Development of a model for measuring water footprint

WP2: T2.2

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Introduction

The objective of this task was to develop a modeling framework/tool designed to calculate and quantify the water footprint for the textile industries. The tool incorporates various elements to assess the water footprint, utilizing data from case studies conducted in a previous task. The primary purpose of the tool is to provide textile industries with a means to accurately measure their water footprint. The creation of the tool involved two key components: a conceptual framework and technical operations.

The initial step in establishing the conceptual framework was to review and gather existing water footprint tools, particularly those tailored to the textile industry. These existing tools formed the foundation for the first version of our tool. To ensure the tool's robustness and accuracy, the initial conceptual framework was presented to and discussed with partner organizations (KTU, UPV, UNIWA, and LATIA) who provided valuable feedback for further improvement. The focus of the improvements was to enhance the quality and reliability of the tool.

Additionally, WFN directed efforts towards defining the technical operations of the tool, which involved specifying the calculations and methodologies used to determine water footprint values for various processing steps within the textile industry. By establishing a sound conceptual framework and incorporating well-defined technical operations, the resulting tool can effectively help textile industries in measuring and managing their water footprint.

Design choices

During the initial partners' meeting held in Kaunas, the decision was made to focus on the water footprint associated with fiber processing steps while excluding the water footprint related to the production process of fibers. Additionally, it was agreed to incorporate multiple fiber categories into the tool to ensure its comprehensiveness and applicability across different scenarios. To enhance accessibility for textile companies, default values for various processing steps and fiber categories were integrated into the tool. These defaults serve as a useful resource for users who lack specific information about their water use and consumption, providing them with an initial insight into their water-related practices.

The generic applicability of the tool is another important aspect of the tool. Water is typified by its local characteristics. The impact of a certain amount of water consumption in one location might differ from the impact the same amount has in a different location. The same applies to water pollution. However, to maximize the usability and reach of the tool the partners decided to highlight the generic applicability of the tool. The generic applicability translates to the water footprint related to water pollution which relies on local water quality standards. In addition, no differentiation in techniques for the different textile processing steps are considered, e.g. no differentiation in dyeing techniques. Moreover, the generic character of the tool implies that the included processing step are predetermined. These predetermined processing steps facilitate users that have no water use data readily available for their own operations.

The takes both the water use and the water consumption into account. Water consumption and water use are two different things. Often, there is confusion about the difference between the two terms in the scientific literature on water use/consumption in textile processing. Water use is the same as water intake from a factory perspective, and water consumption is the water that ‘leaves’ the water system. Water consumption from a factory perspective is the water intake minus the water discharge. Water consumption is more difficult to measure for textile producers than water use To address this, the tool allows users to manually enter their water use data, which is then used to estimate water consumption, providing a more realistic representation compared to using default values.

The accuracy of the tool's results depends on the level of specificity in the data entered by the user. Even with limited information, the tool can provide a preliminary water footprint estimation by considering the type and quantity of processed fibers and the involved processing steps. However, the results at this stage are based on generic default values and may not be specific to the user's situation. Enhanced specificity and usefulness can be achieved by providing more detailed data, such as water use and consumption per processing step, effluent volume, and pollutant concentration. Nevertheless, the less specific results serve as a good first indication and can serve as a starting point for the user in understanding their water footprint.

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Following the presentation of the main results in the tool, contextualization is provided to enhance the significance of the water footprint estimations. While the water footprint estimations offer insight into the amount of water consumed, their meaning is improved when placed within a relevant context. To achieve this, two sections are incorporated at the end of the tool. The first section is dedicated to the water footprint benchmark, which enables users to assess their performance in relation to a predefined benchmark. This assessment provides valuable indications of the water intensity of the user's processing steps and potential opportunities for improvement. It is worth noting that, in this initial version of the water footprint tool, the benchmark values align with the default values, representing the current state of the tool's development. The second section focuses on water footprint reduction targets, which are geographically specific. By inputting their location, users receive indications of desired water reduction targets. This feature serves as a valuable guide for users seeking to align their water consumption practices with local water management goals and environmental sustainability objectives.

The tool encompasses three primary fiber categories commonly used in textile processing: cellulosic, protein, and synthetic fibers. These broad categories consist of multiple fibers, each with slight variations in water intensity. To establish default values, the tool assumes the water use or consumption per fiber category to be equivalent to one of the main fibers within each category. Specifically, for cellulosic fibers, the default value is based on cotton; for protein fibers, it is derived from wool, and for synthetic fibers, it is estimated using polyester. By adopting this approach, the tool provides users with a convenient baseline for water footprint calculations, taking into account the diverse water characteristics of various fibers commonly employed in the textile industry.

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Method and data

The data required as input for the water footprint tool can be classified into two main categories. The first category involves determining which fibers and processing steps to incorporate into the tool. This information was obtained from the case studies conducted in WP 2 (T 2.1) and through discussions with the project partners. Additionally, existing textile tools and relevant literature were consulted to supplement the gathered data in this category.

The second category of data pertains to the water use and consumption associated with the included processing steps for each specific fiber category. This data was acquired through a literature study, examining various sources related to water use and consumption in textile processing. Furthermore, insights from pre-existing textile tools were used to complement the data in this category.

The fiber categories integrated into the water footprint tool comprise cellulosic (plant-based), protein (animal-based), and synthetic materials. Both natural and man-made fibers are encompassed within the first two categories. The inclusion of these fiber categories was determined through extensive discussions with project partners to ensure comprehensive coverage.

The tool incorporates various processing steps typically associated with wet processing in textile manufacturing. These steps are essential for water footprint calculations and are listed below. Although all steps are included in the tool, their applicability may vary for each fiber category. The initial selection of processing steps was drawn from the 'Water Calculation Tool For the Textile Wet Processing Sector' available at https://watercalculator.dnvgl.com/. Subsequently, the findings were validated and augmented based on insights from pertinent literature sources (Muthu, 2021; Senthil Kumar & Grace Pavithra, 2018). This iterative approach ensures the accuracy and relevance of the included processing steps in the water footprint tool.

- Desizing
- Scouring
- Carbonizing
- Rinsing
- Bleaching
- Mercerizing
- Dyeing
- Printing
- Finishing

Most literature on water use and consumption in the textile sector considers the processing steps for natural fibers, whereas protein and synthetic fibers might require alternative processing steps. To ensure comprehensive coverage and consistency within the water footprint tool, the processing steps considered for all three fiber categories were derived from a comprehensive report (Muthu, 2021; Senthil Kumar & Grace Pavithra, 2018). Table 1 provides a detailed list of the processing steps that are applicable to each respective fiber category.

Table 1: Processing steps per fiber category.

Processing step	Cellulosic	Protein	Synthetic
Desizing	X		
Scouring	X	X	X
Carbonizing		X	
Rinsing		X	
Bleaching	X	X	
Mercerizing	X		
Dyeing	X	X	X
Printing	X		X
Finishing	X	X	X

The water footprint tool takes into account both water use and consumption, which are terms often used interchangeably in literature when reporting values for processing steps. To ensure accuracy and prevent the inclusion of incorrect water consumption values, the tool utilizes water use values as input. Subsequently, these water use values are converted to water consumption values using a conversion ratio derived from a study involving 377 textile mills. These mills encompassed cotton weaving mills, knitting mills, and yarn & thread mills. The applied conversion ratio, 10%, represents the average ratio observed across the three types of mills (WFN & C&A Foundation, 2013). According to this ratio, 10% of the water use value is considered as the water consumption for a specific processing step. It is important to note that this 10% conversion factor is solely applied in cases where the user cannot specify the water consumption for a particular processing step. When the user provides direct information on water consumption, the entered values are used. In the tool the question regarding water use and water consumption are accompanied by a informative text box stating the difference between water use and water consumption to prevent any misunderstanding and provide some education on the water footprint.

The water use value for each processing step per fiber category are the input for the blue water footprint in the tool. The values are sourced from Muthu (2019) and represent the most up-to-date information available in the literature at the time of tool development. However, it's important to acknowledge that these values may change in the future as data may evolve as more research is conducted. As new information becomes available, the values in the tool may be adjusted to reflect the most current findings. The default water use values per fiber category and processing step are displayed in Table 2. To maintain the tool's accuracy, updates may be necessary to incorporate new data and reflect the latest findings. The current default water use values per fiber category and processing step are provided in Table 2.

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Processing step	Cellulosic	Protein	Synthetic
Desizing	11.8		
Scouring	32.5	28.0	50.2
Carbonizing		117.5	
Rinsing		584.5	
Bleaching	13.8	12.5	
Mercerizing	24.5		
Dyeing	155.0	19.0	76.5
Printing	6.0		16.4
Finishing	6.0		16.4

Table 2: Water use per processing step and fiber category

The processing steps relevant for the user are presented in the tool based on Table 1 considering the fiber categories selected by the user. Subsequently, the user is requested to input the quantity of fabric processed per fiber category. Regarding the water use data, there are three potential scenarios determined by the user's data availability:

1. The user has detailed data and can directly enter water use values for each processing step.
2. The user has aggregated water use data available at the factory level, allowing them to enter this information.
3. In the absence of specific water-related data, the user can proceed with the tool utilizing default values.

The first option provides a straightforward result for water use, as the user manually defines the values. In contrast, the second option involves a more complex approach to calculate water use per processing step. This complexity arises from the need to allocate factory-level data to the relevant processing steps for each fiber category. To accomplish this, the first step is to compute the water use for each fiber. This value is dependent on the water intensity per fiber category and the quantity processed for that category. The water intensity is derived as the sum of the default water use values per fiber category obtained from Table 2, and the quantity processed is defined by the user. The calculation of water use per fiber category involves taking the average of two distributions. The first distribution is based on the water intensity per fiber category, while the second distribution is based on the quantity processed per fiber category. Equation 1 depicts this calculation.

$$WU_{fiber} = \frac{WU_{tot} * \frac{DWU_{fiber}}{\Sigma DWU_{all\ fibers}} + WU_{tot} * \frac{Q_{fiber}}{\Sigma Q_{all\ fibers}}}{2} \#(1)$$

Where WU_{fiber} is the water use for a fiber category, WU_{tot} is the total water use of the factory, DWU_{fiber} is the default total water use for a fiber category, $DWU_{all\ fibers}$ is the sum of the water

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use of all fibers categories, Q_{fiber} is the quantity per fiber category, and $Q_{all\ fibers}$ is the sum of the quantity of all fibers.

The allocation of water use per fiber category to the respective processing steps is determined based on the relative water intensity of each processing step, as depicted in Equation 2.

$$WU_{process} = WU_{fiber} * \frac{DWU_{process}}{\sum DWU_{all\ processes}} \#(2)$$

Where $WU_{process}$ is the water use for a processing step for a fiber category, WU_{fiber} is the water use for a fiber category, $DWU_{process}$ is the default total water use for the specific processin step, $DWU_{all\ processes}$ is the sum of the water use of all processing steps for that fiber category.

The calculation process for water consumption follows a similar approach, dependent on the data availability provided by the user. There are three scenarios possible. In the first scenario, the user provides the water consumption values for each processing step. In the second scenario, the user can only provide aggregated water consumption data for the entire factory, Equations 1 and 2 are applied, but for water consumption instead of water use. The third scenario, in case the user lacks specific water consumption data a water use to water consumption conversion factor of 10% is applied to the relevant processing steps as described in the study by WFN and the C&A Foundation (2013).

An additional significant environmental impact from textile processing is water pollution. Within the water footprint methodology, water pollution is regarded as an alternative form of water consumption, namely the grey water footprint. This grey water footprint is considered a form of water consumption because it quantifies the volume of freshwater necessary to dilute polluted water to restore its quality to acceptable levels. Although this water is not physically consumed in the traditional sense, it becomes unavailable for immediate reuse due to contamination (Hoekstra et al., 2011). The tool incorporates the grey water footprint to account for water consumption resulting from pollution. Unlike the blue water footprint, which is determined at the processing step level, the grey water footprint is evaluated at the plant level due to the tool's generic applicability.

The pollutants considered in the wastewater from textile processing facilities are taken from the 'InoCottonGROW' water footprint tool (https://wf-tools.see.tu-berlin.de/wf-tools/inoCotton/#/) and complemented with partner input. The list of pollutants considered in the tool is presented below. It is important to acknowledge that this list may not be extensive and is might require updates over time. As new information becomes available or circumstances change, adjustments and additions may be made to ensure the tool's accuracy and completeness.

- COD

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- BOD5
- TSS
- Ammonium nitrate
- Total phosphorus
- Total chromium
- Cadmium
- Nickel
- Lead
- Zinc
- Copper
- Sulfide
- Total phenols
- Pentabromodiphenyl ether (pentaBDE)
- Octabromodiphenyl ether (OctaDBE)

The maximum allowable concentration of these pollutants in different water bodies can vary significantly based on the desired use and environmental requirement of the water body. In addition, different water bodies might respond differently to the same increase in concentration of a specific pollutant, resulting in diverse environmental impacts. This local variability in maximum allowable concentrations hampers the generic applicability of the tool. To circumvent this local aspect, the Zero Discharge of Hazardous Chemicals Wastewater Guidelines (ZDHC, 2022) are implemented in the tool. ZDHC is dedicated to promoting the textile industry's adoption of safer and more sustainable chemicals. In order to achieve this goal, the organization created a list of pollutants with corresponding parameter limit values categorized into three different levels: foundational, progressive and aspirational. These limit values are based on an extensive analysis of over 100 wastewater test reports from the textile and footwear industries. The foundational limits were met by 90% of the test reports, while 50% adhered to the progressive limits, and 20% achieved the aspirational limits (ZDHC, 2023). Among the three categories, the aspirational limits represent the most stringent values and closely align with the maximum allowable concentrations required for calculating the grey water footprint, as presented by Franke et al. (2013). Therefore, the tool employs the aspirational limit values as the maximum allowable concentration for each pollutant in the determination of the grey water footprint. This ensures a more standardized and robust assessment of the environmental impact of wastewater pollution from textile processing, regardless of specific local conditions.

The grey water footprint is computed for the selected pollutants, as specified by the user, following Equation 3. In the original Equation c_{nat} of the receiving water body has to be specified, but it is not considered (equal to zero) in the calculation in the tool since it is a local component that cannot be considered in the tool due to the generic applicability. This will lead to a underestimation of the grey water footprint due to the fact that the dilution capacity of the receive water body is overestimated. The resulting grey water footprint displayed in the tool corresponds to the grey water footprint of the critical pollutant, which denotes the pollutant with the largest grey water footprint among the chosen pollutants (Safaya et al., 2016).

$$GWF_{pollutant} = \frac{c_{pollutant} * effluent}{c_{max}} \#(3)$$

Where $GWF_{pollutant}$ is the grey water footprint of the specific component, $c_{pollutant}$ is the concentration of the specific pollutant, effluent is the effluent volume, and c_{max} is the maximum allowable concentration for the specific pollutant.

In certain scenarios, users may lack information on the concentration of pollutants in their effluent, yet the tool must still provide a grey water footprint value to ensure generic applicability. To address this, a dilution factor is applied in the calculation. The dilution factor denotes the ratio of freshwater required to dilute the effluent, and consequently, the grey water footprint depends on this ratio and the volume of the effluent. The grey water footprint is derived as the product of the dilution factor and the effluent volume.

The dilution factor, a predefined parameter, operates behind the scenes within the tool and comes into play when users lack data on pollutant concentrations. It relies on both the maximum allowable concentration (as previously defined) and the actual concentration of pollutants in the effluent. Obtaining precise data on the actual concentration can be complex, hence the tool adopts an approach based on ZDHC's parameter limit values. ZDHC's analysis of 100 test reports showed that the foundational limit values were met by 90% of the reporters. Therefore, the foundational limit value is considered an approximation for the actual concentration in the effluent from textile processing companies.

The dilution factor is predefined and serves an behind the scenes input for the tool and will be applied when the user does not know the concentration of pollutants. The dilution factor depends on the on the maximum allowable concentration and the actual concentration of pollutants in the effluent. The maximum allowable concentration is defined in the previous section. The actual concentration is complex to define as no data on actual concentration is available. Again, the parameter limit values from ZDHC can be considered to deal with this issue. The 100 test reports used by ZDHC to determine the parameter limit values show that the foundational limit values were met by 90% of the reporters. The tool considers this foundational limit value as the actual concentration since it is met by 90% of the reports and is assumed to be a decent estimation for the actual concentration.

This means that the dilution factor per pollutant is determined by dividing the foundational limit by the aspirational limit. The tool uses an average dilution factor of 51, which results from calculating the average dilution factor across all pollutants. Table 3 provides a detailed overview of the dilution factor for each pollutant, along with the average dilution factor. This methodology allows the tool to generate meaningful grey water footprint values, even in situations where explicit pollutant concentration data is not available.

Table 3: Dilution factor per pollutant and as average of all pollutants.

Pollutant	Foundational (mg/L)	Aspirational (mg/L)	Dilution factor
COD	150	40	3.75
BOD5	30	8	3.75
TSS	50	5	10
Ammonium nitrate	10	0.5	20
Total phosphorus	3	0.1	30
Total chromium	0.2	0.05	4
Cadmium	0.1	0.01	10
Nickel	0.2	0.05	4
Lead	0.1	0.01	10
Zinc	5	0.5	10
Copper	1	0.25	4
Sulfide	0.5	0.01	50
Total phenols	0.5	0.001	500
Pentabromodiphenyl ether (pentaBDE)	-	0.025	-
Octabromodiphenyl ether (OctaDBE)	-	0.025	-
Average			51*

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Presentation of results

After completing all the questions in the tool, the user is directed to a results page. The results are systematically presented along with contextual information to place the results into perspective. Initially, the outcomes of water use and blue water footprint are provided in both tabular and graphical formats for each fiber category, limited to a maximum of three tables and figures. These outcomes serve to highlight the predominant processing step responsible for water use and consumption within each fiber category. Additionally, they provide insights into the proportion of water use that is actually consumed. It is important to note that this latter aspect becomes relevant only when the user has provided their own data on water use and blue water footprint. In the absence of user-specific data, the tool assumes a default water consumption of 10% of the total water use for all processing steps.

Next, the outcomes concerning water use and blue water footprint are specified for each fiber category, aiming to provide an understanding of the significance of each category. The results are presented through both visual and numerical formats: a figure and a table. The figure serves as a graphical representation, allowing the user to visually distinguish the relative importance of each fiber category. The table presents numerical values, enabling the user to obtain the specific values.

The representation of the grey water footprint can vary based on the calculation scenario applied within the tool, dependent on the availability of data provided by the user concerning pollutant concentration in the effluent. There are two distinct scenarios to be considered. When the user cannot provide data on pollutant concentrations in their effluent, the resulting depiction of the grey water footprint is a single bar graph. This graph shows the overall grey water footprint without differentiating between specific pollutants. If the user provides relevant data on pollutant concentrations in the effluent, the grey water footprint is presented in a more elaborately. A bar graph will display the grey water footprint associated with each pollutant, and a corresponding table will provide precise numerical values for each pollutant's grey water footprint. Furthermore, the critical pollutant is highlighted to emphasize its significance in terms of the grey water footprint. A text box will present the critical pollutant, along with the corresponding size of its grey water footprint.

The contextualization is added to enhance the relevance of the water footprint estimations. A water footprint value in itself provides an insight into the water consumption. However, understanding the context of a water footprint value is crucial for accurate interpretation. One of the ways to provide context to the water footprint value is to compare the value to the relevant water footprint benchmark. A water footprint benchmark refers to a standard or reference point against which water footprint values can be compared or evaluated. It serves as a basis for assessing the efficiency in relation to a specific product, process, or industry. To achieve this, the unit blue water footprint for each processing step, expressed in L/kg, is presented in a tabular format alongside the corresponding benchmark value in an adjacent column. Additionally, the last column of the table indicates the percentage deviation from the benchmark value. A negative deviation signifies a water footprint value lower than the benchmark, while a positive deviation indicates an exceedance of the benchmark. Importantly, in the absence of user-provided data, since the benchmark value is set as the default, rendering all deviations from the benchmark as zero. A maximum of three benchmarking tables are generated, one for each fiber category.

The second method of contextualization comes from the geographical location of the user's factory and the incorporation of local water consumption reduction targets. This integration is facilitated through a specialized tool provided by the Science Based Targets Network (https://tools.waterfootprint.org/sbtn-water-targets/). The user specifies their factory's location on the map, which shows the collective water reduction targets at the basin level. Once the user selects the location on the map, the tool assesses the relevance of water reduction targets for the specific basin and presents the reduction targets. These targets represent the desired reduction in water consumption at the basin level, aiming to be achieved by all users within the area. The presented reduction targets could be used for the user’s own water consumption reduction targets.

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Design and routing of questions

The tool consists of two parts. The first part includes the blue water footprint of the textile producers, i.e. freshwater consumption from surface- and groundwater. The second part of the tool encompasses the grey water footprint related to water pollution due to pollutants in the effluent. The blue water footprint will be determined per fiber for each processing step individually, whereas the grey water footprint will be determined at plant/factory level because it is not feasible to assign pollutant loads to the individual processing steps.

All questions of the tool are listed below. The questions that are presented to the user depend on the answers of the user is previous questions. Appendix A contains detailed information about all the questions, the answer possibilities and calculation methodology. An overview of how the questions related to each other is given in the Appendix B.

1. How would you characterize your company?
2. What kind of fibers do you process?
3. How much of each fiber do you process (kg/year)?
4. Please select your processing steps for *X* fibers?
    a. Cellulosic
    b. Protein
    c. Synthetic
5. Do you know you water use?
    a. “Yes, at the level of each processing step”
    b. “Yes, at the level of my entire operations (e.g. factory)”
    c. “No”
6. Please enter water use per processing step for *X* fibers (m^3/year)
7. Please enter water use of your entire operations (m^3/year)
8. Do you know you water consumption?
    a. “Yes, at the level of each processing step”
    b. “Yes, at the level of my entire operations (e.g. factory)”
    c. “No”
9. Please enter water consumption per processing step for *X* fibers (m^3/year)
10. Please enter water consumption of your entire operations (m^3/year)
11. Do you know the volume of the effluent of your operations?
12. Please enter the volume of the effluent of your operations (m^3/year)
13. Do you know the concentration of the pollutants in your effluent?
14. Please enter the concentration per pollutant in your effluent (mg/L)

Question 1 is an introductory question to analyze what type of companies are using the tool and to get a first insight in what processing steps are relevant for the user. Questions 2 to 10 are included to determine the blue water footprint of the processing steps. Question 11 to 14 aim to gather the information necessary to establish the estimation of the grey water footprint at plant level.

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Appendix A – Design and routing of questions

The boxed numbers boxes correspond to the same boxed numbers in the flowchart in Appendix B).

Title

To be shown on homepage/above Q1: The water footprint of textiles processing

Q1: How would you characterize your company?

- Spinning
- Weaving
- Knitting
- Finishing ⓘ
- Non-woven from textile waste
- Clothing manufacturer

*The respondent can select **multiple** answer options.*

[1] *Show the information from Table 1 when clicking on or hovering above the Finishing button*

Table 1: Clarifications guiding company characterization

Company type	Clarifying information to be shown (by clicking or hovering)
Finishing	Finishing refers to all process steps that occur after pre-treatment, such as Dyeing, Printing and Textile Finishing. You can further specify specific Finishing process steps in a later question.

Q2: What kind of fibers do you process?

- Cellulosic (natural & man-made)
- Protein (natural & man-made)
- Synthetic

*The respondent can select **multiple** answer options.*

Depending on answer(s) selected, continue work flow for that specific fiber kind, adapting answer options accordingly.

Q3: How much of each fiber do you process (kg/year)?

*Show entry box for each of the fibers selected in **Question 2**.*

The respondent enters the numeric value(s) manually. Allow for decimal separator.

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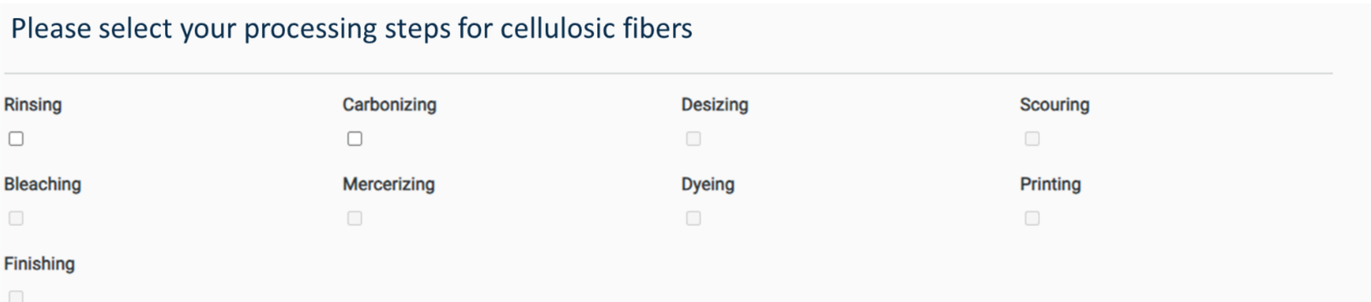
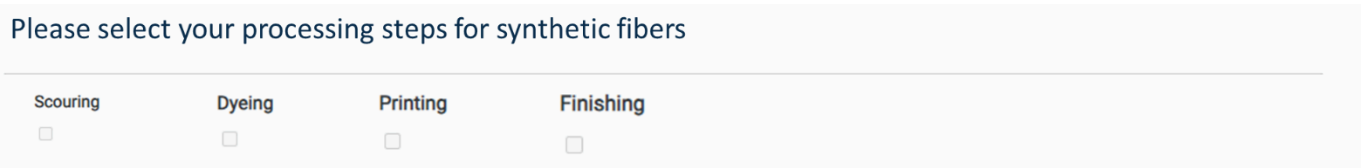
Q4: Please select your processing steps for *X* fibers

- Desizing
- Scouring
- Carbonizing
- Rinsing
- Bleaching
- Mercerizing
- Dyeing
- Printing
- Finishing

*The respondent can select **multiple** answer options.*

2. *Show the options sequentially for the different selected fibers from **Question 2.** Fill in the name of the specific fiber at the end of this question, **Question 4**, (X, for example cellulosic fibers or protein fibers). This question can result in max 3 sub question, because we have 3 fibers. See the example below. In this case 2 fibers are selected so the tool should show two options. This makes it easier to differentiate between the processing steps per fiber category.*





*Show the relevant processing steps based on the fabric selection in **Question 2** according to **Table 2**.*

Table 2: Processing steps per fiber category

Processing step	Cellulosic	Protein	Synthetic
Desizing	X		
Scouring	X	X	X
Carbonizing		X	

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Rinsing		X	
Bleaching	X	X	
Mercerizing	X		
Dyeing	X	X	X
Printing	X		X
Finishing	X	X	X

3. *Display the information from **Table 3** when clicking or hovering above the i-button (information button).*

Table 3: Definition processing steps

Processing step	**Clarifying information to be shown (by clicking or hovering)**
Desizing	Desizing refers to the removal of natural impurities and singeing compounds.
Scouring	After desizing, the fibers may still contain e.g. grease, lubricants, antistatic agents, waxes. Scouring removes such impurities.
Carbonizing	Carbonizing is a continuous process which combines scouring to remove grease and a chemical process to remove organic matter such as seeds, burs and grass. Carbonizing entails the fabric being immersed in acid, for it then to be neutralized by a solution of alkali.
Rinsing	Rinsing refers to the removal of any residual chemicals after carbonizing.
Bleaching	Bleaching refers to the process of decolorization of raw textile material through removal of inherent and or acquired coloring components from the fiber.
Mercerizing	Mercerizing refers to the process in which textiles are treated with a caustic solution to improve the fiber’s tensile strength, luster, and dye affinity.
Dyeing	Dyeing refers to adsorption of dyes from an aqueous solution onto the fibre surface and the diffusion of these dyes into the fibre.
Printing	Printing refers to the decoration of textile fabrics by application of pigments, dyes, or other related materials in the form of patterns.
Finishing	Finishing refers to the processes that convert the woven or knitted cloth into a usable material. Finishing can also be understood as any process performed after dyeing the yarn or fabric to improve the look, performance, or feel of the finish textile or clothing.

INSERT

4. “A water footprint is an indicator of water consumption. The following questions will help calculate your blue water footprint.

   However, not all water that is used is also consumed. Although often used interchangeably, water use and water consumption are two different indicators. They are both relevant so we will calculate them both.

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Water use refers to gross volumes of water, such as the (metered) intake from taps or wells. Water consumption refers to net volumes of water (water that does not or cannot be returned to the water system) and can be calculated by subtracting water discharge from water intake. Water consumption is equal to the blue water footprint."

Q5: Do you know your water use?

- Yes, at the level of each processing step
- Yes, at the level of my entire operations (e.g. factory)
- No

*The respondent can select **one** answer option*

*If 'Yes, at the level of each processing step', proceed to **Question 6***

*If 'Yes, at the level of the entire plant', proceed to **Question 7***

5. *If 'No', proceed to **Question 8.** Behind the scenes, water use is set at the default water use for the selected fiber(s) and processing steps selected in **Question 4** combined with the processed quantity of each fiber from **Question 3** (see **Equation 1**). The total water use of a fiber is the sum of the water use per processing step. Default water use values per processing step are provided in* Table 4. *(For example if a respondent shows it processes cellulosic fiber and it includes Dyeing and Printing, then the water use values are 155.0 L/kg and 6.0 L/kg respectively).*

$$WU_{process} = DWU_{process} * Q_{fiber} * 0.001\#(1)$$

*For example, a respondent showed that it processed cellulosic (500 kg/year) and one of the processing steps is dyeing. Then the $WU_{process}$ becomes 155.0 * 500 = 77,500 L/year, multiplying this by 0.001 to convert it from liters to m^3 results in 77.5 m^3/year.*

Table 4: Water use per processing step and fiber category

Processing step	Cellulosic	Protein	Synthetic
Desizing	11.8		
Scouring	32.5	28.0	50.2
Carbonizing		117.5	
Rinsing		584.5	
Bleaching	13.8	12.5	
Mercerizing	24.5		
Dyeing	155.0	19.0	76.5
Printing	6.0		16.4
Finishing	6.0		16.4

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Q6: Please enter water use per processing step for *X* fibers (m^3/year)

*Show processing steps selected in **Question 4** only. The respondent manually enters the numeric value(s) per processing step. Allow for decimal separator.*

*Show the options sequentially for the different selected fibers from **Question 2**. Fill in the name of the specific fiber at the end of this question, **Question 6**, (X, for example cellulosic fibers or protein fibers). This question can result in max 3 sub question, because we have 3 fibers. See the example below. In this case 2 fibers are selected so the tool should show two options. This makes it easier to differentiate between the water use per processing steps per fiber category.*

Please enter water use per processing step for cellulosic fibers (m3/year)

Desizing | Scouring | Bleaching | Mercerizing

Dyeing | Printing | Finishing

Please enter water use per processing step for synthetic fibers (m3/year)

Scouring | Dyeing | Printing | Finishing

*Proceed to **Question 8 (skip Question 7)***

Q7: Please enter water use of your entire operations (m^3/year)

The respondent manually enters the numeric value(s) per processing step. Allow for decimal separator.

6. *Behind the scenes, water use at operations level is attributed to the relevant fiber categories (from **Question 2**) based on the relative share in default water use of the different fibers according to* Table 5 *and the quantity per fiber as defined in **Question 3**.*

Table 5: Default average water use per fiber category (unspecified by process step).

Fiber category	Default average water use (L/kg)
Cellulosic	249.5
Protein	761.5
Synthetic	159.3

*The water use per fiber, WU_{fiber}, is calculated according to **Equation 2**. First the distribution of the overall water use (at plant level), WU_{tot}, is determined by*

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multiplying WU_{tot} by the fraction of the default water use (DWU_{fiber}) and the sum of the default water use ($DWU_{all\ fibers}$) (highlighted in green in the equation), and second the distribution of the overall water use (at plant level), WU_{tot}, is determined by multiplying WU_{tot} by the fraction of the fiber quantity (Q_{fiber}) and the sum of the fiber quantity ($Q_{all\ fibers}$) (highlighted in yellow in the equation). These two components are then added and divided by 2 to obtain the average water use per fiber of both manners of distribution.

$$WU_{fiber} = \frac{WU_{tot} * \frac{DWU_{fiber}}{\sum DWU_{all\ fibers}} + WU_{tot} * \frac{Q_{fiber}}{\sum Q_{all\ fibers}}}{2} \#(2)$$

*For example a respondent showed that it processed cellulosic (500 kg) and synthetic fibers (600 kg). Calculate WU for cellulosic, WU_{tot} is 80,000 m^3 and DWU can be taken from the table above. WU_{fiber} becomes (80,000 * (249.5 / (249.5 + 159.3)) + 80,000 * (500 / (500 + 600))) / 2 = 42,594.73 m^3.*

*The water use at plant level is divided over the relevant processing steps based on the relative default water use values for the corresponding processing steps, see **Equation 3**.*

$$WU_{process} = WU_{fiber} * \frac{DWU_{process}}{\sum DWU_{all\ processes}} \#(3)$$

*The water use of a processing step for a certain fiber is the overall water use of the fiber (WU_{fiber}) multiplied by the ratio of the default water use of the corresponding process, $DWU_{process}$, and all the processes that are included for that fiber, $DWU_{all\ processes}$, (as given in **Question 4**). The default water use values are displayed in **Table 4**.*

*For example if the overall water use of a fiber category is 8,000 m^3 and the relevant processing steps for a cellulosic fiber are dyeing and printing based on **Question 4**, then the water use for dyeing of the cellulosic fiber is 8,000 * (155.0/(155.0 + 6.0) = 7,701.9 m^3.*

7. *The text box explaining the difference between water use and water consumption from **Question 5** should be repeated to prevent misunderstandings.*

Q8: Do you know your water consumption?

- Yes, at the level of each processing step
- Yes, at the level of my entire operations (e.g. factory)
- No

*The respondent can select **one** answer option*

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If 'Yes, at the level of each processing step', proceed to ***Question 9***

If 'Yes, at the level of the entire plant', proceed to ***Question 10***

8. *If 'No', proceed to* ***Question 11.*** *Behind the scenes, the water consumption is determined by considering a percentage of the water use at* ***Question 6 or Question 7*** *as the water consumption. This percentage is 10%. The water consumption per processing step in* m^3 *is calculated according to* ***Equation 4****. The total water consumption of a fiber is the sum of the water consumption per processing step.*

$$WC_{process} = WU_{process} * 0.10 \#(4)$$

Q9: Please enter water consumption per processing step for *X* fibers (m^3/year)

Show relevant processing steps based on ***Question 4*** *(the processing steps chosen by the respondent) and display the possibility for the respondent to enter the amount manually per processing step.*

Show the options sequentially for the different selected fibers from ***Question 2****. Fill in the name of the specific fiber at the end of this question,* ***Question 9****, (X, for example cellulosic fibers or protein fibers). This question can result in max 3 sub question, because we have 3 fibers. See the example below. In this case 2 fibers are selected so the tool should show two options. This makes it easier to differentiate between the water consumption per processing steps per fiber category.*

Please enter water consumption per processing step for cellulosic fibers (m3/year)

Desizing	Scouring	Bleaching	Mercerizing
Dyeing	Printing	Finishing	

Please enter water consumption per processing step for synthetic fibers (m3/year)

Scouring	Dyeing	Printing	Finishing

Proceed to ***Question 11,*** *skip* ***Question 10****.*

Q10: Please enter water consumption of your entire operations (m^3/year)

Display the possibility for the respondent to manually enter the water consumption for the entire plant. The water consumption at plant level is divided over the relevant fiber categories

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based on the relative default water consumption of the different fibers (according to table below) and the quantity per fiber as defined in ***Question 3****.*

Table 6: Total default average water consumption per fiber category

Fiber category	Default average water consumption (L/kg)
Cellulosic	24.95
Protein	76.2
Synthetic	15.93

9. *The water consumption per fiber, WC_{fiber}, is calculated according to* ***Equation 5****. First the distribution of the overall water consumption (at plant level), WU_{tot}, is determined by multiplying WC_{tot} by the fraction of the default water consumption (DWC_{fiber}) and the sum of the default water consumption ($DWU_{all\ fibers}$) (highlighted in green in the equation), and second the distribution of the overall water consumption (at plant level), WC_{tot}, is determined by multiplying WC_{tot} by the fraction of the fiber quantity (Q_{fiber}) and the sum of the fiber quantity ($Q_{all\ fibers}$) (highlighted in yellow in the equation). These two components are then added and divided by 2 to obtain the average water consumption per fiber of both manners of distribution.*

$$WC_{fiber} = \frac{WC_{tot} * \frac{DWC_{fiber}}{\sum DWC_{all\ fibers}} + WC_{tot} * \frac{Q_{fiber,x}}{\sum Q_{all\ fibers}}}{2} \#(5)$$

*For example a respondent showed that it processed cellulosic (500 kg) and synthetic fibers (600 kg). Calculate WC for cellulosic, WC_{tot} is 80,000 liters and DWC can be taken from the table above. WC_{fiber} becomes (80,000 * (24.95 / (24.95 + 15.93)) + 80,000 * (500 / (500 + 600))) / 2 = 42,594.73 liters.*

The water consumption at plant level is divided over the relevant processing steps based on the relative default water consumption values for the corresponding processing steps, see ***Equation 6****.*

$$WC_{process} = WC_{fiber} * \frac{DWC_{process}}{\sum DWC_{all\ processes}} \#(6)$$

The water consumption of a processing step for a certain fiber is the overall water consumption of the fiber (WC_{fiber}) multiplied by the ratio of the default water consumption of the corresponding process, $DWC_{process}$, and all the processes that are included for that fiber, $DWC_{all\ processes}$, (as given in ***Question 4****). The default water consumption values are displayed in the table below.*

For example if the overall water consumption of a fiber category is 8,000 liters and the relevant processing steps for a cellulosic fiber are dyeing and printing based on ***Question 4****, then the water consumption for dyeing of the cellulosic fiber is 8,000 * (15.5/(15.5 + 0.6) = 7701.9 liters.*

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Table 7: Water consumption per processing step and fiber category (L/kg)

Processing step	Cellulosic	Protein	Synthetic
Desizing	1.18		
Scouring	3.25	2.8	5.02
Carbonizing		11.75	
Rinsing		58.45	
Bleaching	1.38	1.25	
Mercerizing	2.45		
Dyeing	15.5	1.90	7.65
Printing	0.6		1.64
Finishing	0.6		1.64

INSERT

"A water footprint also includes a pollution component, the grey water footprint. The grey water footprint of a product is an indicator of freshwater pollution. It is defined as the volume of freshwater that is required to assimilate the load of pollutants based. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards. The following questions will help calculate your grey water footprint."

Q11: Do you know the volume of the effluent of your operations (m^3/year)?

- Yes
- No

*The respondent can select **one** answer option*

*If 'Yes' proceed to **Question 12**,*

10 *If 'No' proceed to **Question 13.** Behind the scenes, effluent volumes are calculated as the difference between the total water use of all processing steps and fabrics combined and total water consumption of all processing steps and fabrics combined at operations level (see **Equation 7**). In m^3/year.*

$$Effluent = Water\ use - water\ consumption \#(7)$$

Q12: Please enter the volume of the effluent of your operations (m^3/year)

The respondent manually enters the numeric value. Allow for decimal separator.

Q13: Do you know the concentrations of pollutants in your effluent?

- Yes
- No

*The respondent can select **one** answer option*

If 'Yes' proceed to ***Question 14***

11. *If 'No', END. Proceed to* ***Results.*** *The grey water footprint (water consumption related to pollution) is set equal to the volume of the effluent multiplied by a dilution factor of 51,* ***Equation 8****. This water footprint is unrelated to the processing steps. In* m^3*/year.*

$$GWF = effluent * f_{dilution} \#(8)$$

Q14: Please enter the concentrations per pollutant in your effluent (mg/L)

The respondent manually enters the numeric value(s) per pollutant listed below. Allow for decimal separator.

- *COD*
- *BOD5*
- *TSS*
- *Ammonium nitrate*
- *Total phosphorus*
- *Total chromium*
- *Cadmium*
- *Nickel*
- *Lead*
- *Zinc*
- *Copper*
- *Sulfide*
- *Total phenols*
- *Pentabromodiphenyl ether (pentaBDE)*
- *Octobromodiphenyl ether (ocotBDE)*

12. *The grey water footprint (GWF) is determined according to* ***Equation 9****. In the equation* $c_{pollutant}$ *is the concentration of the pollutant in the effluent, which is multiplied by the size of the effluent to determine the pollutant's load on the environment. This load is divided by the maximum allowable concentration (*c_{max}*) to calculate the grey water footprint.* $C_{pollutant}$ *is the concentration the respondent enters. The maximum allowable concentration is given in* Table 8.

$$GWF_{pollutant} = \frac{c_{pollutant} * effluent}{c_{max}} \#(9)$$

Where, $c_{pollutant}$ *(from* ***Question 14****) and* c_{max} *(****Table 8****) are in mg/L and effluent (from* ***Question 11*** *or* ***Q12****) in* m^3

The GWF will be determined for each of the pollutants, but the pollutants with the highest GWF is leading and is the value that will be displayed in the results. The

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results should show the value of the grey water footprint and the pollutant that is causing it.

Table 8: Maximum allowable concentration per pollutant

Pollutant	Max concentration (mg/L)
COD	40
BOD5	8
TSS	5
Ammonium nitrate	0.5
Total phosphorus	0.1
Total chromium	0.05
Cadmium	0.01
Nickel	0.05
Lead	0.01
Zinc	0.5
Copper	0.25
Sulfide	0.01
Total phenols	0.001
Pentabromodiphenyl ether (pentaBDE)	0.025
Octobromodiphenyl ether (octoBDE)	0.025

Final page questionnaire

Display the following text:

'*Thank you for completing the questions in this water footprint tool. The results will show after submitting the data'.*

Results

Show the following text:

"The results generated by this tool are intended to provide preliminary insights and should be regarded as approximate indications of the water footprint. A more comprehensive and detailed analysis, incorporating site-specific data and robust methodologies, is necessary to obtain a more precise estimation of the water footprint associated with the specific activities or processes being evaluated. By providing more specific input and obtaining tailored results, the user can gain a better understanding of its water footprint and its potential impact. Customized assessments can enable the user to identify areas for improvement, implement targeted strategies, and make informed decisions towards reducing its water footprint."

Title: Water use and the blue water footprint

Show the following text:

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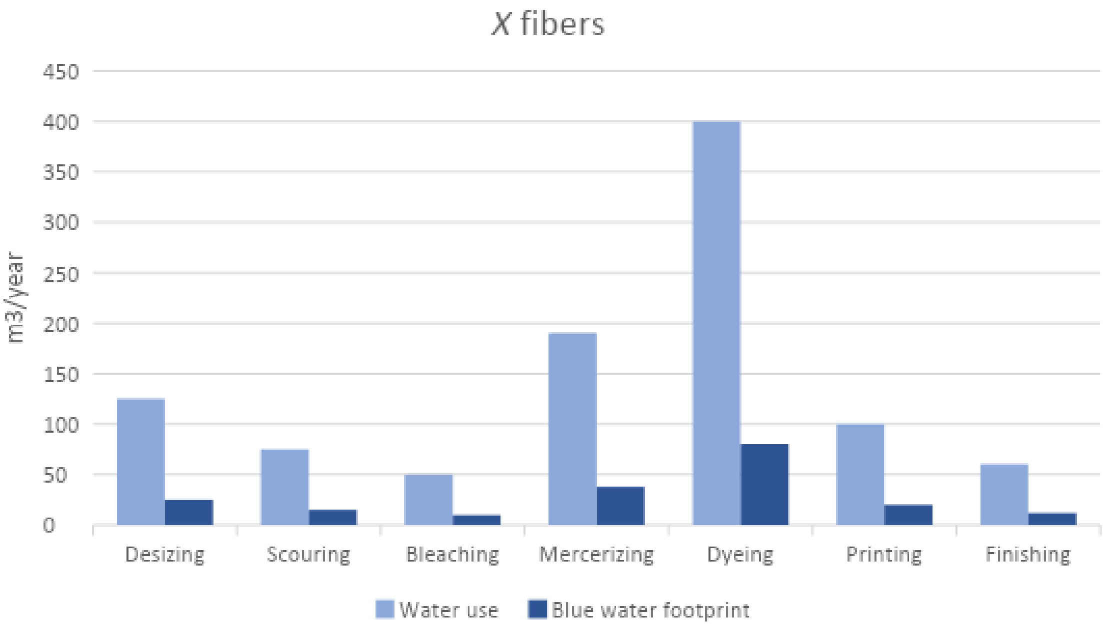
"This section presents the water use and blue water footprint results for each fiber throughout the processing steps. The water use indicates the amount of water withdrawn, while the blue water footprint represents freshwater consumption.

To reiterate the difference between water use and water consumption: Water use refers to gross volumes of water, such as the (metered) intake from taps or wells. Water consumption refers to net volumes of water (water that does not or cannot be returned to the water system) and can be calculated by subtracting water discharge from water intake."

Section title: "Water use and blue water footprint per processing step for each fiber category"

Show different bar graph and table for each fiber (max 3, because only 3 fiber categories available). First show the bar graph and the corresponding table per fiber before going to the next fiber.



Consider the graph above as an example of how the figure should look like (more or less). The details are specified below. Number of bars depend on how many processing steps are included for the selected fiber.

Color code water use:	*#8FAADC*
Color code blue water footprint:	*#2F5597*
Graph title:	*Show the name of the fiber corresponding to the graph for X (for example 'Cellulosic fibers')*
Axis:	*Horizontal and vertical axis labels (amount of water and processing steps),* ***only vertical axis*** *title (m3/year)*
Legend:	*Under the graph show the colors of both bars with the corresponding labels*

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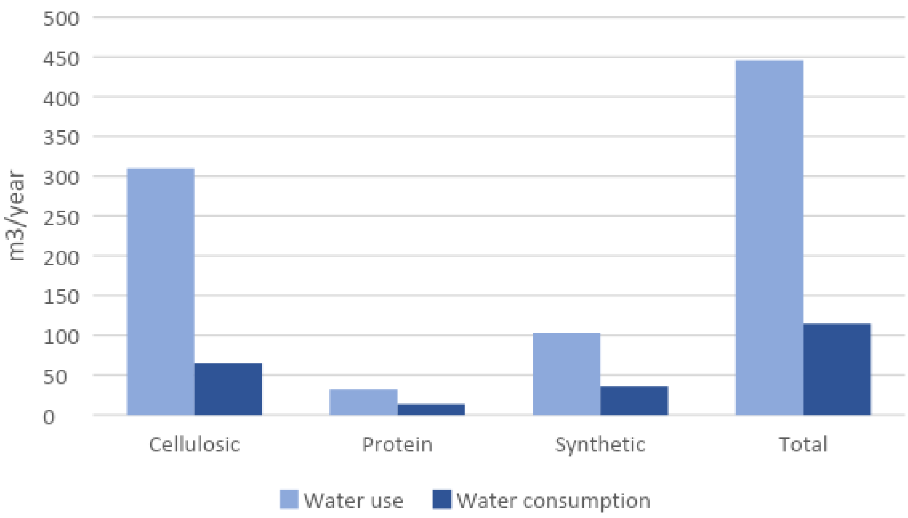
Table title: "X fibers". *Fill in the fiber category it concerns for X (for example 'Cellulosic fibers').*

Processing step	Water use (m^3/year)	Blue water footprint (m^3/year)
Desizing		
Scouring		
Carbonizing		
Rinsing		
Bleaching		
Mercerizing		
Dyeing		
Printing		
Finishing		

Calculation of results

*The calculation methods for the water use for the different processing steps are given in **Question 6 and 7** and for water consumption these are **Question 9 and 10**. Please make sure that the results are given in m^3.*

Section title*:* "Total water use and blue water footprint per fiber"



Consider the graph above as an example of how the figure should look like (more or less). The details are specified below. Number of bars depend on how many fibers are selected.

Color code water use: *#8FAADC*
Color code blue water footprint: *#2F5597*
Axis: *Horizontal and vertical axis labels (amount of water and fiber), **only vertical axis** title (m3/year)*
Legend: Under the graph show the colors of both bars with the corresponding labels

Fiber	Water use (m^3/year)	Blue water footprint (m^3/year)

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Cellulosic		
Protein		
Synthetic		
Total		

The number of rows depend on the which fiber are selected by the user

Title: Grey water footprint

Show the following text:

“The grey water footprint measures the volume of freshwater required to dilute and treat the pollutants generated during the production or consumption of goods and services. It focuses on the environmental impact of water pollution, considering the type and amount of contaminants released. In contrast to water use and the blue water footprint, the grey water footprint is calculated at factory level.”

For the grey water footprint there are 2 options based on the level of detail of the provided information by the user:

- *The first option is that the user **does not know** the concentration of pollutants in its effluent. In that case, the results should be presented according to option 1 (see below).*
- *The second option is that the user **does know** the concentration of pollutants in its effluent. In that case, the results should be presented according to option 2 (see below).*

Grey water footprint results – option 1

Show the following text:

“The grey water footprint is estimated by considering the size of the total effluent and a predetermined dilution factor. The grey water footprint is displayed in the graph below. In order to obtain an more precise picture of the grey water footprint detailed information of the pollutants in the effluent is required.”

Display the graph below

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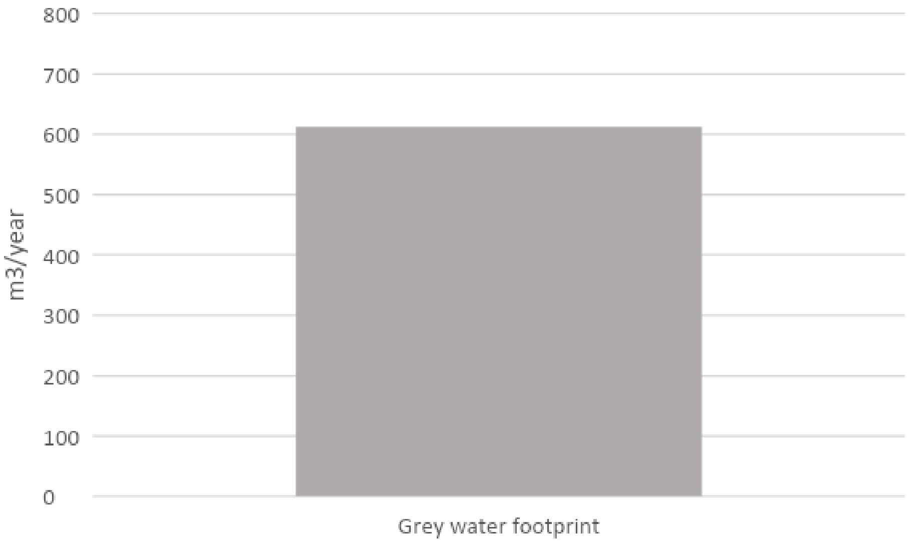
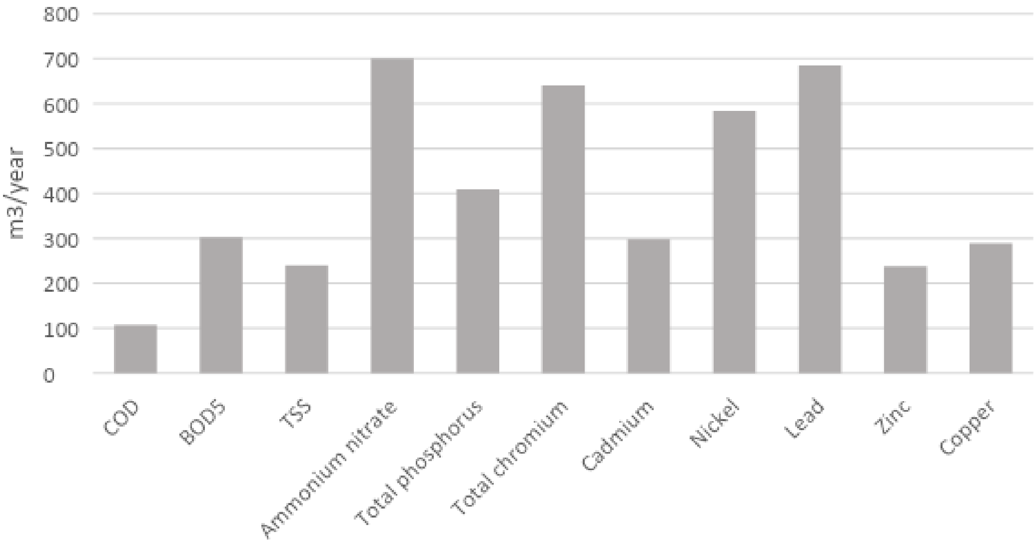


Grey water footprint results – option 2

Display the graph below with the grey water footprint value for all relevant pollutants (the ones selected by the user)



Consider the graph above as an example of how the figure should look like (more or less). The details are specified below. Number of bars depend on how many fibers are selected.

Color code bars:	*#AFABAB*
Axis:	Horizontal and vertical axis labels (amount of water and fiber), only vertical axis title (m3/year)

Show the following text:

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"The grey water footprint is calculated for all relevant pollutants. However, in case of the grey water footprint, the pollutant with the largest grey water footprint is leading. This means that the overall grey water footprint is equal to the maximum grey water footprint of all components. In the current analysis the maximum grey water footprint is the result of ***(name of the component with the largest grey water footprint)*** and is ***(size grey water footprint)*** m^3/year"

Highlight the component with the largest grey water footprint in red, like in the table below.

Pollutant	**Grey water footprint (m^3/year)**
COD	107.11
BOD5	302.3
TSS	240.02
Ammonium nitrate	699.81
Total phosphorus	408.79
Total chromium	640.29
Cadmium	298.85
Nickel	583.59
Lead	684.83
Zinc	237.03
Copper	288.77

Section title: "Contextualization of the water footprint"

Show the following text:

"A water footprint value in itself provides an insight into the water consumption. However, understanding the context of a water footprint value is crucial for accurate interpretation and meaningful decision-making. By analyzing the context of water footprint values, informed choices can be made and effective strategies for sustainable water management and resource conservation can be developed."

Section title: "Water footprint benchmark"

Show the following text:

"One of the ways to provide context the water footprint value is to compare the value to the relevant water footprint benchmark. A water footprint benchmark refers to a standard or reference point against which water footprint values can be compared or evaluated. It serves as a basis for assessing the efficiency in relation to a specific product, process, or industry."

Show the following text:

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"The table(s) below shows the water footprint per processing step for each fiber as calculated in the tool and the corresponding benchmark value, which is based on a literature review. The last column displays the deviation from the benchmark. A negative percentage indicates the actual water footprint is lower than the benchmark and a positive percentage indicates an exceedance of the benchmark. The process with the largest exceedance can be considered a priority in improving the water footprint."

Show different table for each fiber (max 3, because only 3 fiber categories available)

Table title: "Fiber X". Fill in the fiber category it concerns for Fiber X.

	Benchmark (L/kg)	Actual (L/kg)	Deviation from benchmark
Desizing	50	43	-14%
Scouring	23	46	100%
Bleaching	37	24	-35%
Mercerizing	66	69	5%
Dyeing	34	47	38%
Printing	36	59	64%
Finishing	21	12	-43%

*The actual benchmark values (Actual (L/kg)) can be calculated by taking values from $WC_{process}$ (**Equation 6**) and multiplying it by 1000 (to convert m^3 to L) and dividing it by Q_{fiber} (**Question 3**), summarized in **Equation 8** (below).*

$$Actual\ WF = \frac{WC_{process} * 1000}{Q_{fiber}} \quad \#(8)$$

The water footprint benchmark values for the comparison are given in the table below.

Benchmark values water consumption

Processing step	*Cellulosic*	*Protein*	*Synthetic*
Desizing	*1.18*		
Scouring	*3.25*	*2.8*	*5.02*
Carbonizing		*11.75*	
Rinsing		*58.45*	
Bleaching	*1.38*	*1.25*	
Mercerizing	*2.45*		
Dyeing	*15.5*	*1.90*	*7.65*
Printing	*0.6*		*1.64*
Finishing	*0.6*		*1.64*

Section title: "Water footprint reduction targets"

Show the following text:

“The geographical location of a textile processing factory is essential in order to help set water reduction targets. The geographical location determines the water situation at the site of the factory and if and to what extent water reduction is relevant at the site of the factory. Click on the following link to determine water reduction targets at the location of your factory: https://tools.waterfootprint.org/sbtn-water-targets/”

Section title*: “Additional water footprint information”*

Show the following text:

“More information on water footprint is available on the website of the Water Footprint Network.

Information on what a water footprint in can be found on https://www.waterfootprint.org/water-footprint-2/what-is-a-water-footprint/

Interactive tools about the water footprint and the water footprint on products can be found on https://www.waterfootprint.org/resources/interactive-tools/”

Appendix B – Flowchart tool design

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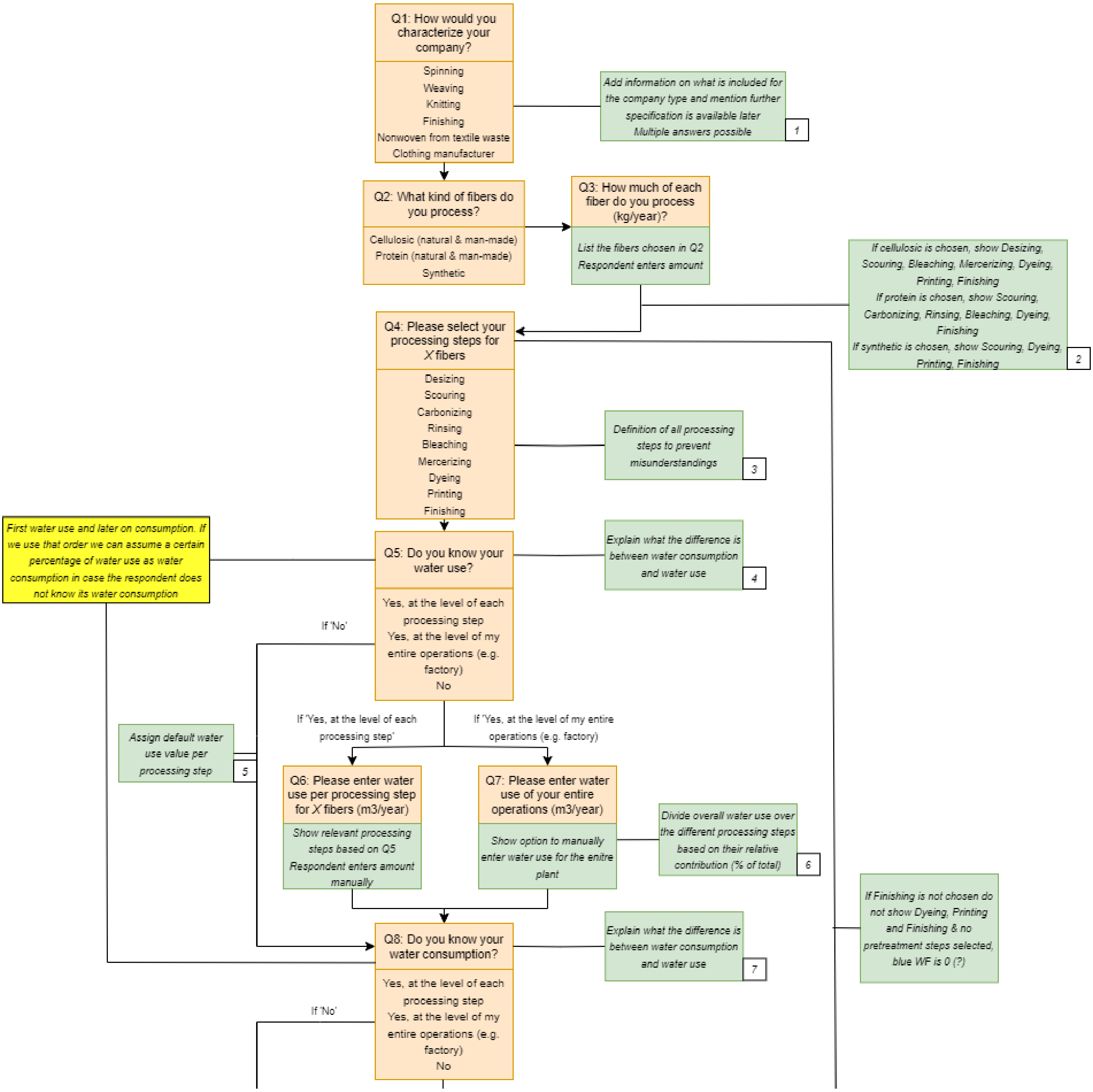

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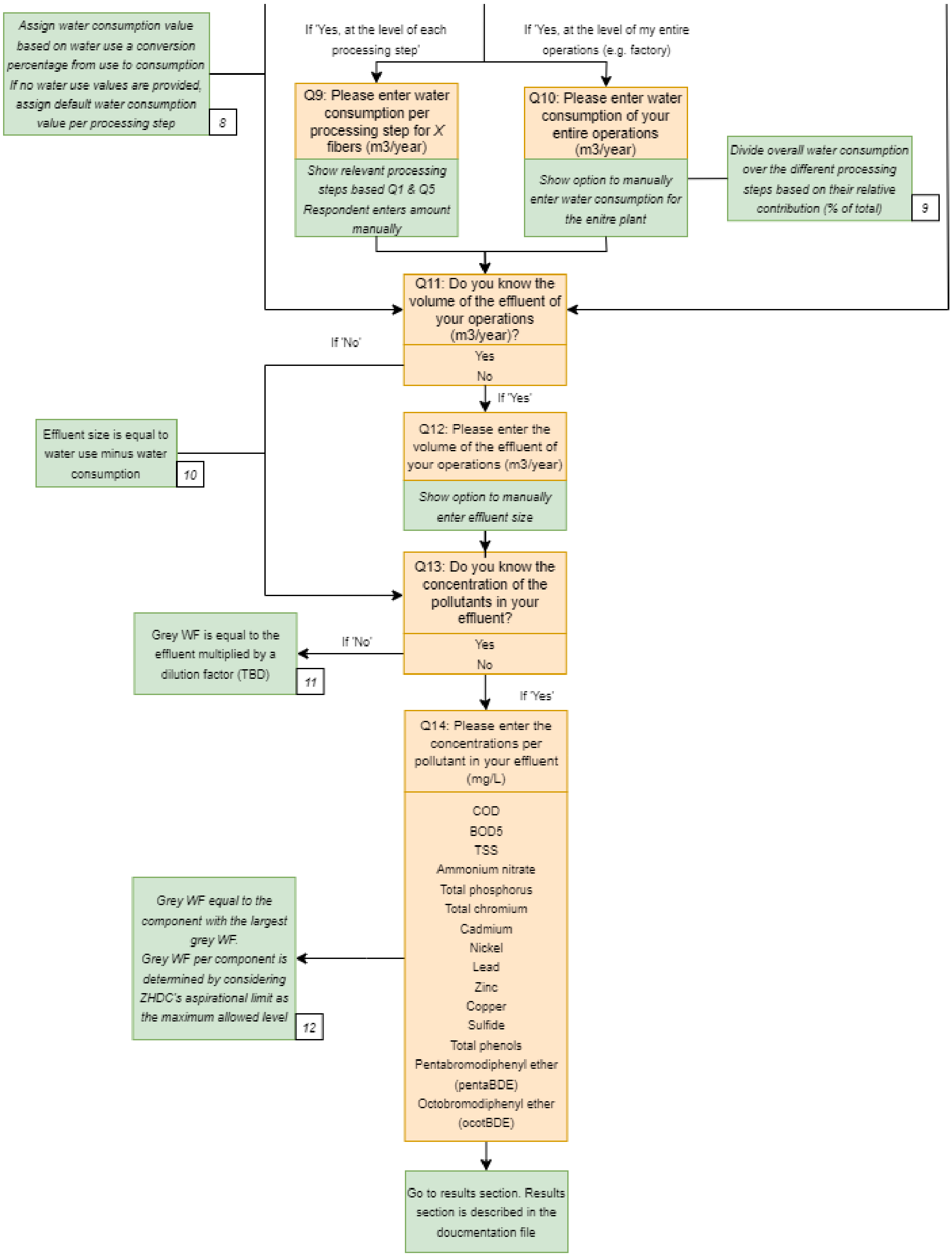

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