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EFFICIENCY OF AN AEROBIC TREATMENT FOR THE REMOVAL OF ORGANIC MATTER IN TEXTILE EFFLUENTS USING BIOLOGICAL REACTORS

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ABSTRACT

Objective: To evaluate the efficiency of an aerobic treatment using sequential biological reactors in effluents of textile origin.

Theoretical framework: The removal of dyes through biological treatment techniques has gained momentum in recent years because they are efficient, sustainable, renewable, and environmentally friendly.

Materials and methods: Aerobic biological reactors with a volume of 2 L were used for the treatment of effluents of textile origin using two operational cycle times, 12 and 16 hours. Parameters such as color, turbidity, pH and organic matter were measured at the entrance and exit of the reactors.

Results and discussion: Removal percentages greater than 73, 86 and 94% were obtained in the removal of organic matter, color and turbidity, respectively. Once treated, the textile effluent is suitable for discharge into natural water bodies, complying with the provisions of Venezuelan regulations.

Implications of the research: The treatments applied to the textile industrial effluent indicate the good performance of the aerobic biological reactors to adapt to different operating conditions.

Value/originality: Treatment in aerobic reactors is an excellent option for small and medium-sized companies dedicated to fabric dyeing, representing a mitigation technique for the environmental impact caused by the discharge of effluents without treatment.

Keywords: Textile Effluents, Organic Matter, Biological Treatment, Dye Removal.

EFICIÊNCIA DE UM TRATAMENTO AERÓBIO PARA A REMOÇÃO DE MATÉRIA ORGÂNICA EM EFLUENTES TÊXTEIS UTILIZANDO REATORES BIOLÓGICOS

RESUMO

Objetivo: Avaliar a eficiência de um tratamento aeróbio utilizando reatores biológicos sequenciais em efluentes de origem têxtil.

Referencial teórico: A remoção de corantes através de técnicas de tratamento biológico ganhou força nos últimos anos por serem eficientes, sustentáveis, renováveis e ecologicamente corretas.

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Materiais e métodos: Foram utilizados reatores biológicos aeróbios com volume de 2 L para tratamento de efluentes de origem têxtil utilizando dois tempos de ciclo operacional, 12 e 16 horas.
Parâmetros como cor, turbidez, pH e matéria orgânica foram medidos na entrada e saída dos reatores.

Resultados e discussão: Foram obtidos percentuais de remoção superiores a 73, 86 e 94% na remoção de matéria orgânica, cor e turbidez, respectivamente. Uma vez tratado, o efluente têxtil é adequado para lançamento em corpos hídricos naturais, atendendo às disposições da regulamentação venezuelana.

Implicações da pesquisa: Os tratamentos aplicados ao efluente industrial têxtil indicam o bom desempenho dos reatores biológicos aeróbios para adaptação às diferentes condições de operação.

Valor/originalidade: O tratamento em reatores aeróbios é uma excelente opção para pequenas e médias empresas dedicadas ao tingimento de tecidos, representando uma técnica de mitigação do impacto ambiental causado pelo lançamento de efluentes sem tratamento.

Palavras-chave: Efluentes Têxteis, Matéria Orgânica, Tratamento Biológico, Remoção de Corantes.

EFICIENCIA DE UN TRATAMIENTO AERÓBICO PARA LA REMOCIÓN DE MATERIA ORGÁNICA EN EFLUENTES DE ORIGEN TEXTIL USANDO REACTORES BIOLÓGICOS

RESUMEN

Objetivo: Evaluar la eficiencia de un tratamiento aeróbico usando reactores biológicos secuenciales en efluentes de origen textil.

Marco teórico: La remoción de colorantes mediante técnicas de tratamiento biológico ha cobrado impulso en los últimos años por ser eficientes, sostenibles, renovables, y respetuosas con el medio ambiente.

Materiales y métodos: Se usaron reactores biológicos aeróbicos con un volumen de 2 L para el tratamiento de efluentes de origen textil usando dos tiempos de ciclo operaciones, 12 y 16 horas. Se midieron parámetros como color, turbidez, pH y materia orgánica a la entrada y salida de los reactores.

Resultados y discusión: Se obtuvieron porcentajes de remoción superiores a 73, 86 y 94 %, en la remoción de materia orgánica, color y turbidez, respectivamente. El efluente textil una vez tratado resulta apto para su vertido en cuerpos de agua naturales, cumpliendo con lo establecido en la normativa venezolana.

Implicaciones de la investigación: Los tratamientos aplicados al efluente industrial textil indica el buen desempeño de los reactores biológicos aeróbicos para adaptarse a distintas condiciones de operación.

Valor/originalidad: El tratamiento en reactores aeróbicos es una excelente opción para pequeñas y medianas empresas dedicadas a la tinción de telas, representando una técnica de mitigación para el impacto ambiental ocasionado por la descarga de efluentes sin tratamiento.

Palabras claves: Efluentes Textiles, Materia Orgánica, Tratamiento Biológico, Remoción de Colorantes.

1 INTRODUCTION

The textile industry is known for the production of large volumes of hazardous effluents that carry residues of reactive dyes, aerosols, leveling agents, acids, alkalis, amines, heavy metals, chlorophenol, and other recalcitrant or hazardous contaminants that are harmful to aquatic ecosystems (Azizi et al., 2015; Madhav et al., 2018). The discharge of textile waste has a detrimental effect on the ability of plants to perform photosynthesis. This is due to the obstruction of light penetration caused by these effluents, which in turn causes a decrease in oxygen levels in the body of water where they are released (Holkar et al. 2016: Varjani et al. 2021).

The textile industry is responsible for more than 54 per cent of dye effluents released into the environment. About 2.8×10^5 tons of textile wastewater containing a large number of different categories of synthetic dyes are released into the environment annually (Srisuwun et al. 2018).

Dyes are synthetic aromatic organic compounds that are used to color a variety of substances. They are essentially chemicals that stick to the substrate and add color to its characteristic. The color of the dye varies by chromophore group. It is usually a complicated structure with a substrate of relatively high biotoxicity (Lawal et al. 2023).

Conventional physicochemical processes such as coagulation-flocculation using aluminum sulfate, ferrous sulfate or aluminum polychloride provide limited COD removal, from 10 to 48 %, for wastewater with dyes (Gilpavas et al. 2017; Karam et al. 2020), which is why the use of systems that have higher efficiency and lower cost such as activated sludge, bioreactors and biofilters is recommended (Malik et al. 2021; Yang et al. 2021).

Sequential charge reactors are a variant of the conventional activated sludge process. This reactor operates in successive cycles, each consisting of a sequence of five discrete stages: filling, reaction, sedimentation, discharge and purging of excess biomass. It is easy to monitor and control, features flexible operation and compact design. The application of SBR in the treatment of textile wastewater for the elimination of azo dyes has received the attention of researchers. Different operating sequences have been evaluated, such as aerobic (Kouni et al., 2012), anaerobic (Ong et al., 2005) and anaerobic-aerobic (Mohan et al., 2013).

Due to its simplicity of use and operational costs, aerobic biological systems where oxygen is introduced into the reactor are preferred, usually using a thin bubble lower diffuser.

Elimination of azo dyes is possible under low-activity aerobic conditions because oxygen is a more efficient electron acceptor than azo dyes (Korenak et al. 2017).

The objective of this research was to determine the efficiency of removal of organic matter from a sequential biological reactor operated at different aeration times in the treatment of wastewater from an industry dedicated to the coloring of denim pants.

2 MATERIALS AND METHODS

2.1 CHARACTERIZATION OF TEXTILE EFFLUENT

The textile effluent was obtained in a company dedicated to dyeing and washing denim pants located in La Grita, Táchira state, Venezuela. Effluent collection was performed according to the standards established in the standardized methods, using method 1060 for sample collection and preservation (APHA et al., 2005). This effluent was characterized by the physicochemical parameters indicated in Table 1.

Table 1

Physicochemical parameters measured in characterization

Parameter	**Method***	**Type of method**
Temperature	2550	*On-site*
Apparent color	2120	Spectrophotometric
Actual Color	2120	Spectrophotometric
Turbidity	2130	Nephelometric
Electrical conductivity	2510	*On-site*
pH	4500-H^+	*On-site*
ST	2540–B	Gravimetric
SST	2540-D	Gravimetric
SS	2540-F	Gravimetric
Cl^-	**4500 Cl^-**	Argentometric
NTK	4500-NorgA	Volumetric
PT	4500 P C	Colorimetric
$BOD_{5.20}$	5210–B	Volumetric
COD	5220–C	Volumetric
Aceites y grasas	5520-B	Gravimetric

Note: *Standard method of analysis of water and waste liquids (APHA et al.2005). pH: hydrogen potential, ST: total solids. SST: Total suspended solids. SS: sedimentable solids. NTK: Kjeldahl total nitrogen. PT: total phosphorus. $BOD_{5,20}$: Biochemical oxygen demand. COD: chemical oxygen demand.

2.2 ADAPTATION AND STARTING OF THE REACTOR

The biomass was obtained from a biological system that treated effluents from a dairy industry, it was inoculated in a sequential biological reactor whose useful volume was 2 L, of which 30% corresponded to the biomass and 70% was completed from the effluent. For the adaptation of biomass, a synthetic effluent (ES) was prepared (Table 2), which was mixed with the textile industrial waste water (ARI) in different proportions (ARI/AS: 20/80; 40/60; 80/20), to promote the appropriate conditions for the development of microorganisms. The reactor was subjected to a continuous aeration process with 24-hour cycles (TCO) for 17 days. During this period, daily analyzes were carried out until consistent results were obtained, where the COD removal values measured at the exit of the reactor were greater than 60% and good sedimentation characteristics of the sludge were presented (Di Iaconi et al., 2002).

Table 2

Chemical composition of synthetic water used in SBR starting

Nutrient	Concentration (mg/L)
$MgCl_2.6H2O$	0.17
$(NH_4)Mo_7O_{24}.4H_2O$	0.08
$CoCl_2.6H_2O$	0.1
NH_4Cl	3.82
$CaCl_2.2H_2O$	0.106
$MnCl_2.4H_2O$	1.00
$KH_2PO_4+K_2HPO_4$	0.044+0.073
$FeCl_2$	0.12

Note: Di Iaconi et al. (2002)

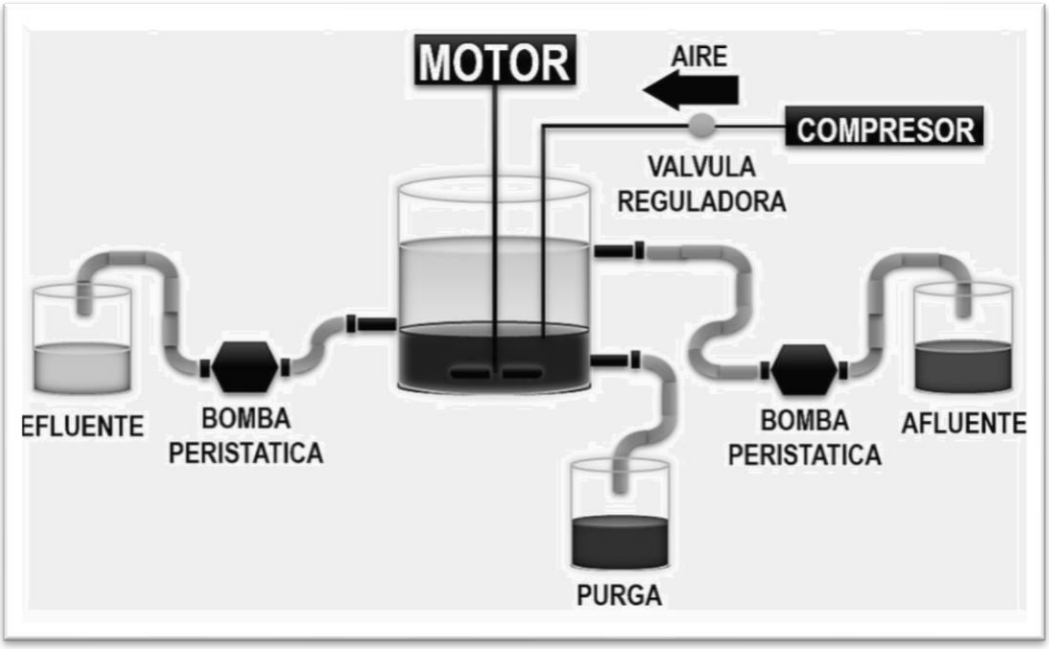
3 TREATMENT IN THE SEQUENTIAL BIOLOGICAL REACTOR

Once the adaptation phase was completed, treatment was started in two reactors that operated in parallel, each one had a useful volume and a total capacity of 4 L (Figure 1). The operation of the reactor consisted of four stages: filling, reaction, sedimentation and discharge. Two operational cycle times (OCT), T1 of 12 h and T2 of 16 h were evaluated. In the reaction stage, agitation and aeration were provided to achieve a homogeneous mixture between the textile waste water and the biological sludge; the sedimentation stage was developed by the action of gravity force, in which agitation and aeration were stopped and the mixture was allowed to rest until a clarified supernatant was obtained, which was subsequently extracted in the discharge phase.

The time of the filling (0.25 h), sedimentation (0.5 h) and discharge (0.25 h) stages remained constant during the evaluation of the two TCOs. The aeration time was 11 and 15 h for T1 and T2, respectively. A cell retention time of 15 days and a static filling were used.

Figure 1

Schematic of the SBR reactor used in this work



Note: Own elaboration

Samples were collected at the start, during and end of each operational cycle in the reactor. Physicochemical parameters measured were COD, pH, real color, turbidity, total solids, and total alkalinity. The experiments were conducted by a completely random design, for a total of two treatments (T1: 12 h and T2: 16 h of TCO), with 12 repetitions each. For each treatment, the removal efficiency of organic matter was determined, using Equation 1.

$$EDQO\ (mg/L) = \left(\frac{DQOo - DQOf}{DQOo}\right) \times 100 \qquad (1)$$

Where:

$DQOo$: COD concentration at reactor inlet (mg/L)and $DQOf$: COD concentration at outlet (mg/L).

Similarly, the efficiencies of real color removal, turbidity and ST were calculated by Equation 1, replacing the initial and final concentrations of each parameter. These results were compared by a single-way analysis of variance and the rest of the variables were presented using descriptive statistics, pointing out the central trend values and their dispersion, with the use of the SPSS statistical program, version 20.0.

Additionally, the volumetric organic loads were determined using Equation 2, proposed by Mekonnen and Leta (2011). A Pearson correlation analysis between VOC and COD removed during effluent characterization was also performed.

$$COV\ (mg/Ld) = \frac{DQOAR \times VLL}{Vr \times TCO} \qquad (2)$$

Where:

$_{COD}$: COD of raw waste water (mg/L), $_{VLL}$: volume of waste water fed in each cycle (L), $_{Vr}$: reactor useful volume (L), TCO: cycle duration in SBR (d).

4 RESULTS AND DISCUSSION

4.1 CHARACTERIZATION OF TEXTILE EFFLUENT

The physicochemical characteristics measured in the textile effluent are presented in Table 3, which includes the mean values and their dispersion; expressed through the standard deviation, as well as the limits established by the Venezuelan norm for discharges to bodies of water (Decree 883, 1995).

The average temperature of the effluent was 39.30 ± 6.30 °C, which is above room temperature. Textile effluents are characterized by having high temperatures due to the preparation, dyeing and finishing processes, which are carried out at high temperatures (Hayat et al., 2015).

The effluent presented a real color value with an average value of 568 ± 162 UC Pt-Co, the presence of dyes in the wastewater is mainly due to the fact that, during the process of finishing fabrics and threads, particularly during dyeing, the dye is not completely fixed. According to Sudarshan et al. (2022) between 10 and 15 % of dyes remain unfixed in fabric fabrics.

Table 3

Characteristics of wastewater from the textile industry

Parameter	Unit of expression	Average value	Standard deviation	Maximum limit for discharge to bodies of water[1]
Temperature	°C	39.30	6.30	-
Apparent color	UC Pt-Co	833	289	-
Actual Color	UC Pt-Co	568	162	500
Turbidity	UNT	69.67	12.74	-
Electrical conductivity	µS/cm	1,797	472	-
pH	-	6.50	0.36	6 - 9
ST	mg/L	1,930	812	-
SST	mg/L	282	133	80
SS	mg/L	11.33	6.35	1
Cl^-	mg/L	109	59	1000
NTK	mg/L	22.4	5.1	40
PT	mg/L	4.0	0.9	10
$BOD_{5.20}$	mg/L	470	54	60%
COD	mg/L	1,314	97	350
Oils and fats	mg/L	10.8	2.8	20

Note: Own elaboration. n:3. n: number of repetitions. 1: Decree 883 (1995). ST: total solids. SST: total suspended solids. SS: sedimentable solids. NTK: Kjeldahl total nitrogen. PT: total phosphorus. $BOD_{5,20}$: Biochemical oxygen demand. COD: chemical oxygen demand.

The textile effluent can be described as slightly acidic, since it presented an average pH of 6.50 ± 0.36 units. The average concentration of was 109 ± 59 mg/L, considered as non-saline compared to that studied by Mirbolooky et al. (2017), who classify textile effluents as highly saline when their concentration of chlorides is between 1,000 and 10,000 mg/L.

The average concentrations of PT and NTK found in the textile effluent were 4.0 ± 0.9 and 22.4 ± 5.1 mg/L, respectively; both parameters did not exceed the maximum values allowed by the Venezuelan norm for discharges to bodies of water, where a limit of 10 and 40 mg/L is established, respectively (Decree 883, 1995). Regarding the $_{DQOT}$/NTK/PT ratio, it was low, of 100:1,71:0,31; which confirms the statement by Sanz (2015), who in his research indicates that textile effluents are usually nutrient deficient. However, phosphorus and nitrogen are two essential elements for bacterial development, since without them microorganisms can not properly synthesize their proteins, which generates the decrease in the performance of purification, if it is biological type, therefore, if N or P is missing, it must be added until reaching the correct proportion.

The mean concentration of organic matter, measured as $BOD_{5.20}$ was 470 ± 53 mg/L;

and measured as COD ranged from 1,292 to 1,421 mg/L, with an average value of 1,314 ± 97 mg/L; exceeding the Venezuelan standard for discharges to bodies (Decree 883, 1995). This is because the textile industry, dry cleaning plants, finishes and jeans laundry, generate liquid waste with a wide variety of dyes, recalcitrant organic compounds and other chemical compounds, including acids, bases, salts, wetting agents, dyes, among others, which do not remain in the final textile product, but are discarded after fulfilling a specific use. The $BOD_{5.20}$/COD ratio of the characterized effluent was 0.4, indicating that biological treatments should be applied in combination with physicochemicals because the effluent has a character of average biodegradability. However, it has been shown that biological treatment is comparatively safe and more energy efficient, compared to physical and chemical treatments, so in this research it was decided to apply only biological treatment

4.2 BIOMASS ADAPTATION

Table 4 shows the mean values and standard deviations of COD at entry, COD at exit and the percentage of COD removal, for each of the proportions used during the treatment of textile effluent in the adaptation phase of microbial biomass, this phase of the research lasted 17 days.

Table 4

Adaptation of the biomass used in the SBR reactor for the treatment of textile effluent

Proportion (ARI/AS)	CODe (mg/L) ± SD	CODs (mg/L) ± SD	% Removal ± SD	VOC ± DE
20/80	1,487 ± 116	548 ± 26	63.1 ± 1.6	1.04 ± 0.08
40/60	1,195 ± 258	461 ± 54	60.1 ± 7.6	0,84 ± 0,18
80/20	1,212 ± 158.02	462 ± 10	61.6 ± 3.6	0,85 ± 0,10
100/0	957 ± 125.66	378 ± 32	60.2 ± 4.5	0,67 ± 0,09

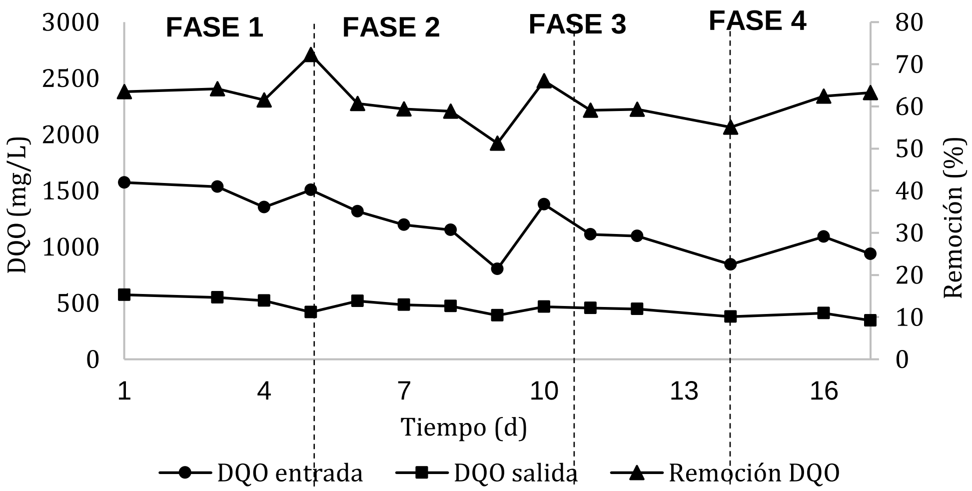
Note: Own production. n:17. n: number of samples. for ARI: industrial waste water. AS: synthetic water. DE: standard deviation. CODe: COD at the reactor inlet. CODs: COD at the exit of the reactor. VOC: Volumetric organic load.

In the first phase, which lasted 4 days, the reactor was fed with an ARI/AS ratio of 20/80, obtaining average concentrations of COD at the inlet of 1,487 ± 117 mg/L, while the values at the outlet were 548 ± 27 mg/L, representing a removal of 63.1%. The second phase lasted 5 days, where a 40/60 ratio was added, achieving a 60.1% removal of COD, then the proportion of textile wastewater was increased to 80%, phase that lasted 3 days, achieving an average removal in this phase of 61.6%. Finally, only raw industrial wastewater was added, obtaining an average value at the exit of the reactor of 378 ± 32 mg/L and a removal of 60.2%; which was constant in the experimentation.

During the adaptation of biomass, in general, the variations in the percentages of removal of organic matter (COD), for the different proportions of effluents, were not appreciable, which was considered indicative of the good acclimatization of the microbial community to the textile effluent (Figure 3).Other authors have reported acclimatization times for sludge of 30 days, such as the case of Hayat et al. (2015) in aerobic reactors, while Vacca et al. (2008), achieved acclimatization by an anaerobic reactor in 17 weeks.

Figure 3

Variation of COD concentration of inlet, outlet and removal percentage during acclimatization to textile effluent.



Note: Own elaboration

4.3 TREATMENT EFFICIENCY IN SEQUENTIAL BIOLOGICAL REACTORS

After the process of acclimatization of the textile effluent, the comparison of the efficiency of the sequential reactor per load was started operating with two operational cycle times; 12 and 16 h. As for the actual color, the mean value at the exit of the reactors in T1 was 79 ± 18 UC-Pt Co, while for the T2 treatment it was 61 ± 9 UC-Pt Co, thus obtaining mean removal percentages of 86 ± 4 and 89 ± 2%, respectively (Table 4), which had no significant statistical differences ($p = 0.066$). The high levels of real color removal obtained in the present investigation may result from the activity of different microorganisms present in the reactor sludge, which discolor the dye through its synergy. There are several as yet unproven phenomena that can occur in the discoloration of textile wastewater, such as physical color adsorption on the biomass of suspended bacteria, photochemical effect or biological oxidation.

Enzymes produced by microorganisms in wastewater (mono and dioxygenase) catalyze the integration of O_2 oxygen into the aromatic ring of organic compounds prior to ring fission (Khoune et al., 2012).

Table 5

Mean concentrations of real color at inlet, outlet and removal percentages in SBR reactor during textile effluent treatment

Treatment	TCO (h)	Input (UC) ± DE	Output (UC) ± DE	%Removal ± SD
T1	12	563 ± 125	79^{a} ± 18	86^{a} ±4
T2	16	571 ± 189	61^{a}±9	89^{a} ±2

Note: Own elaboration. n:12. n: number of measurements made. TCO: operational cycle time. DE: standard deviation. Note: Mean followed by equal letters in each row indicate no significant differences based on a one-way analysis of variance (p>0.05).

Textile wastewater comes from the manufacture of denim pants, so the dye that occurs in greater proportion is indigo, one of the most difficult to remove because it has a complex aromatic molecular structure, which is more stable and more difficult to biodegrade (Carrasquero et al. 2022). Color removal is positively correlated with turbidity reduction, Table 5 shows the average results of removal of this parameter. It is inferred that the removal of turbidity is by action of the microorganisms present in the biomass in the reactor, specifically to the ciliated protozoa who in high quantities help to reduce turbidity.

Table 6

Average turbidity concentrations at reactor inlet and outlet and removal percentages

Treatment	TCO (h)	Input (UNT) ± DE	Output (UNT) ± DE	%Removal ± SD
T1	12	67.9 ± 15.7	3.2^{b} ± 0.5	94.7^{a} ± 1.6
T2	16	73.1 ± 39.1	2.0^{to} ± 0.7	96.1^{a} ± 3.5

Note: Own elaboration. n:12. n: number of measurements made. TCO: operational cycle time. DE: standard deviation. Note: Mean followed by equal letters in each row indicate no significant differences based on a one-way analysis of variance (p>0.05).

Table 6 shows the concentrations of organic matter, expressed as COD, at the entrance and exit of the rector by sequential load, as well as the removal percentages for the treatments applied. The removal percentages for both OCTs did not differ significantly from each other (p=0.978). Similarly, the volume organic load applied in each treatment, did not show significant differences (p = 0.157). That is why the most appropriate TCO for the treatment of this type of effluent using a sequence reactor is 12 h, which allows greater effluent processing, with a lower energy consumption, achieving results equal to those subjected to greater contact times.

Table 7

Average COD concentrations at inlet, outlet and removal percentages in the SBR reactor during textile effluent treatment.

TCO (h)	CODe (mg/L) ± SD	CODs (mg/L) ± SD	CODr (mg/L) ± SD	%Removal ± SD	VOC ± OF
112	1,007 ± 540	245 ± 100	761[a] ± 440	74.1[a] ± 4.1	1.41[a] ± 0.76
166	1,091 ± 405	266 ± 8	824[a] ± 397	73.2[a] ± 8.8	1.15[a] ± 0.76

Note: Own elaboration. n:12. n: number of measurements made. TCO: operational cycle time. DE: standard deviation. CODe: COD at the reactor inlet. CODs: COD at the exit of the reactor. DQOr: DQO removed. VOC: Volumetric organic load. Note: Mean followed by equal letters in each row indicate no significant differences based on a one-way analysis of variance (p>0.05).

The reactor demonstrated adaptability due to this type of biological treatment to the fluctuations of organic matter that may occur. In addition, a continuous reduction of TCO allows a better quality of biomass, so in the reactors should be used an aeration time that allows to obtain high percentages of removal of organic matter and a quality biomass that can sediment.

Despite the nutritional deficiencies presented by the treated effluent, microbial biomass was able to remove organic matter efficiently. According to the literature, aerobic sludge treatments have been widely used for the removal of color and organic matter from dye wastewater. Granular aerobic sludge can be generated under microaerophilic conditions and with a low concentration of dissolved oxygen (≤ 2 mg/L), generating advantages such as a stable microbial structure, good sedimentation, high biomass concentration and resistance to shock loads, and an improved effluent-biomass separation (Bashiri et al. 2018).

COD concentrations at the outlet of the reactor were below the permissible limit for discharges to bodies of water, being this 350 mg/L (Decree 883, 1995), so it is not necessary to apply an after-treatment to the textile effluent for the decrease of this parameter.

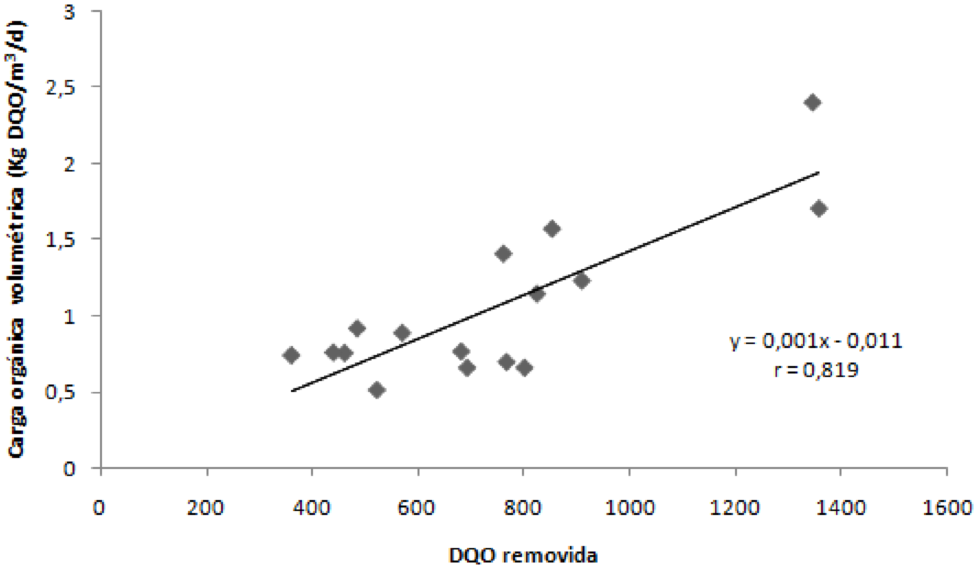
A Pearson correlation analysis was performed using the results of COD removed in both treatments with the applied VOC, a highly significant ($p<0.0001$) and positive ($r=0.819$) association was found (Figure 2), which establishes that, the higher the organic load applied to the reactor, the greater the COD removal.

Regarding the monitoring parameters, the mean pH values for each operational cycle time of the reactor ranged between 6.23 and 6.81 units for the input and between 7.03 and 7.23 units for the output with a TCO of 12 h (T1) and between 6.19 and 7.07 units for the input and between 7.27 and 8.04 units for the output with a TCO of 16 h (T2) (Table 6). The increase can be attributed to biological reactions resulting from the degradation of certain components of the effluent, which generates a release of CO_2, thus decreasing the concentration of the hydronium ion (H^+) and producing an increase in pH at the exit of the reactor.

The total alkalinity values at the reactor inlet (Table 8) indicated that the effluent had a good buffer capacity (Kundu et al., 2013), since the alkalinity values are above 500 mg/L $CaCO_3$, which is evidenced by the discrete pH variations at the reactor inlet and outlet.

Figure 2

Correlation between the volumetric organic load (VOC) and the removed COD (mg/L) in the SBR reactor, for the treatment of textile effluent



Note: Own elaboration

Table 8

Mean pH concentrations at the inlet and outlet of the SBR reactor during textile effluent treatment

Treatment	**TCO (h)**	**Input ± DE**	**Output ± SD**
T1	12	6.48 ± 0.25	7,10 ± 0,09
T2	16	6.56 ± 0.30	7,56 ± 0,25

Note: Own elaboration n:12. n: number of measurements made. TCO: operational cycle time. DE: standard deviation.

Table 9

Mean total alkalinity concentrations at the inlet and outlet of the SBR reactor during textile effluent treatment

Treatment	**TCO (h)**	**Input (mg $CaCO_3$/L) ± DE**	**Output (mg $CaCO_3$/L) ± DE**
T1	12	560 ± 80	760 ± 160
T2	16	680 ± 184	980 ± 75

Note: Own elaboration n:12. n: number of measurements made. TCO: operational cycle time. DE: standard deviation.

The increase in alkalinity is attributed to the generation of carbonate ions, from the dissolution of the CO_2 generated due to the aerobic nature of the biological process. Somasiri et al. (2007) refer to the use of the damping capacity of this type of effluent, to reduce or control the economic costs of the color degradation and COD processes, since, when maintaining the pH values stable, without abrupt or important variations, it is not necessary to add acid or basic agents to the water to modify or control it, which reduces operating costs during treatment.

5 CONCLUSIONS

The evaluated effluent of the textile industry was characterized by high concentrations of real color, total suspended solids (TSS), chlorides, $BOD_{5,20}$ and COD, so that the industrial effluent does not comply with the current Venezuelan regulations for discharges into water bodies.

With the two treatments applied to industrial textile effluent, organic matter removal measured as COD, real color and turbidity greater than 69% was achieved, indicating the good performance of the reactor to adapt to different operating conditions.

For both treatments evaluated no significant statistical differences were found, so the effect of the increase in the operational cycle time did not affect the removal of any of the parameters evaluated. Therefore, it is concluded that the TCO of 12 h is the most suitable for the treatment of textile effluents, being the shortest operational time, which implies an optimal use of energy.

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