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BIOGRAPE: INNOVATION FOR TEXTILE EFFLUENT TREATMENT USING BACTERIAL CELLULOSE FROM WINE RESIDUE

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ABSTRACT

Water is one of the most important natural resources and is essential for activities that sustain society, such as agriculture, energy, and consumption. However, this resource is constantly polluted by textile industries which are major sources of pollution. This occurs because the dyes used in dyeing are not completely fixed to the textile fibers and often get discarded without any treatment, causing numerous environmental and social damages. In Brazil, 20% of the produced dyes are discarded every year. Therefore, the project aimed to develop a sustainable alternative for textile effluent treatment by using bacterial cellulose produced with agro-industrial wine residues. In the first stage, a factorial design 2^3 with surface response methodology was performed to evaluate the variables glucose, sucrose, and grape byproduct from wine production concentrations in bacterial cellulose optimization. In the second, bacterial celluloses were tested for the removal of indigo carmine dye at concentrations of 5mg/L, 15mg/L, and 50mg/L using an agitation adsorption process. Afterward, they were tested for the removal of green and red-colored textile effluents collected from industries. It was possible to observe a removal of 50%, 80%, and 80% of the indigo carmine dye at the respective concentrations, showing a higher removal rate compared with the literature. The removal of textile effluent was close to 50% for the green dye and 30% for the red dye. Thus, the project proved to be a promising alternative to meet an urgent demand, showing environmental, social, scientific, and technological relevance by generating an alternative for the treatment of textile effluent contributing to 8 of the 17 Sustainable Development Goals created by the UN.

Keywords: Bacterial cellulose. Bioprocess. Agro-industrial residue. Textile effluent.

Contents

1. INTRODUCTION

Water is the most precious environmental resource, essential for various activities that sustain society, such as agriculture, consumption, and energy production (DIAS, 2013). However, water is constantly contaminated and polluted by textile industries, which often discharge effluents without any treatment, causing significant damage to the environment and even to human health (RICACZESKI, 2017).

About ten thousand dyes are produced on an industrial scale, and about two thousand dyes are available for the textile sector. In Brazil, tons of dyes are used each year, and 20% does not adhere to the fabric and is discarded as effluent. The main source of losses of these dyes is the incomplete fixation of the dyes to the textile fibers during the dyeing process (GUARATINI et al., 2000; WEBER et al., 1993). The improper disposal of textile effluent not only affects the quality of water but also reduces and prevents the passage of light, altering biological processes such as photosynthesis, which are essential for the ecosystem. In addition, some dyes have toxic, allergenic, and even mutagenic properties, since a large part of the substances present are not part of the molecules produced and integrated into the evolution of man and the planet. Several of these elements and substances present results in harmful effects on the ecosystem organisms, leading to the selective elimination of organisms and changes in the biological and environmental characteristics (AKAR et al., 2009; GAYLARDE et al., 2005).

Contamination of water bodies by textile effluent causes visual pollution and prevents the possibility of using water resources in activities that sustain society, such as agriculture and consumption. Dyes have high stability and oxygen demand, low biodegradability, besides having total dissolved solids (RICACZESKI, 2017) and heavy metals such as cadmium, copper, lead, chromium, mercury, and zinc (BELTRAME, 2000).

The effluent from the coloring of clothing can be treated through chemical, physical or biological processes. The adsorption process has been considered an alternative because it is an economically feasible form of treatment, especially in the low cost of adsorbent.

In this context, the use of agro-industrial residues together with biotechnological processes can be fundamentally applied in the development of alternative and sustainable materials. Thus, the research aims to develop a sustainable alternative for the treatment of textile effluent through biodegradable bacterial cellulose (biomembrane) produced from the residue of wine production. The motivation comes from the fact that residue from wine production is generated in abundance in Brazil, becoming a contamination source for groundwater when incorrectly disposed of. The specific objectives are to search for sustainable materials that can purify water so it can be properly disposed of and to search for viable alternatives for wine production residue, commonly discarded and becoming a serious source of water and soil pollution. The research used statistical methods to produce bacterial cellulose, using resources and materials available in the scientific laboratory of the Federal Institute of Education, Science, and Technology of Rio Grande do Sul *(Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul - in Portuguese)* - Osório Campus. The methodology applied was defined as a scientific method, through experimentation and quantification of the data.

2. METHODOLOGY

2.1. Development of bacterial cellulose

The grape byproducts were collected in Wine Industries in the city of Bento Gonçalves, Rio Grande do Sul, Brazil. These materials were stored in the freezer. After the collection, a 2^3 Factorial Design with Response Surface methodology was performed, based on preliminary studies, to evaluate the statistical significance of wine residue, sucrose, and glucose (NETO, 2001). The residues used are composed of grape skins, seeds, and pulp. Table 1 shows the coded setting levels and actual values of the experimental design.

Table 1 – Factorial Design

Essay	Coded setting values			Actual values		
	x_1	x_2	x_3	X_1	X_2	$\boldsymbol{X_3}$
1	-1	-1	-1	10	10	10
2	1	-1	-1	120	10	10
3	-1	1	-1	10	50	10
4	-1	-1	1	10	10	50
5	1	1	-1	120	50	10
6	1	-1	1	120	10	50
7	-1	1	1	10	50	50
8	1	1	1	120	50	50
9	0	0	0	65	30	30
10	0	0	0	65	30	30
11	0	0	0	65	30	30
12	0	0	0	65	30	30

X_1* = concentration of wine residue [g/L]; X_2* = sucrose concentration [g/L]; X_3* = glucose concentration [g/L].

Source: Authors, 2022.

The coded settings were defined as follows equation (Eq. 1):

$$x_i = \frac{x_i - x_0}{\Delta x_i} \qquad \text{Eq. 1}$$

Where x_i is the coded value of the independent variable, x_0 is the real value of the independent variable in the 0 central point, and Δx_i is the step change value. The ranges and the level of the variables investigated were given in Table 1. The model for predicting the optimal point was expressed according to equation (2):

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_1 x_2 + \beta_5 x_1 x_3 + \beta_6 x_3 + \beta_7 x_1 x_3 x_{2+\varepsilon.} \text{ Eq. (2)}$$

Where Y represents the response variable for each attribute, β0 is the interception coefficient, β_1, β_2, β_3, β_4, β_5, β_6 , and β_7 are the linear terms, $\boldsymbol{x_1}$, $\boldsymbol{x_2}$ and $\boldsymbol{x_3}$, and represent the studied variables. The statistical significance of the model was evaluated by the F-test analysis of variance (ANOVA) with 95% reliability.

With the concentrations of inputs stipulated in the Factorial Design, the culture media were developed from the infusion of 10g/L of Camellia Sinensis. The media were then homogenized and autoclaved. The culture media received 16% of inoculum about its total volume and remained in the static medium for fermentation for 14 days. The developed bacterial celluloses were removed from their culture media, washed in running water, and dried in an oven at 35°C until constant weight.

2.2. Bacterial cellulose properties

The bacterial celluloses were evaluated for thickness and mechanical strength. The thickness of the cellulose was measured using a digital micrometer (Mitutoyo Corp. Tokyo, Japan; MDC-25) with a precision of 0.001 mm and a resolution from 0 to 25 mm. The thickness of each cellulose was determined by the average of sixteen different measures from random positions. The tensile strength of the cellulose was measured using cellulose cut into 8 strips (5 cm x 1 cm).

From the thickness data of each strip, the mechanical properties of tensile strength [MPa], Elongation at break [%], and Young's modulus [MPa] were determined using a texturometer (TA.XT2i and Stable Micro Systems, UK - United Kingdom). These analyses were according to the American Society for Testing and Materials D882-12.

2.3. Testing of the adsorbent material

To quantify the solutions of indigo carmine dye, the calibration curve according to the Lambert-Beer law was used with the spectrophotometer at the wavelength of 615 nm.

Three different solutions of indigo carmine dye, with concentrations of 5 mg/L, 15 mg/L, and 50 m/L, were prepared to test the adsorption of the bacterial celluloses produced.

The adsorptive filtration was used for the adsorption analysis of the dye and the effluent collected from the industries, at room temperature and fixed mass and volume. For this purpose, 8 squares (0.5 cm x 0.5 cm) of bacterial celluloses were placed in contact with sodium hydroxide (NaOH) 2.5% solution, where they remained for 1 hour. The celluloses were then washed.

Erlenmeyer flasks were filled with 30 ml of the solution containing indigo carmine at the concentrations described above, that had been in agitation for 24 hours. The solutions were read on a UV-Vis spectrophotometer. The test was carried out in duplicate. To calculate the removal of the dye, the following equation was used.

$$\%removal = \frac{(C_0 - C_e)}{C_0} \times 100\% \qquad \text{Eq. (3)}$$

where C_0 is the initial concentration of the adsorbate (mg/L) and C_e is the concentration of the adsorbate at equilibrium (mg/L).

After the tests with indigo carmine dye, tests were performed with textile effluent collected from a textile dyeing industry, with green and red coloration, with wavelengths of 500 nm and 610 nm, respectively. The effluent was collected directly after the dyeing process of polyamide and acrylic yarns.

3. RESULTS

3.1. Characterization of bacterial celluloses

The development of bacterial cellulose was observed in all culture media produced, demonstrating the potential of wine production residue in biotechnological processes. The Factorial Design was used to optimize the cellulose production process. The responses evaluated were thickness, elongation at break, stress, and Young's modulus (Table 2). The significance of each coefficient was determined by Student's *t-test* and *p*-value.

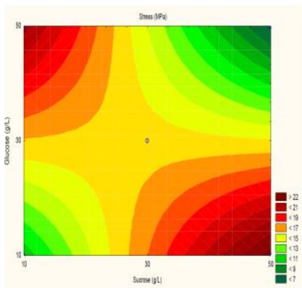
Table 2 – Characteristics of bacterial celluloses

Essay	**Stress (MPa)**	**Elongation to break (%)**	**The module of Young (MPa)**	**Performance [%]**	**Thickness [mm]**
1	12.04 ± 0.44 [a]	5.99 ± 0.84 [a]	201.72 ± 16.75 [d]	4.2 ± 0.68 [c]	0.130 ± 0.034 [a]
2	10.35 ± 1.56 [a]	15.93 ± 3.69 [b]	63.35 ± 3.63 [b]	1.92 ± 0.16 [a]	0.102 ± 0.036 [b]
3	19.61 ± 3.29 [b]	24.26 ± 0.87 [c,d]	123.77 ± 24.93 [c]	8.96 ± 1.43 [b]	0.162 ± 0.025 [c]
4	15.21 ± 1.81 [b]	35.12 ± 3.12 [e]	57.10 ± 5.42 [b]	8.16 ± 6.24 [a]	0.076 ± 0.025 [c]
5	27.21 ± 1.52 [b]	17.98 ± 1.25 [b,c,d]	217.01 ± 12.81 [d]	2.43 ± 0.74 [a]	0.098 ± 0.035 [c]
6	25.29 ± 4.00 [b]	23.68 ± 3.27 [b,e,d]	214.32 ± 7.8 [d]	2.98 ± 0.72 [a]	0.094 ± 0.024 [c]
7	4.95 ± 0.40 [a]	25.62 ± 3.82 [d]	24.84 ± 3.45 [a]	8.75 ± 1.03 [a]	0.092 ± 0.019 [d]
8	9.69 ± 3.28 [a]	16.65 ±3.95 [b,c]	75.90 ± 10.16 [b]	0.53 ± 0.67 [a]	0.115 ± 0.076 [d]
9	10.71 ± 1.32 [a]	73.31 ± 1.47 [f]	10.26 ± 0.01 [a]	3.46 ± 0.67 [a]	0.100 ± 0.016 [c]
10	17.19 ± 1.29 [a]	92.34 ± 10.11 [g]	11.42 ± 1.91 [a]	3.60 ± 0.33 [b]	0.207 ± 0.050 [e]
11	◉	◉	◉	3.11 ± 0.015 [b]	0.212 ± 0.032 [d]

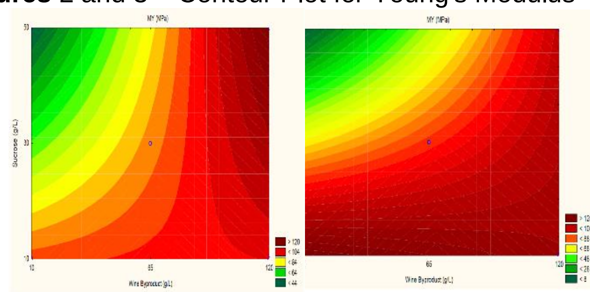
The symbol ◉ represents the tests where there was cellulose development, however, they were not used in the tests, as they were irregular in the center. Source: Authors, 2022.

The contour plot indicates that the glucose and sucrose variables were significant, indicating that changes in their concentrations will change stress. While the Young's Modulus Boundary Surface indicates that all variables were significant, indicating that changes in their concentrations will change Young's Modulus. Figures 1, 2, and 3 show the Contour Plots

Figure 1 – Contour Plot for Stress



Figures 2 and 3 – Contour Plot for Young's Modulus



Source: Authors, 2022.

3.2. Adsorption

The developed bacterial celluloses were evaluated as alternative adsorbent materials for the treatment of dye and industrial textile effluent which, if improperly disposed of, cause countless damages to our most precious resource, water. For this purpose, tests were conducted with the dye indigo carmine (IC), which is widely used in the textile industry for dyeing jeans. (TONETTO, 2018).

Table 3 shows dye removal at different concentrations using the developed bacterial celluloses:

Table 3 - Removal of the indigo carmine dye

Essay	5mg/L	15mg/L	50mg/L
1	◉	10.13 ± 1.08^{a}	5.24 ± 0.25^{a}
2	◉	42.47 ± 0.10^{c}	56.95 ± 0.166^{d}
3	57.59 ± 0.44^{e}	72.04 ± 0.43^{f}	16.92 ± 0.41^{b}
4	55.37 ± 0.44^{d}	26.49 ± 0.32^{b}	80.188 ± 0.166^{g}
5	◉	59.52 ± 0.10^{e}	38.50 ± 0.08^{c}
6	29.58 ± 1.11^{b}	78.11 ± 1.84^{g}	72.81 ± 0.08^{f}
7	73.43 ± 0.44^{f}	63.74 ± 1.08^{f}	63.14 ± 0.08^{e}
8	57.43 ± 0.22^{e}	52.99 ± 0.21^{d}	58.31 ± 0.25^{d}
9	49.52 ± 0.67^{c}	80.26 ± 0.10^{h}	72.52 ± 2.50^{f}

The ◉ symbol indicates that there was no removal. Source: Authors, 2023.

In the tests performed, it was possible to analyze that the bacterial cellulose has greater adsorption of the dye at higher concentrations or intermediate concentrations, such as 15 mg/L and 50 mg/L, since there was a removal in all the tests performed with the corresponding concentrations. According to Zhang and Wang (2015), this proves the idea that higher dye concentrations have higher concentration gradients, which increases the possibility of collisions between metal ions and active sites of the material.

In Figures 4, 5, and 6, it is possible to observe what happens to the dye before and after the bacterial cellulose treatment:

Figure 4 – IC Removal (5mg/L)

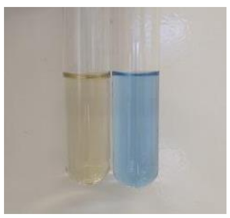
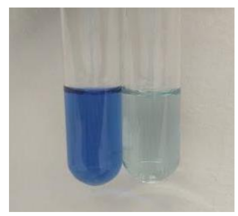


Figure 5 – IC Removal (15mg/L)

Figure 6 – IC Removal (50mg/L)



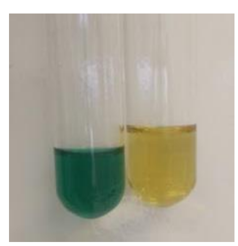
Source: Authors, 2023.

In addition, two industrial effluents, colored green and red, were collected from industries located in Brazil. They were evaluated according to the methodology presented in point 2.3. In Table 4, it is possible to observe the removal of the industrial effluents:

Table 4 – Removal of industrial effluent

Assay	Green	Red
1	53.06 ± 1.26^{c}	31.53 ± 0.26^{d}
2	54.03 ± 0.10^{c}	21.99 ± 0.08^{c}
3	51.94 ± 3.48^{c}	0.80 ± 0.08^{a}
4	56.80 ± 1.05^{c}	1.17 ± 0.08^{a}
5	44.02 ± 1.06^{b}	4.52 ± 0.08^{b}
6	16.51 ± 3.69^{a}	◉
7	40.13 ± 0.31^{b}	6.56 ± 1.05^{b}
8	45.66 ± 0,31^{b}	4.27 ± 0.08^{b}
9	41.33 ± 0,95^{b}	5.82 ± 2.45^{b}

Figure 7 – Removal of green industrial effluent



The ◉ symbol indicates that there was no removal. Source: Authors, 2023.

There was the removal of the green industrial effluent in all experiments carried out, with the removal of close to 50% of the effluent in all tests, except essay 6, showing the ability of cellulose to remove effluents collected from industrial textiles, of green and red coloration.

4. CONCLUSIONS AND RECOMMENDATIONS

This research has achieved its objective by developing a biodegradable alternative to the residue generated during the processing of grapes and the treatment of textile effluent. The project shows relevance by using agro-industrial residue in biotechnological processes. This bacterial cellulose can be highlighted by its application as an adsorbent membrane. The project presented results superior to those found in the literature, such as Boran (2022) who obtained only 5% removal of indigo carmine dye in 24 hours at a concentration of 50mg/L using cellulose produced from *Komagataeibacter saccharivorans* LN886705.

The project is highly relevant in terms of protecting water resources. Not only is it an alternative to the textile wastewater treatment process, but it also promotes the reuse of waste from wine production which, if improperly disposed of, can pollute surface and groundwater, and contribute to water table and groundwater contamination. Thus, both the use of agro-industrial residues and the textile effluent treatment process provides sustainable alternatives that save our most precious resource, water, while rethinking industrial processes.

The bacterial cellulose showed superior characteristics, such as dye removal, and can be applied in effluent treatment. Combining these characteristics of the developed cellulose, its low production cost, and its facility of biosynthesis, the bacterial cellulose produced with the grape agro-industrial residue showed technical feasibility. Using the markup method, the production cost of the developed 2 cm² cellulose was calculated to be R$ 0.46 (US$ 0.09)[1] to treat 1 liter of textile wastewater.

[1] Amount referring to the average conversion of the Real (Brazilian currency) to the US Dollar, conversion made on May 22, 2023, where 1 US dollar is equivalent to approximately 5.0342 reals.

This research proves to be promising in proposing an alternative to the waste generated during grape processing and biosynthesis of bacterial cellulose, addressing 8 of the 17 Sustainable Development Goals of the United Nations, being goals number 2 (Zero Hunger and Sustainable Agriculture), 6 (Drinking Water and Sanitation), 9 (Industry, Innovation, and Infrastructure), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), 13 (Combating Global Climate Change), 14 (Life in Water) and 15 (Life on Land).

Other forms of textile effluent treatment, such as the use of activated carbon, were compared, through a literature review, of the developed project. By comparing the benefit, we can conclude that the use of cellulose is more sustainable than the use of activated carbon, since the manufacture of coal involves the burning of vegetable matter, causing the generation of pollutants during the process. On the other hand, cellulose does not generate pollutants during its development but contributes to the correct and sustainable disposal of waste that, if disposed of incorrectly, can become polluting.

The project also sought to influence other young people about the importance of science in their daily lives, showing the importance of preserving water and other natural resources. Sharing ideas and data with the community, from children and teenagers from schools in the region to teachers and adults from the region and the state of Rio Grande do Sul. The project was developed having as its basis the sharing of ideas and experiences, seeking to generate awareness and impact on the lives of others. In addition, the project was developed by aggregating the concepts of circular economy and aggregating the tripod of sustainability: economic, social, and environmental.

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ANNEX A. QUESTIONS ABOUT THE PROJECT

1. **What are the major contributions expected from the implementation of this project considering the society, the economy, the environment, and especially the water resources?**

The project has important relevance for society, the economy, the environment, and especially water resources since its objective is to treat textile effluents from the biodegradable membrane produced with the residue from wine production. Textile effluents are some of the main contaminants of water resources, which bring numerous damages to the environment and society. The treatment of such effluents is necessary for environmental and social health, conserving our most precious resource, water. Considering this, new and more sustainable materials such as biodegradable membranes must be studied. The development of biodegradable materials also brings an alternative to synthetic plastics, since this is a biodegradable material, which does not harm the environment when discarded and degrades in, at most, 15 days, unlike synthetic plastics that degrade in four hundred years. In addition, the use of wine production residues brings great economic and environmental benefits. Improper disposal of agro-industrial waste can lead to soil contamination, as well as surface and groundwater pollution. Moreover, the utilization of wine production waste adds environmental and economic value by providing an alternative to disposal, thereby avoiding transportation costs as well.

2. **What innovation was proposed? How does it relate to existing solutions?**

The present project has two major points of innovation: the use of agro-industrial residue from wine production and the use of bacterial cellulose for the treatment of textile effluents. The use of such waste is very present in the southern region of Brazil, especially in the state of Rio Grande do Sul, it was not found in other works and projects searched in the literature review. The use of biodegradable membranes in the treatment of textile effluents brings another great point of innovation. The biodegradable membrane has been recently studied for this application, but the studies use more expensive resources, making the membrane's production cost higher. Thus, the project shows itself to be strongly innovative, by using residues and methods little or no explored, such as the residue from wine production. The project also has a potential of 100% use, aiming at the reuse of waste and considering desorption processes after the treatment of textile effluents.

3. **Which region or situation is the project applicable? Is it possible to replicate it? Does it serve developing and developed countries?**

The project can be used widely, the effluent from wine production is generated in massive quantities in the state of Rio Grande do Sul, but grapes are grown in several countries, and their derivatives, such as wine, are widely produced around the world. For example, China, Argentina, and Uruguay. Thus, biodegradable development membranes could be applied widely. Furthermore, membrane production can be conducted using several types of inputs, using those regionally present. The biodegradable development membranes could serve both developing and developed countries since industrial methods like the methods used in this project already exist. These existing industrial methods could be adapted and introduced to the project methodology, giving great amplitude to its application. The problems faced by the textile industries, especially in the disposal of effluents, have been affecting the entire world, directly or indirectly. It is of extreme relevance that sustainable and alternative materials are developed to solve the problems faced, and the implementation of innovative technologies becomes essential for the environment. Biodegradable membranes could be widely expanded, depending on their production and industrial level. Moreover, one of the main goals of this project is the sharing of ideas and the search for awareness, because it can be applied and performed anywhere in the world, in developed or developing countries, building consciousness about the textile industry and its impacts.

4. **What is the implementation cost of the project?**

According to the Mark Up method, the production cost of the developed membrane was calculated as U$0.092, using 8 squares with 0.25 cm² to treat 1 liter of textile effluent. The value was calculated considering the inputs and equipment used. The project uses waste that is discarded by industries, which adds value to the development of the membrane, reducing its cost. The production of membranes could be developed in fermentation tanks already existing in the market, which are used for the fermentation of beverages, without the need to develop new equipment, cheapening the process. For the implementation of the biodegradable membrane as adsorbent material in the industries of the sector, it would be necessary to establish partnerships with them, adapting their treatment systems and equipment to meet the methodology presented in the project. Also, it would require changes in the treatment process currently used, but the implementation cost for the technology would be zero. The economic costs are presented as an investment, giving long-term results by preserving the environment and a better world for this and future generations.

5. **What would be or were the biggest difficulties for the development and implementation of the project?**

The biggest challenges faced in the development of the project were the numerous tests performed since when building a new technology, we had to develop and adapt the methods from the very beginning. In addition, it was necessary to adapt the tests to the space and equipment present in the laboratory of the IFRS-Campus Osório. Some tests had to be performed in partnership with the Federal University of Rio Grande do Sul. The adaptation of the methodology was one of the greatest difficulties faced in the development of the project, but also one of the challenges that brought the most resilience to the author. The future difficulties faced in the implementation of the project would be its insertion in the market and its implementation in industries since adaptations in the treatment plants would be necessary to meet the methodological needs of the project. Moreover, it is predictable that difficulties will be encountered around the awareness about the impacts of textile industries, since we are inserted in a linear economic system and influenced by trends that aim at convenience and consumerism, such as fast fashion.

6. **Which Sustainable Development Objectives (SDOs) and goals does your work most relate to?**

The project is related to 8 of the 17 Sustainable Development Goals, goals number 2 (Zero Hunger and sustainable agriculture) by aiming at a sustainable agricultural production that uses passive methods for the use of its residues, without the generation of contaminants, relating to goal 2. an in the development of technologies; 6 (Clean water and sanitation), relating to generating an alternative for the treatment of textile effluents, one of the significant polluting agents of water resources, implementing the goals 6.3, 6.6 and 6. a; 9 (Industry, innovation, and infrastructure) aiming at the development of new sustainable technologies, meeting the goals 9.4, 0.5, 9. a and 9. b; 11 (Sustainable cities and communities) by contributing to more sustainable environments that have less impact on the environment; 12 (Responsible consumption and production) by using agro-industrial waste and generating an alternative treatment for textile effluents, meeting targets 12.2 to 12. 12.8 and 12. a and 12. b; 13 (Climate action) by developing an alternative capable of preserving natural resources, meeting the target 13.3; 14 (Life below water) by generating a biodegradable alternative to synthetic plastics, one of the biggest polluters of life in water, meeting the target 14.1; and 15 (Life on land) seeking to preserve the means of terrestrial life, especially fresh water, and its ecosystem, meeting the target 15.1.

7. **How does the work relate to the annual theme of SIWI's World Water Week 2023?**

The project is aligned with the social issues addressed by dealing with textile effluents, one of the biggest contaminants of water resources. Countless populations derive their sustenance from the rivers present in their regions; when contaminated these water bodies, they become unsuitable for the population to make a living, generating a major social crisis. The contamination of water resources also brings countless and serious damages to the environment, such as ecosystem interference and biodiversity loss. All the damages mentioned above are caused by human activities, putting our most precious resource into an unprecedented crisis. These actions happen all over the world, with no borders to the damage and challenges faced. In this way, the project relates to the theme by developing an innovation that deals directly with water, giving an alternative to one of the main industries that pollute water resources. The project can be applied in different regions, having a global reach, which relates to and enables the treatment and preservation of water without borders.

8. What moved you to choose this theme?

The initial motivation for the project was generated from the student's discomfort about plastic pollution, especially in the surroundings of her house and in her backyard when she found a plastic container that was not hers, seeing the need to generate some change against this problem after watching documentaries and reports and realizing that her discomfort comes from her childhood. The student saw the opportunity for change through science. After developing the biodegradable material, the feasibility of an innovative, sustainable, and thought-provoking approach was developed. Reviewed of the literature and its applicability as an alternative adsorbent material was found. Its use was chosen because of the shock of reading the data referring to textile pollution and its damage when faced with images that bring immense damage to the environment and society. In addition, the theme was chosen because it was innovative and challenging.