R, 2010). The working pressure was 4 bar following the Innocenzi (2018) procedure, as well as the result of preliminary tests.

It was observed that the pH of the effluent water from the textile industry decreased from an initial alkaline pH (10.02), to 8.22 (average of 3 measurements) as the treatment time progressed, see Table 1. As the cavitation process progresses, it tends to decrease alkalinity, while improving the other parameters studied. This is related to the decrease in OH radicals present in the environment when reacting with organic pollutants.

*Table 1: pH variation in cavitation treatment*

| *Treatment* | *pH Initial* | *Average pH final* | *Average percentage of pH decrease* |
|---|---|---|---|
| *TT-1 (15 min)* | *10.02* | *8.35* | *17%* |

| | | | |
|---|---|---|---|
| *TT-2 (30 min)* | *10.02* | *8.79* | *12%* |
| *TT-3 (45 min)* | *10.02* | *8.76* | *13%* |
| *TT-4 (60 min)* | *10.02* | *8.22* | *18%* |

Regarding the total suspended solids, after 15 minutes in which it was monitored, they drastically decrease from 782 mg / L to 207 mg / L, that is, 74%, and then as the cavitation time passes, the decrease is slowly in such a way that after 60 minutes about 75% decrease with respect to the initial value is maintained, see Table 2.

*Table 2: Total suspended solids (TSS) in cavitation treatment.*

| Treatment | TSS Initial (mg/L) | Average TSS final (mg/L) | Average percentage of decrease |
|---|---|---|---|
| TT-1 (15 min) | 782 | 207 | 74% |
| TT-2 (30 min) | 782 | 206 | 74% |
| TT-3 (45 min) | 782 | 197 | 75% |
| TT-4 (60 min) | 782 | 198 | 75% |

The biochemical oxygen demand (BOD5) after 15 minutes of treatment is verified to decrease by 60% and remains almost constant until 60 minutes after treatment. Regarding the chemical oxygen demand (COD), it is reduced and maintained around 57 and 58% from 15 minutes to 60 minutes of treatment, see Table 3. COD as well as BOD5 is reduced almost immediately at the beginning of the treatment, as it is verified that after 15 minutes, they decrease around 60%, not suffering any further alteration. It must be taken into account that the treatment was only with hydrodynamic cavitation and that it is very likely that the results can be improved by using a cavitation system combined with other elements such as that performed by Badmus et al. (2020).

*Table 3: Biochemical oxygen demand (BOD5) and Chemical oxygen demand (COD) in cavitation treatment.*

| Treatment | $BOD_5$ Initial (mg/L) | Average $BOD_5$ final (mg/L) | Average percentage of decrease | COD Initial (mg/L) | Average COD final (mg/L) | Average percentage of decrease |
|---|---|---|---|---|---|---|
| TT-1 (15 min) | 860 | 346.67 | 60% | 1400 | 606.45 | 57% |
| TT-2 (30 min) | 860 | 347.22 | 60% | 1400 | 600.89 | 57% |
| TT-3 (45 min) | 860 | 342.45 | 60% | 1400 | 585.45 | 58% |
| TT-4 (60 min) | 860 | 329.33 | 62% | 1400 | 589.55 | 58% |

The results at 15 minutes in terms of oils and fats (O and F) showed a reduction of 91% and then slowly decreasing until reaching a 93% reduction after 60 minutes, See Table 4.

*Table 4: Oils and fats (O and F) in cavitation treatment*

| Treatment | Oils and fats Initial (mg/L) | Average Oils and fats final (mg/L) | Average percentage of decrease |
|---|---|---|---|
| TT-1 (15 min) | 148 | 13.46 | 91% |
| TT-2 (30 min) | 148 | 12.19 | 92% |
| TT-3 (45 min) | 148 | 11.34 | 92% |
| TT-4 (60 min) | 148 | 10.70 | 93% |

**3.2. Microbiological parameters**

The variation of the microbiological parameter related to *Escherichia Coli* was verified, observing that its concentration decreases as the treatment time advances. It is reduced by a percentage of 91% at 15 minutes and at 45 minutes it reached total removal, see Table 5. Taking into account the results of the pH, at almost neutral values the highest degradation of *E. Coli* was obtained and it remained stable. In other investigations that studied the degradation of methyl orange dye with hydrodynamic cavitation combined with chlorine dioxide, the pH range with the best results was between 3 and 9 (Yang et al. 2017).

*Table 5: Escherichia Coli in cavitation treatment*

| Treatment | *Escherichia Coli* Initial (mg/L) | Average *Escherichia Coli* final (mg/L) | Average percentage of decrease |
|---|---|---|---|
| TT-1 (15 min) | 2400 | 216.67 | 91% |
| TT-2 (30 min) | 2400 | 69.22 | 97% |
| TT-3 (45 min) | 2400 | 0.00 | 100% |
| TT-4 (60 min) | 2400 | 0.00 | 100% |

The reduction of parameters presents in textile effluent, that are linked to the presence of organic matter (BOD, COD, SST, AyG, E. Coli) suffered variation with hydrodynamic cavitation due to the occurrence of the phenomenon of formation, development, growth and implosion of cavities (bubbles) in the liquid medium by the variation of the pressure existing in the fluid with increasing speed due to the geometry of the conduit (cavitant element). The implosion of the cavities is the main part of the process, originating a thermolytic reaction that dissociates the water into the hydrogen ($H^+$) and hydroxyl ($OH^-$) radicals, which by molecular diffusion produces the chemical oxidation reaction on the pollutants in the environment (Dindar E, 2016) and (Wang N, 2016).
This used methodology could be complemented with another advanced oxidation method as well as using another cavitation means (Venturi) seeking to improve the results. The research was carried out in a team at the pilot plant level, so the results obey a reality compared to investigations carried out at the laboratory level.

## 4 Conclusion

Through the hydrodynamic cavitation process, it was possible to improve the main physicochemical and microbiological properties of wastewater from a textile industry. In this way, it is determined that this method turns out to be a viable way, with environmental characteristics, with a high potential to improve water quality and the elimination of microbiological contaminants. Likewise, it can be considered as a clean technology as it does not generate waste and has a wide range of application.


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