Design Project 2 – Wastewater Filtration

Mechanical Design of Filters in a Wastewater Treatment Plant

ENGINEER 1P13 – Integrated Cornerstone Design Projects in Engineering

Tutorial 05

Tues 34

Seher Mian (mians15)

Jamin Xu (xu826)

Ramil Jiwani (jiwanr4)

Niyah Miller (millen22)

Qianxiang Sun (sunq55)

February 15, 2025

Course Instructors: Dr. McDonald, Dr. Doyle, Dr. Ebrahimi, Dr. Fleisig, Dr. Hassan, Dr. Zurob

Table of Contents

Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Seher Mian 400557429

(Student Signature)

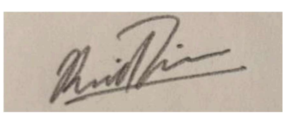
The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Jamin Xu 400557470

(Student Signature)

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

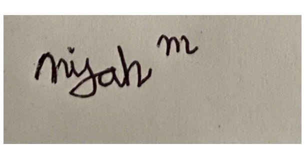
Ramil Jiwani 400562208



(Student Signature)

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

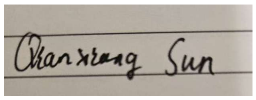
Niyah Miller 400589416



(Student Signature)

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

Qianxiang Sun 400586197

________

____

(Student Signature) *

Main Body

Finalized Problem Statement

Design an environmentally sustainable water filtration system capable of removing microplastics from large-scale plants. The filtration system must comply with Health Canada regulations, meet budget constraints, and consider both material and mechanical properties. The device must be durable and support the volume of microplastic filtration of a large-scale plant.

Justification of Technical Objectives and Material Performance Indices

The main objectives for this project while designing a water filter for large-scale microplastic filtration were minimizing cost and minimizing carbon footprint. These objectives were chosen to reflect the priorities of a large-scale plant when looking for an effective filtration method. Cost efficiency was the primary objective because, at this scale, even small cost differences can have a huge financial impact. The plant requires massive amounts of filtration material, along with installation, maintenance, and operational costs. If the system is too expensive, becomes financially unsustainable, and limits its feasibility. Additionally, cost efficiency extends beyond just materials. A filtration system that requires high energy input or frequent repairs can drastically increase utility bills and labor costs. Prioritizing a low-cost but durable solution ensures that the plant remains financially viable while maintaining effective filtration. The secondary objective was minimizing carbon footprint because wastewater treatment plants consume significant energy and resources, contributing to greenhouse gas emissions. Reducing the carbon footprint ensures compliance with environmental regulations, promotes sustainable material use, and aligns well with the triple bottom line [1]. It also aligns with global sustainability goals, helping to lower overall emissions while maintaining effective wastewater treatment. Integrating these considerations into material performance indices, the final derived equations focused on comparing both Young's Modulus and yield strength against cost as well as carbon footprint to arrive at the final material.

Porosity Calculations

Before calculating porosity, the team considered the contaminant size, and length of the filter, as well as diameter, 10-20µm, 20 cm, and 6.5 mm respectively. When calculating the number of pores, the maximum value was roughly 5 million pores, however, the chosen number of pores was 700 thousand, yielding a porosity of roughly 14%. This porosity is suitable for the given scenario considering the contaminant size is relatively larger and having a higher porosity would not necessarily contribute to effective filtration. Since the given scenario requires microplastic filtration, a higher porosity would allow everything through the filter, failing to treat the wastewater. The chosen pore radius was 8µm, smaller than the contaminant size.

Porosity Calculations

Diameter = 6.50 mm = 6.50×10^{-3} m

Length = 20 cm = 0.20 m

Contaminant Size = 10 - 20 μm = 10×10^{-6} m

$$\text{Porosity} = \frac{(\#\text{ pores})(\text{Volume singular})}{\text{Volume of filter fibre}}$$

① $V_{\text{filter fibre}} = \pi r^2 h$

$= \pi (3.25 \times 10^{-3})^2 (0.20)$

$= 6.64 \times 10^{-6}$ m^3

② $V_{\text{singular}} = \pi (\text{Pore radius})^2 (\text{thickness})$

Pore radius - Smaller than contaminant size

$= 8 \times 10^{-6}$ m

Thickness - diameter in this case

$V_{\text{singul.}} = \pi (8 \times 10^{-6})^2 (6.50 \times 10^{-3})$

$= 1.307 \times 10^{-12}$ m^3

③ $\#\text{ Pores} = \frac{V_{\text{Fibre}}}{V_{\text{singul.}}}$

$\#\text{Pores} = \frac{6.64 \times 10^{-6}}{1.307 \times 10^{-12}}$

$= 5.08 \times 10^{6}$ pores

This is max value, Choose less.

Chosen # pores = 7.00×10^5 pores

④ $P = \frac{(\#\text{ Pores})(1.307 \times 10^{-12})}{(6.64 \times 10^{-6})}$

$= 0.1378$

Figure 1. Porosity Calculations

Justification of Eco Audit

Our team performed an Eco-Audit on the top three materials that were selected based on the requirements of our solution. Through this process, we concluded that Hemp Fiber was the most environmentally sustainable material out of the three. The Eco-Audit takes into account energy usage and CO2 emissions through the process of producing, transporting, and disposing of the material. Figure [1] and [2] compares the total energy and CO2 emissions of our three materials showing hemp fiber with an evident lead in both aspects. In addition, Hemp Fiber also exhibits a relatively even distribution between material and transport in both Energy Usage and CO2 emissions (see *Figure [3.1]*) making it less susceptible to sudden shifts in the market such as increased regulation for plant growth that would lead to higher Energy Usage and CO2 emissions, greatly impacting a material like cotton (see *Figure [5.1]* - 90% of Energy Usage is in material production) but having a comparatively smaller impact on Hemp Fiber. Taking into account the fact that hemp fiber also yielded the highest score on the decision matrix, it is naturally the most desirable material for our solution.

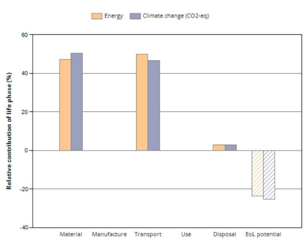
Eco-Audit Documentation

Material	Total Energy (MJ)	End of Life Potential (MJ)
Hemp Fiber	0.242	-0.0573
Flax Fiber	11.5	-4.02
Cotton	0.577	-0.261

Figure [1] Energy Usage

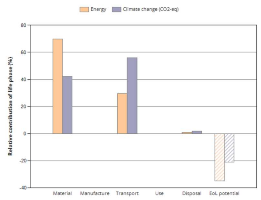
Material	Total CO_2-eq (kg)	End of Life Potential (kg)
Hemp Fiber	0.0182	-0.00461
Flax Fiber	0.404	-0.0852
Cotton	0.0861	-0.0412

Figure [2] CO2 Emissions



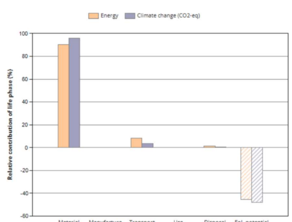
Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	0.114	47.2	0.0092	50.5
Manufacture	0	0.0	0	0.0
Transport	0.121	49.8	0.00849	46.6
Use	0	0.0	0	0.0
Disposal	0.00742	3.1	0.000519	2.9
Total (for first life)	**0.242**	**100**	**0.0182**	**100**
End of life potential	-0.0573		-0.00461	

Figure [3] & [3.1] Hemp Fiber Eco-Audit



Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	8.05	69.7	0.17	42.1
Manufacture	0	0.0	0	0.0
Transport	3.4	29.4	0.226	56.1
Use	0	0.0	0	0.0
Disposal	0.105	0.9	0.00735	1.8
Total (for first life)	**11.5**	**100**	**0.404**	**100**
End of life potential	-4.02		-0.0852	

Figure [4] & [4.1] Flax Fiber Eco-Audit



Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	0.521	90.4	0.0824	95.7
Manufacture	0	0.0	0	0.0
Transport	0.0485	8.4	0.0032	3.7
Use	0	0.0	0	0.0
Disposal	0.00688	1.2	0.000482	0.6
Total (for first life)	**0.577**	**100**	**0.0861**	**100**
End of life potential	-0.261		-0.0412	

Figure [5] & [5.1] Cotton Eco-Audit

Conceptual Design

The first step in selecting the material was completed by graphing the chosen material performance indices in GRANTA. The applied limits were excellent water quality as well as biodegradable materials. Certain materials were removed from the subset including “Ceramics and Glasses”, “Woods”, as well as “Ferrous materials”. These decisions were made due to cost efficiency, porosity, as well as durability. Once the index line was added, the top 5 materials were selected from each material performance index, completed by each member. These selected materials were then evaluated by the team, collectively deciding the top 3 material finalists. The top 3 materials were hemp fiber, flax fiber, and cotton fiber. The team evaluated these materials in a simple decision matrix, considering cost, ease of access, mechanical performance, maintenance, etc. From this, hemp fiber scored the highest and was chosen as the final material due to its low cost, ease of access, and high mechanical performance [2]. As a result, the selection process ensured that the chosen material aligned with the project's objectives of cost efficiency, sustainability, and performance, making hemp fiber the optimal choice.

	Hemp fiber	Flax fiber	Cotton fiber
Ease of production (5, easiest, 1 hardest)	4	3	5
Ease of access (5 easiest, 1 lowest)	5	5	5
Corrosion resistance (5 high, 1 low)	4	4	2
Low Cost (5 lowest, 1 highest)	5	4	5
Mechanical performance (5 best, 1 worst)	4	3	1
Ease of maintenance (5 easiest, 1 lowest)	4	4	4
TOTAL	**26**	23	22

Table 1. Decision Matrix

Discussion of Regulations

During the discussion of regulations, the team focused on the regulations about environmentally preferable goods and services in order to guide the design and material selection. According to research and the team's discussion, they summarized an outline of Canadian policy and requirements for products and organizations, including responsible management, value for money, vendor access, transparency and fairness, quality service delivery, and upholding Ontario's trade agreements. This guided the team to look for biograde and more environmentally friendly material in the following steps, and learnt what quality the design should have to meet business policies. The team also researched related environmental regulations. Although the team found that there is no current clear standard for filters for microplastic, there are many regulations about water quality and prohibition of microplastics in many products. Even though these microplastics are already abandoned, they still have to be considered in the design in order to purify the waterways. The team also found an electricity standard that limits the electric circuit of the water treatment system, which reminded them to improve energy efficiency.

Discussion of Sustainable Choices

Not only was hemp fiber selected for its performance capabilities, but also because of how sustainable of a material it is in the long-term. During the design process, the team considered factors such as biodegradability, lifespan and environmental impact when deciding on whether hemp fiber was the right choice or not. It was discussed how one of the major benefits of hemp fiber is the fact that it is biodegradable. This means that less waste would end up in landfills because at the end of its life, the fibers could be composted or repurposed. The team also noticed that compared to the other two fibers in the top three, hemp fiber had a longer lifespan. This made it the more sustainable option because it would minimize the rate at which new products were produced to replace the old ones, therefore reducing waste. Additionally, the team noticed while researching that hemp fibers do not degrade into microplastics or release toxic residue into the water system because they are made from a natural material. This is especially important from a sustainability perspective because it implies that less material is needed to filter the water, rather than needing to go through multiple iterations to fully clean it.

One aspect of hemp fibers that could have been researched more during the design process was the location of composting facilities. Even though the team chose this fiber for its ability to biodegrade, this would not be very sustainable if it could not be properly disposed of. Also, the team could have looked into the location of facilities that could repurpose the old hemp fibers. As mentioned earlier, not being able to repurpose this material when it has the ability to do so would be less sustainable and less efficient. Researching these kinds of facilities plays a big role in the sustainability of the product as the eco-audit would change due to the added transportation considerations. As for the build of the filter, the team could have considered creating an entirely biodegradable structure so that the whole filter can decompose naturally. This idea would simplify the end of life disposal of the product by eliminating the frequency of which the waste needs to be transported, which in turn lowers the amount of energy required during the lifecycle of this product.

Concluding Remarks

Our team gained valuable insights into the complexities of designing an effective and sustainable filter for a large-scale plant. We learned the importance of balancing cost, efficiency, and sustainability in such a design while navigating the challenges of filtering microplastics effectively without excessive resource consumption. Many trade-offs were considered between mechanical performance, material availability, and maintenance needs, all crucial in the final decision. We learned that sustainable wastewater treatment requires innovation and cost-conscious engineering, considering scalability and feasibility when it comes to real-world implementation. In the future, we would consider the degradation and longevity of the material, and how additional regulatory and environmental standards impact our decision. Further research would allow us to evaluate the optimization of energy consumption and monitor the filter to optimize efficiency.

Summary of Contributions

Name	**MacID**	**Role**	**Contributions**
Seher Mian	mians15	Subject Matter Expert	-Conducted research on material selection and mechanical performance indices -Porosity Calculations -Assisted in decision matrix and final material selection as well as eco audits -Comprehensive list of sources
Jamin Xu	xu826	Subject Matter Expert	Contributions in: - MPI calculations - Material research - Eco Audit - Decision Matrix
Niyah Miller	millen22	Administrator	- Eco Audit for Cotton Fiber - Researching Cotton Fiber - submitting all team deliverables - Updating Gantt chart - Objective tree - Design matrix
Ramil Jiwani	jiwanr4	Manager	- Creation of project timeline - Decision matrix - Objective tree - Eco Audit for Hemp Fiber - Life Cycle for Hemp Fiber
Qianxiang Sun	sunq55	Coordinator	- discussion of regulation - Design matrix -

Table 2. Summary of Contributions

Reference List

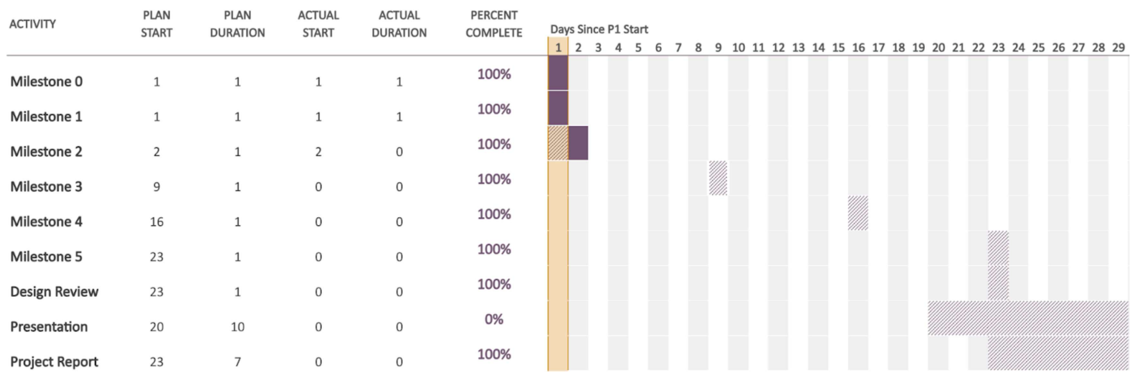
[1] "What Is the Triple Bottom Line?" *Harvard Business School Online*, Jan. 14, 2022. [Online]. Available: https://online.hbs.edu/blog/post/what-is-the-triple-bottom-line

[2] Na Lu, R. H. Swan Jr., and I. Ferguson, "Composition, structure, and mechanical properties of hemp fiber reinforced composite with recycled high-density polyethylene matrix," *J. Compos. Mater.*, vol. 0, no. 0, pp. 1–11, 2011, doi: 10.1177/0021998311427778.

Appendices

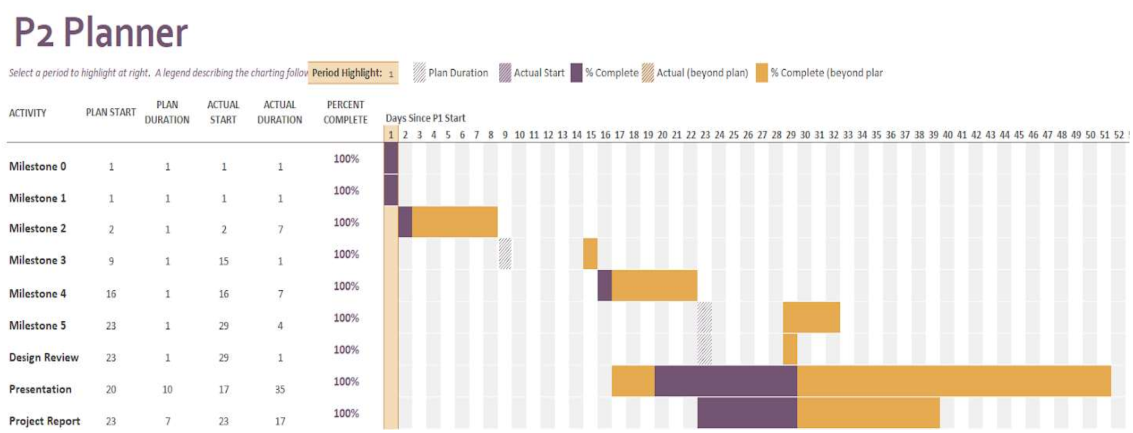
Appendix A: Project Schedule

Preliminary Gantt Chart:



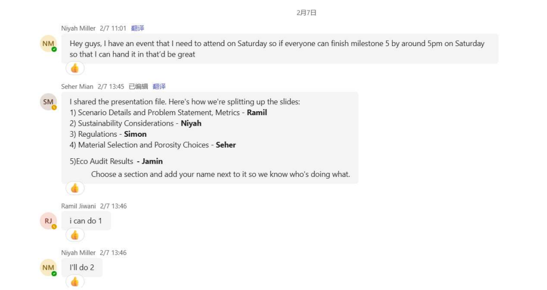
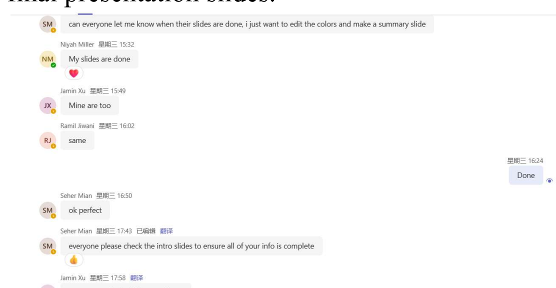
ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1	1	1	1	1	100%
Milestone 2	2	1	2	0	100%
Milestone 3	9	1	0	0	100%
Milestone 4	16	1	0	0	100%
Milestone 5	23	1	0	0	100%
Design Review	23	1	0	0	100%
Presentation	20	10	0	0	0%
Project Report	23	7	0	0	100%

Final Gantt Chart:



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1	1	1	1	1	100%
Milestone 2	2	1	2	7	100%
Milestone 3	9	1	15	1	100%
Milestone 4	16	1	16	7	100%
Milestone 5	23	1	29	4	100%
Design Review	23	1	29	1	100%
Presentation	20	10	17	35	100%
Project Report	23	7	23	17	100%

logbook of additional meetings and discussions

<table>
<tr><td>February 7th(virtual)</td><td>We discussed which part should each person work with in the final presentation slides and design report, and shared the information and materials we have to organize information we have.

</td></tr>
<tr><td>February 13th(virtual)</td><td>We had our last check and discussion about the final presentation slides.

</td></tr>
<tr><td>February 14th(in person)(delayed)</td><td>We planned to practice the presentation before Lab A but it is canceled and delayed because of the snow day and university closure, and we plan to have it before the final presentation</td></tr>
</table>

Appendix B: Scheduled Weekly Meetings

Weekly Design Studio Agenda:

week	agenda
1	Complete both the Milestone Zero and One Team worksheet and start to analyze the objective tree according to the assigned scenario.
2	Establish metrics and Morph chart for objectives and functions, discussing regulation with provided documents and materials searched by ourselves.
3	search for best materials for the design with MPI calculation and chart in Granta
4	select material by calculating and comparing the porosity of top three materials in overall MPI ranking. Make the summary of chosen material properties.

5	provide life circles and related information for top three materials. Make Granta Eco-Audit. Discuss the influence of this information to material selection.
6	Work period for preparing for the final presentation

Weekly Design Studio Meeting Minutes:

week	meeting minutes
1	Assigned roles, exchanged personal contact info, and took a group photo. learn which scenario we have and set the basic objective tree of our design.
2	Discuss how to design metric, what objectives and functions should be included in our design and how we measure them. Have regulation research and discussion to improve our understanding of product requirements.
3	Calculate the MPI together, discuss what limit should be added to the material selection, and used Granta chart to look for the top five materials
4	Discuss how to select the top three materials and rank them with Decision Matrix and porosity calculation. Research the best material's properties and make a summary
5	Design everyone's life cycle diagram and update Life Cycle Inventory. Provide Granta Eco-Audit for all three top material choices.

Appendix C: Comprehensive List of Sources

[1] R. B. Bird, W. E. Stewart, and E. N. Lightfoot, *Transport Phenomena*, 2nd ed. Wiley, 2007. [Online]. Available: *Insert URL*. [Accessed: Feb. 12, 2025].

[2] J. Smith and A. Brown, "Microplastic filtration using advanced membranes," *Environmental Engineering Journal*, Mar. 2023. [Online]. Available: *Insert URL*. [Accessed: Feb. 12, 2025].

[3] L. Wang, "Efficient removal of microplastics in wastewater treatment," in *Proc. IEEE Int. Conf. Environ. Technol.*, London, UK, 2022. [Online]. Available: *Insert URL*. [Accessed: Feb. 12, 2025].

[4] U.S. Environmental Protection Agency, "Microplastics in wastewater treatment," EPA, Jan. 5, 2024. [Online]. Available: https://www.epa.gov/microplastics. [Accessed: Feb. 12, 2025].

[1] University of Waterloo, "Scientists can now remove microplastics from our water with 94 per cent efficiency," *University of Waterloo News*, Dec. 13, 2023. [Online]. Available: https://uwaterloo.ca/news/media/scientists-can-now-remove-microplastics-our-water-94-cent . [Accessed: Feb. 12, 2025].

[2] L. O. Santos, S. Magro, A. B. Riegel-Vidotti, and L. F. F. Boechat, "Microplastic removal efficiency in wastewater treatment plants: A global perspective," *Science of The Total Environment*, vol. 858, p. 159743, 2023. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0048969722057825. [Accessed: Feb. 12, 2025].

[3] Health Canada, "Microbeads," *Government of Canada*, June 28, 2022. [Online]. Available: https://www.canada.ca/en/health-canada/services/chemical-substances/other-chemical-substances-interest/microbeads.html. [Accessed: Feb. 12, 2025].

[4] D. Suzuki Foundation, "Carbon pricing explained," *David Suzuki Foundation*, 2023. [Online]. Available: https://davidsuzuki.org/what-you-can-do/carbon-pricing-explained/#:~:text=A%20carbon%20levy%20sends%20a,available%20and%20lowering%20their%20prices. [Accessed: Feb. 12, 2025].

[5] Environment and Climate Change Canada, "The Government of Canada is taking steps to address plastic waste and pollution from the textile and apparel sector," *Government of Canada*, July 2024. [Online]. Available: https://www.canada.ca/en/environment-climate-change/news/2024/07/the-government-of-canada-is-taking-steps-to-address-plastic-waste-and-pollution-from-the-textile-and-apparel-sector.html. [Accessed: Feb. 12, 2025].

[6] Chemical Institute of Canada, "Using wood dust and tannic acid to trap microplastics," *Chemical Institute of Canada Magazine*, 2024. [Online]. Available: https://www.cheminst.ca/magazine/article/using-wood-dust-and-tannic-acid-to-trap-microplastics/#:~:text=Researchers%20at%20the%20University%20of,water%20using%20bark%20and%20sawdust. [Accessed: Feb. 12, 2025].

[7] F. Liu, T. Huang, M. Yu, H. Wang, X. Du, and X. Yang, “Utilization of magnetic biochar for enhanced microplastic removal from water,” *Chemical Engineering Journal*, vol. 451, p. 138636, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1385894722066347. [Accessed: Feb. 12, 2025].

[8] EcoWatch, “Microplastics filter made from cotton and squid bone could revolutionize wastewater treatment,” *EcoWatch*, 2024. [Online]. Available: https://www.ecowatch.com/microplastics-filter-cotton-squid-bone.html#:~:text=In%20a%20new%20study%20led,99.9%25%20effective%20in%20filtering%20microplastics. [Accessed: Feb. 12, 2025].

[9] L. Wang, “Efficient removal of microplastics in wastewater treatment,” in Proc. IEEE Int. Conf. Environ. Technol., London, UK, 2022. [Online]. Available: Insert URL. [Accessed: Feb. 12, 2025].

[10] U.S. Environmental Protection Agency, “Microplastics in wastewater treatment,” EPA, Jan. 5, 2024. [Online]. Available: https://www.epa.gov/microplastics. [Accessed: Feb. 12, 2025].

[11] University of Waterloo, “Scientists can now remove microplastics from our water with 94 per cent efficiency,” University of Waterloo News, Dec. 13, 2023. [Online]. Available: https://uwaterloo.ca/news/media/scientists-can-now-remove-microplastics-our-water-94-cent. [Accessed: Feb. 12, 2025].

[12] L. O. Santos, S. Magro, A. B. Riegel-Vidotti, and L. F. F. Boechat, “Microplastic removal efficiency in wastewater treatment plants: A global perspective,” Science of The Total Environment, vol. 858, p. 159743, 2023. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0048969722057825. [Accessed: Feb. 12, 2025].

[13] Health Canada, “Microbeads,” Government of Canada, June 28, 2022. [Online]. Available: https://www.canada.ca/en/health-canada/services/chemical-substances/other-chemical-substances-interest/microbeads.html. [Accessed: Feb. 12, 2025].

[14] D. Suzuki Foundation, “Carbon pricing explained,” David Suzuki Foundation, 2023. [Online]. Available: https://davidsuzuki.org/what-you-can-do/carbon-pricing-explained/#:~:text=A%20carbon%20levy%20sends%20a,available%20and%20lowering%20their%20prices. [Accessed: Feb. 12, 2025].

[15] Environment and Climate Change Canada, “The Government of Canada is taking steps to address plastic waste and pollution from the textile and apparel sector,” Government of Canada, July 2024. [Online]. Available: https://www.canada.ca/en/environment-climate-change/news/2024/07/the-government-of-canada-is-taking-steps-to-address-plastic-waste-and-pollution-from-the-textile-and-apparel-sector.html. [Accessed: Feb. 12, 2025].

[16] Chemical Institute of Canada, “Using wood dust and tannic acid to trap microplastics,” Chemical Institute of Canada Magazine, 2024. [Online]. Available: https://www.cheminst.ca/magazine/article/using-wood-dust-and-tannic-acid-to-trap-microplastics/#:~:text=Researchers%20at%20the%20University%20of,water%20using%20bark%20and%20sawdust. [Accessed: Feb. 12, 2025].

[17] F. Liu, T. Huang, M. Yu, H. Wang, X. Du, and X. Yang, “Utilization of magnetic biochar for enhanced microplastic removal from water,” Chemical Engineering Journal, vol. 451, p. 138636, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1385894722066347. [Accessed: Feb. 12, 2025].

[18] EcoWatch, “Microplastics filter made from cotton and squid bone could revolutionize wastewater treatment,” EcoWatch, 2024. [Online]. Available: https://www.ecowatch.com/microplastics-filter-cotton-squid-bone.html#:~:text=In%20a%20new%20study%20led,99.9%25%20effective%20in%20filtering%20microplastics. [Accessed: Feb. 12, 2025].

Appendix D: Additional Documentation (Life cycle inventory)

Material	Mass (kg)	Process	End of Life
Hemp Fiber	0.0106	Retting	Recycle
Flax Fiber	0.150	Breaking/Hackling	Recycle
Cotton Fiber	0.00983	Spinning	Recycle

References

[1] Alliance Flax Linen Hemp, "All about European linen," *Alliance Flax Linen Hemp*. https://allianceflaxlinenhemp.eu/en/all-about-european-linen. [Accessed: Feb. 4, 2025].

[2] Fehr Graham, "What is a typical wastewater treatment plant life expectancy?" *Fehr Graham*. https://www.fehrgraham.com/about-us/blog/what-is-a-typical-wastewater-treatment-plant-life-expectancy-fg#:~:text=However%2C%20the%20average%20wastewater%20treatment,lasts%2015%20to%2020%20years. [Accessed: Feb. 4, 2025].

[3] A. Bourmaud, W. Dang, J. R. Duflou, and S. González-García, “Environmental impact assessment of end of life options for flax-mapp composites,” Industrial Crops and Products, https://www.sciencedirect.com/science/article/pii/S0926669016305854 [Accessed Feb. 7, 2025].

[4] N. Chand and M. Fahim, “Flax fiber,” Flax Fiber - an overview | ScienceDirect Topics, https://www.sciencedirect.com/topics/engineering/flax-fiber [Accessed Feb. 7, 2025].

[5] “Raw Cotton,” *Coppersmith*, Apr. 27, 2023. https://www.coppersmith.com/industry/raw-cotton/ (accessed Feb. 07, 2025).

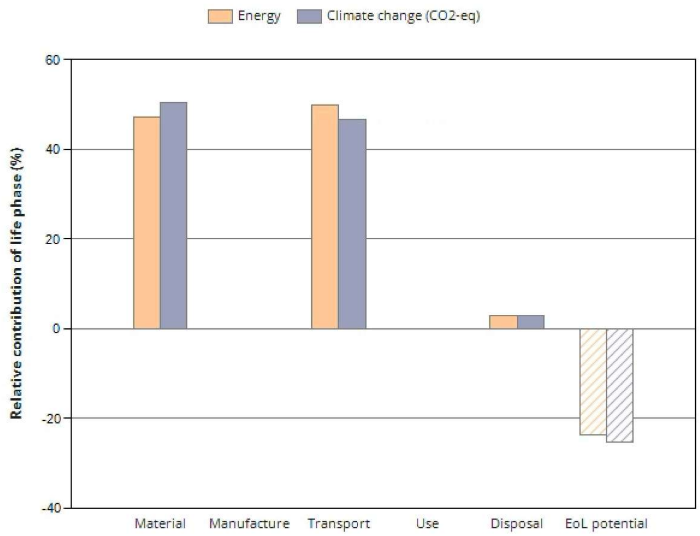
[6] “From Raw Cotton to Cotton Fabrics | Toyota Industries Corporation,” *www.toyota-industries.com*. https://www.toyota-industries.com/products/relation/textile_process/ (accessed Feb. 07, 2025)

[7] Lemieux, “Lemieux Spinning | Yarn Specialist Since 1906,” *Lemieux Spinning*. https://www.lemieuxspinning.com/en/ (accessed Feb. 07, 2025).

[8] “How Quickly Do Textile Microfibers Degrade in Aquatic Environments? -,” Feb. 18, 2019. https://cottontoday.cottoninc.com/how-quickly-do-textile-microfibers-degrade-in-aquatic-environments/ (accessed Feb. 07, 2025)

[9]“Recyclability,” *CottonToday*. https://cottontoday.cottoninc.com/our-sustainability-story/circularity/recyclability/ (accessed Feb. 07, 2025)

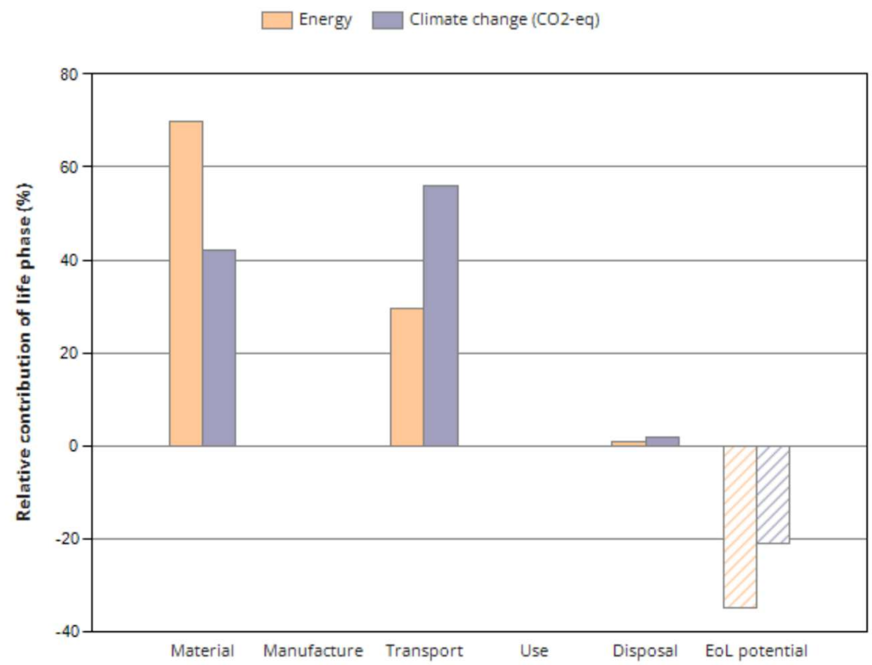
Eco-Audit (Material 1)



Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	0.114	47.2	0.0092	50.5
Manufacture	0	0.0	0	0.0
Transport	0.121	49.8	0.00849	46.6
Use	0	0.0	0	0.0
Disposal	0.00742	3.1	0.000519	2.9
Total (for first life)	**0.242**	**100**	**0.0182**	**100**
End of life potential	-0.0573		-0.00461	

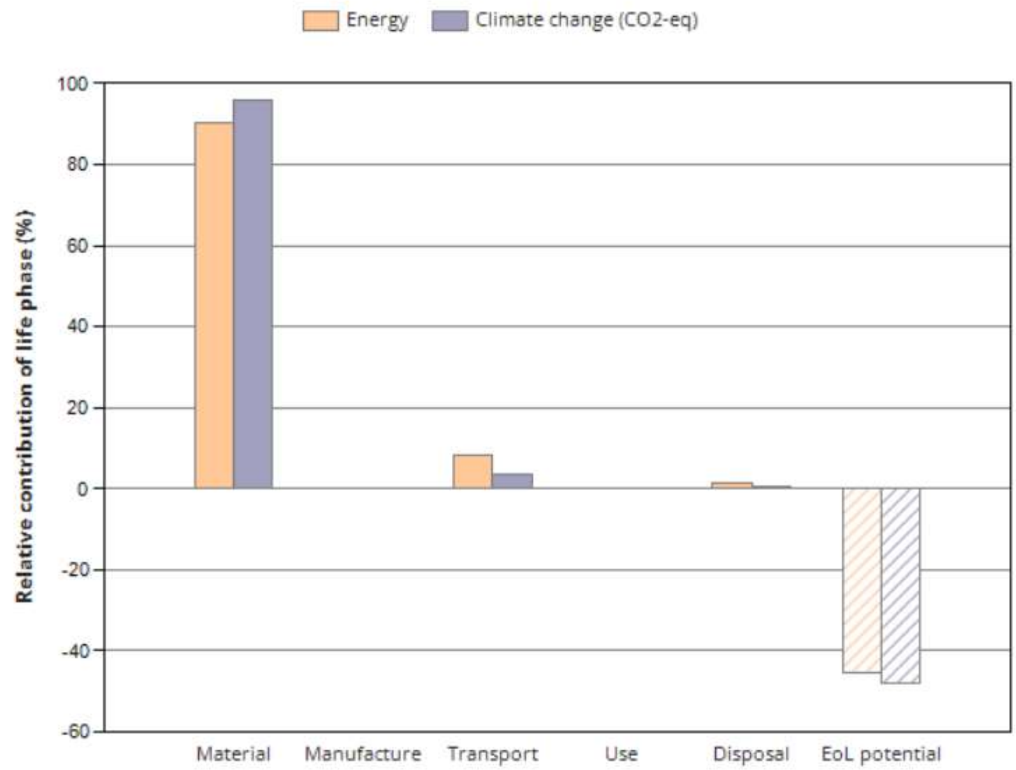
Eco-Audit (Material 2)

SUMMARY:



Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	8.05	69.7	0.17	42.1
Manufacture	0	0.0	0	0.0
Transport	3.4	29.4	0.226	56.1
Use	0	0.0	0	0.0
Disposal	0.105	0.9	0.00735	1.8
Total (for first life)	**11.5**	**100**	**0.404**	**100**
End of life potential	-4.02		-0.0852	

Eco-Audit (Material 3)



Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	0.521	90.4	0.0824	95.7
Manufacture	0	0.0	0	0.0
Transport	0.0485	8.4	0.0032	3.7
Use	0	0.0	0	0.0
Disposal	0.00688	1.2	0.000482	0.6
Total (for first life)	**0.577**	**100**	**0.0861**	**100**
End of life potential	-0.261		-0.0412	

Appendix E: Design Studio Worksheets

Project Two Milestone (Team) Worksheets

Milestone 0 (Team): Cover Page

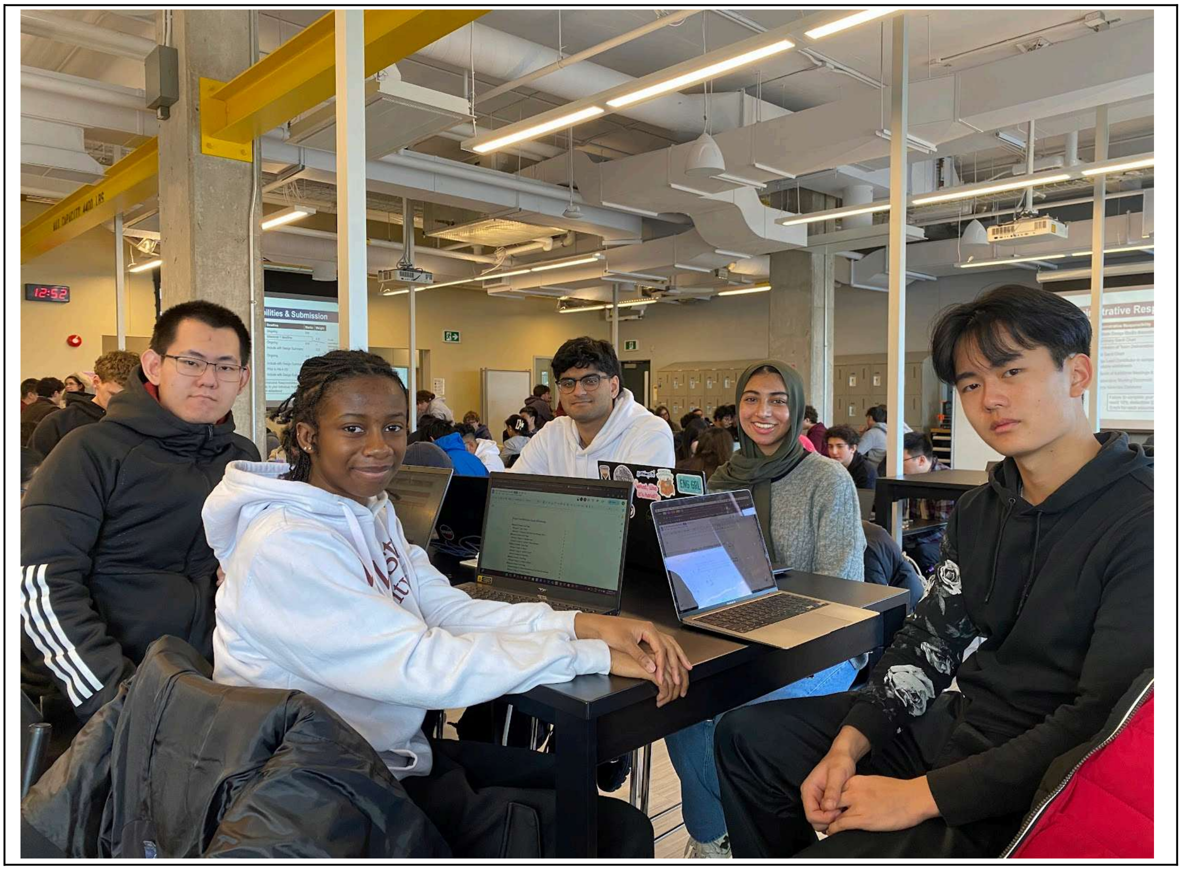
Team ID: Tues-34

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Niyah Miller	millen22
Seher Mian	mians15
Qianxiang Sun	sunq55
Jamin Xu`	xu826
Ramil Jiwani	jiwanr4

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-2 grade.

Insert your Team Portrait in the dialog box below



Milestone 0 – Team Charter

Team ID: Tues-34

Project Leads:

Identify team member details (Name and MacID) in the space below.

Role:	Team Member Name:	MacID
Manager	Ramil Jiwani	jiwanr4
Administrator	Niyah Miller	millen22
Coordinator	Qianxiang Sun	sunq55
Subject Matter Expert	Jamin Xu	xu826
Subject Matter Expert	Seher Mian	mians15

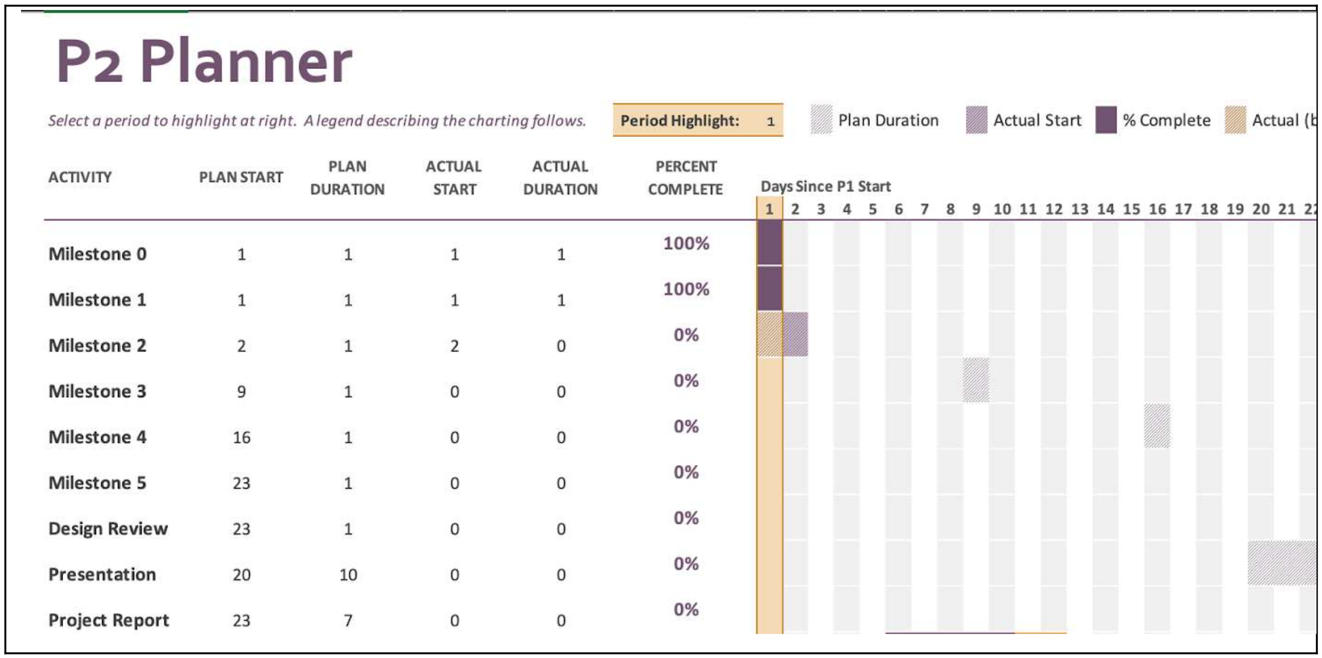
Milestone 0 – Preliminary Gantt Chart (Team Manager ONLY)

Team ID:	Tues-34

Only the **Project Manager** is completing this section!

Full Name of Team Manager:	MacID:
Ramil Jiwani	jiwanr4

Preliminary Gantt chart



P2 Planner

Select a period to highlight at right. A legend describing the charting follows.

Period Highlight: 1

Plan Duration · Actual Start · % Complete · Actual (b

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1	1	1	1	1	100%
Milestone 2	2	1	2	0	0%
Milestone 3	9	1	0	0	0%
Milestone 4	16	1	0	0	0%
Milestone 5	23	1	0	0	0%
Design Review	23	1	0	0	0%
Presentation	20	10	0	0	0%
Project Report	23	7	0	0	0%

MILESTONE 1 (TEAM): COVER PAGE

Team ID: Tues-34

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Niyah Miller	millen22
Seher Mian	mians15
Qianxiang Sun	sunq55
Jamin Xu`	xu826
Ramil Jiwani	jiwanr4

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-2 grade.

Milestone 1 (Stage 2) – Objective Trees

Team ID: Tues-34

For your assigned engineering scenario, you will be submitting an objective tree agreed upon by the group. Each branch of the objective tree should have a minimum of 3 layers. This can be hand-drawn or done on a computer.

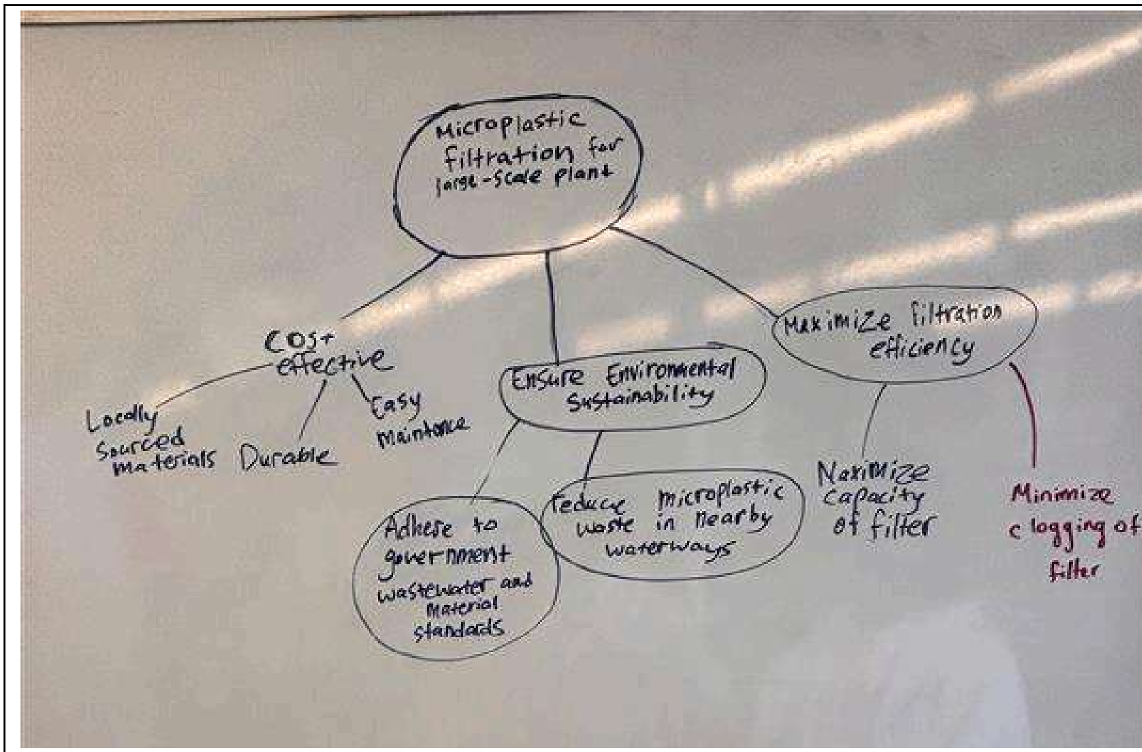
Engineering Scenario

The title of the scenario

Microplastic Filtration for Large-Scale Plant

Team objective tree diagram

Please insert a copy of the team objective tree for your assigned scenario.



Milestone 1 (Stage 3) – Refined Problem Statement

As a team, generate a problem statement in the box below.

Design an environmentally sustainable water filtration system capable of removing microplastics from large-scale plants. The filtration system must comply with Health Canada regulations, meet budget constraints, and consider both material and mechanical properties. The device must be durable and support the volume of microplastic filtration of a large-scale plant.

MILESTONE 2 (TEAM) – COVER PAGE

Team Number:	Tues - 34

Please list full names and MacID's of all *present* Team Members

Full Name:	**MacID:**
Jamin Xu	xu826
Niyah Miller	millen22
Qianxiang Sun	sunq55
Seher Mian	mians15
Ramil Jiwani	jiwanr4

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-2 grade.

Milestone 2 (Stage 1) – Metrics

Team ID: Tues - 34

For your selected top three objectives fill out the table below with associated metrics (including units) for each objective.

Objective 1:	Cost Effective
Unit/Metric: $/Litre filtered	- Cost-to-performance ratio - Lifespan of product - Decide if a material is cost effective based on the payback ratio plays out

Objective 2:	Environmentally Sustainable
Unit/Metric: kWh	- Tons of CO_2 equivalent per unit of production - Energy consumed per hour - Decide if a material is sustainable or not based on energy used in production as well as CO_2 emissions

Objective 3:	Maximize Filtration Efficiency
Unit/Metric: L/s	- Flow rate of water - How many litres can be filtered in a given time interval to maximize efficiency

MILESTONE 2 (STAGE 2) – MORPH CHART

Team ID: Tues - 34

Identify means to achieve the following functions: Remove contaminants, regulate flow, and [add two more functions].

→ For the "remove contaminants" function, assume that each method is practical. This assumption is not required for the other functions.

Functions	Means			
Remove Contaminants	Activated carbon filtration	Reverse Osmosis	Sand filtration system	Magnetic separation
Regulate Flow	Water Pumps	Pressure-Reducing Valves	Pressure Regulators	Sensors to measure flow rate
Increase Product Lifespan	Durable material selection	Reduce clogging of pores	Temperature resistant	limit water pressure
Ecologically Sustainable	Reduce carbon footprint	Reduce waste produced	Increase recycle factor	Reduce resource usage

MILESTONE 2 (STAGE 3) – REGULATIONS

Team ID: Tues - 34

Based on your team's assigned scenario, discuss regulations such as material acquisition, contaminant/waste standards, electricity standards, and optimal energy output.

Material Acquisition:

"**Responsible management**

No matter how small the organization or the procurement, there should be an adequate organizational structure, policies and procedures to be able to manage procurement contracts fairly and effectively.

Value for money

Buyers should consider factors such as the requirements of the business, alternatives, timing, supply strategy and total life cycle costs of the good or service when evaluating vendors' submissions.

Vendor access, transparency and fairness

Publicly funded organizations should provide all qualified vendors with fair access to the purchase of goods and services. Buyers should avoid conflict of interest, both real and perceived, and choose the successful vendor in a fair and non-discriminatory process.

Quality service delivery

Procurement activities should result in the delivery of the required product or service at the right time and place to organizations. This is especially critical for those organizations involved in healthcare, education and social services.

Upholding Ontario's trade agreements

Organizations should recognize and respect Ontario's trade agreements with other jurisdictions that open access to publicly funded procurement where they apply. [1]"

2.1.7 Environment

The Policy on Management of Materiel requires that:

- material assets are managed and disposed of in an environmentally responsible manner consistent with the principles of sustainable development.
- manage assets in a manner that minimizes the effect on the environment and promotes sustainable development
- responsibility includes applying the three R's (reduce, reuse, and recycle) at each phase of life-cycle material management..

7.2.4

The policy on green procurement states that:

- Buy environmentally preferable goods and services where value for money is demonstrated
- appropriate balance of many factors, such as

- cost
- performance
- availability
- quality
- environmental performance

Contaminant/Waste:

Health Canada clearly provides a restriction on the use of microbeads in toiletries that directly contribute to microplastic contamination in waterways. This regulation classifies “any plastic particle equal to or less than 5 mm” as a microplastic. The cosmetic industry plays a role in microplastic contamination and filtration of these beads is necessary even after the prohibition in order to purify waterways.

Electricity Standards:

The CSA (Canadian Standards Association) defines the CSA B483.1:21 standard which defines the electricity standards for water treatment systems both indoors and outdoors that are permanently connected by a plug, cord or class-2 power supply with an electrical circuit of 250V or less (Standards Council of Canada [2]). This standard aims to ensure the safety and reliability of the equipment used, while also ensuring that operational costs are kept to a minimum.

References (adhere to IEEE notation)

***references do not count toward word count / page limit

[1] Canada GOV. “Guide to Management of Materiel.” Government of Canada, https://www.tbs-sct.canada.ca/pol/doc-eng.aspx?id=14671&section=html#:~:text=Departments%20have%20the%20responsibility%20to,Works%20and%20Government%20Services%20Canada. Accessed 14 Jan 2025.

[2] Canada GOV. “Policy on Green Procurement.” Government of Canada, 2022, https://www.tbs-sct.canada.ca/pol/doc-eng.aspx?id=32573. Accessed 14 Jan 2025.

[3] Health Canada, "Microbeads," Canada.ca, Dec. 8, 2023. [Online]. https://www.canada.ca/en/health-canada/services/chemical-substances/other-chemical-substances-interest/microbeads.html. [Accessed: Jan. 14, 2025].

[4] Ontario GOV. “Procurement Guideline for Publicly Funded Organizations in Ontario.” doingbusiness.mgs.gov, https://www.doingbusiness.mgs.gov.on.ca/mbs/psb/psb.nsf/0/993aef5394e028c38525803d00618598/%24FILE/Procurement_Guideline_for_PFOs.pdf. Accessed 14 Jan 2025.

[5]“| Standards Council of Canada,” *Scc-ccn.ca*, 2023. https://scc-ccn.ca/standardsdb/standards/4031289 (accessed Jan. 14, 2025).

Based on your team's scenario, evaluate, and suggest sustainable practices, providing clear examples and justification.

Reduce Single-Use Plastic Packaging
Many industries across Canada use single-use plastic packaging to sell many of their goods, contributing to secondary microplastic contamination due to the breakdown of larger plastics. This practice should be standardized and enforced with regulations upheld by the Canadian government. Many companies continue to use packing peanuts that produce waste and are harmful to the environment. Some have made their way into using brown honeycomb paper that is less wasteful and can be recycled. Sustainable alternatives like these can make all the difference once society moves away from harmful single-use plastic packaging.

Re-investing Carbon Tax Funds
Canada's main cause of pollution is carbon emissions and to combat this, the Canadian government has issued a Carbon tax. This carbon tax "sends a price signal" to producers and consumers to move away from carbon products and look into more sustainable alternatives. The government generates a large revenue from this tax and many people receive carbon rebates. A portion of this revenue should go back into society to educate producers and consumers about making more sustainable choices in their daily lives. This can be done by reducing their plastic consumption, opting for more reusable containers, and educating those around them.

Sustainable Material Acquisition Practices
This can be accomplished by using materials in a productive manner while actively researching ways to use less resources. Another implementation would be to reduce the use of toxic chemicals in the acquisition process and ensure to minimize the environmental impacts of the acquisition. An example of this could be if one tree is cut down then it is ensured another one is planted.

Reduce Consumption of Microplastic High Products
Two sources with very high levels of microplastic contamination include Shellfish and Cosmetics. Shellfish are bottom feeders in the food chain, meaning they will ingest small particles including microplastics. Instead, consumers can opt for other seafood including sardines that have a considerably lower amount of microplastics. Cosmetics are also a large source of microplastics as many of these products use polyethylene. Instead, consumers should search for organically produced cosmetics with biodegradable materials.

MILESTONE 3 (TEAM) – COVER PAGE

Team Number:	Tues - 34

Please list full names and MacID's of all *present* Team Members

Full Name:	**MacID:**
Niyah Miller	millen22
Qianxiang Sun	sunq55
Ramil Jiwani	jiwanr4
Jamin Xu	xu826
Seher Mian	mians15

Any student that is ***not*** present for their scheduled Lab-B session will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-2 grade.

MILESTONE 3 (STAGE 1) – PROBLEM DEFINITION

Team ID: Tues - 34

1. Copy-and-paste the title of your *assigned* scenario in the space below.

Microplastic Filtration for Large-Scale Plant

2. MPI selection
   → List one primary objective and one secondary objective in the table below
   → For each objective, list the MPI
   → Write a short justification for your selected objectives

	Objective	MPI-stiffness	MPI-strength	Justification for this objective
Primary	Minimize Cost	$\frac{E^{1/3}}{\rho Cm}$	$\frac{\sigma^{1/2}}{\rho Cm}$	Since this filter will be used in a large-scale plant, it is important that it is as cheap as possible
Secondary	Minimize Carbon Footprint	$\frac{E^{1/3}}{\rho CO_2}$	$\frac{\sigma^{1/2}}{\rho CO_2}$	Ensures that the process of filtering water isn't counteractive and ends up hurting the environment through its process
Constraint	Biodegradable, non toxic	N/A	N/A	Biodegradable materials reduce waste and nontoxic materials both make the product safe for the environment, ensuring environmental sustainability

Milestone 4 (Team) – Cover Page

Team Number:	Tues - 34

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Jamin Xu	xu826
Niyah Miller	millen22
Ramil Jiwani	jiwanr4
Seher Mian	mians15
Qianxiang Sun	sunq55

Any student that is ***not*** present for their scheduled Design Studio session will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-2 grade.

Milestone 4 (Stage 1) – Material Alternatives and Final Selection worksheet

As a team, fill out the table below and narrow down the possible materials for your assigned scenario by choosing the 3 materials that showed up the most across all MPI rankings in the table above.

Note: The limits of the Ashby Charts were changed to Water (fresh). Certain materials were removed from the material subset including, ceramics and glasses, wood and wood-like materials, as well as ferrous materials.

Team Member: Niyah Miller

Material Ranking					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Assigned MPI: Minimize Cost - Strength	Hemp Fiber	Flax Fiber	Cotton Fiber	Flexible Polymer Foam (VLD)	Flexible Polymer Foam (LD)

Team Member: Qianxiang Sun

Material Ranking					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Assigned MPI: Minimize Cost - Stiffness	Hemp fiber	Flax fiber	Flexible Polymer Foam (VLD)	Flexible Polymer Foam (LD)	Flexible Polymer Foam (MD)

Team Member: Ramil Jiwani

Material Ranking					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Assigned MPI: Minimize Carbon Footprint - Stiffness	Rigid Polymer Foam	Ceramic Foam	Coir Fiber	Hemp Fiber	Flax Fiber

- Remember to save the datasheets of all 3 material finalists

Narrowing Material Candidate List to 3 Finalists	
Material Finalist 1:	Hemp fiber
Material Finalist 2:	Flax fiber
Material Finalist 3:	Cotton fiber

As a team, compare material alternatives and make a final selection based on a simple decision matrix.

→ As a team, consider *at least* 3 additional criteria that are relevant to your assigned scenario and discuss your 3 materials finalists for each criterion

- Feel free to pause at this stage and do some quick research on the materials finalists
- You may refer to the material finalists' datasheets for any relevant information that will enable your discussion.

Additional Criteria	**Possible question prompt**
Ease of access to material	Is the material easy to source in the country, are there tariffs due to international trade policy?
Chemical, weather and/or corrosion resistance	Will the material degrade over time (e.g. due to chemical resistance, corrosion resistance, fatigue resistance)?
Ease of maintenance	Consider maintenance if the part got damaged. Based on the material, is it easy to fix or will the entire part need replacement?

- To help you come up with your additional criteria, below are some question prompts that you may consider. Please note that you are not limited to these suggestions, and they may or may not be relevant to your assigned scenario

→ Remember that:

- Your MPI ranking takes into consideration both material and mechanical properties relevant to the objectives of your assigned scenario.

- Your additional considerations should not include previously evaluated objectives e.g. If minimizing the carbon footprint was either your primary or secondary objective, then it should not be an additional criterion

→ Compare the material alternatives and make a final selection based on a simple decision matrix

- Choose a range for the score (e.g., 1 to 5) for each material on each criterion. Give each material a score based on how successfully it meets each criterion. The higher the score, the better the material is for that criterion.
- Add additional rows as needed.
- Add up the total score for each material alternative.

Simple Decision Matrix - Template			
	Material 1: Hemp Fiber	*Material 2: Flax Fiber*	*Material 3: Cotton Fiber*
Ease of production	4	3	5
Ease of access	5	5	5
Corrosion resistance	4	4	2
Cost effective	5	4	5
Mechanical Performance	4	3	1
Ease of Maintenance	4	4	4
TOTAL	26/30	23/30	22/30

1.

→ State your chosen material and justify your final selection

Justification	
Chosen Material:	Hemp Fiber

Discuss and justify your final selection in the space below (based on the decision matrix results and any other relevant considerations).

Based on the decision matrix, Hemp fiber is the overall best material. The material performs well in all aspects required for our scenario. This is important as even if another material had a higher overall score, but performed worse in one aspect, that material would be unacceptable due to a limitation acting as a bottleneck in the process. In addition, hemp fiber also had the highest overall score, making it far more suitable than the other materials with a lower score, and certain outlier categories. Certain aspects that make hemp fiber even more appealing include the ease of production and access to the material and the fact that it can be locally sourced, supporting Canadians in the process.

Summary of Chosen Material's Properties

Material Name	Average value
Young's modulus (GPa):	62.5
Yield strength (MPa):	300
Tensile strength (MPa):	400 to 900
Density (kg/m^3):	1,480
Embodiment energy (MJ/kg)	10–12
Specific carbon footprint (kg/kg)	-1.5 to -0.5
Number of Pores	2.00 x 10^6
Pore Size (m)	<10 µm (10^{-6} m)

Milestone 4 (Stage 2) – Porosity Conditions

Below, provide step-by-step calculations determining the porosity of your chosen material and its adjusted yield strength / elastic modulus. State all your assumptions and reference the project module for any values related to your scenario.

Porosity ()	0.0398
Pore Size ()	< 10 µm
Diameter (mm)	6.50
Length (cm)	20

Porosity Calculations

Diameter = 6.50 mm = 6.50×10^{-3} m

Length = 20 cm = 0.20 m

Contaminant size = 10 – 20 µm = 10×10^{-6} m

$$\text{Porosity} = \frac{(\#\text{ pores})(\text{Volume singular})}{\text{Volume of filter fibre}}$$

① $V_{filter\ fibre} = \pi r^2 h$

$= \pi (3.25 \times 10^{-3})^2 (0.20)$

$= 6.64 \times 10^{-6}\ m^3$

② $V_{singular} = \pi (\text{pore radius})^2 (\text{thickness})$

Pore radius – smaller than contaminant size

$= 8 \times 10^{-6}$ m

Thickness – diameter in this case

$V_{singul.} = \pi (8 \times 10^{-6})^2 (6.50 \times 10^{-3})$

$= 1.307 \times 10^{-12}\ m^3$

③ $\#\text{ Pores} = \frac{V_{fibre}}{V_{singul.}}$

$\#\text{Pores} = \frac{6.64 \times 10^{-6}}{1.307 \times 10^{-12}}$

$= 5.08 \times 10^{6}$ pores

This is max value, choose less.

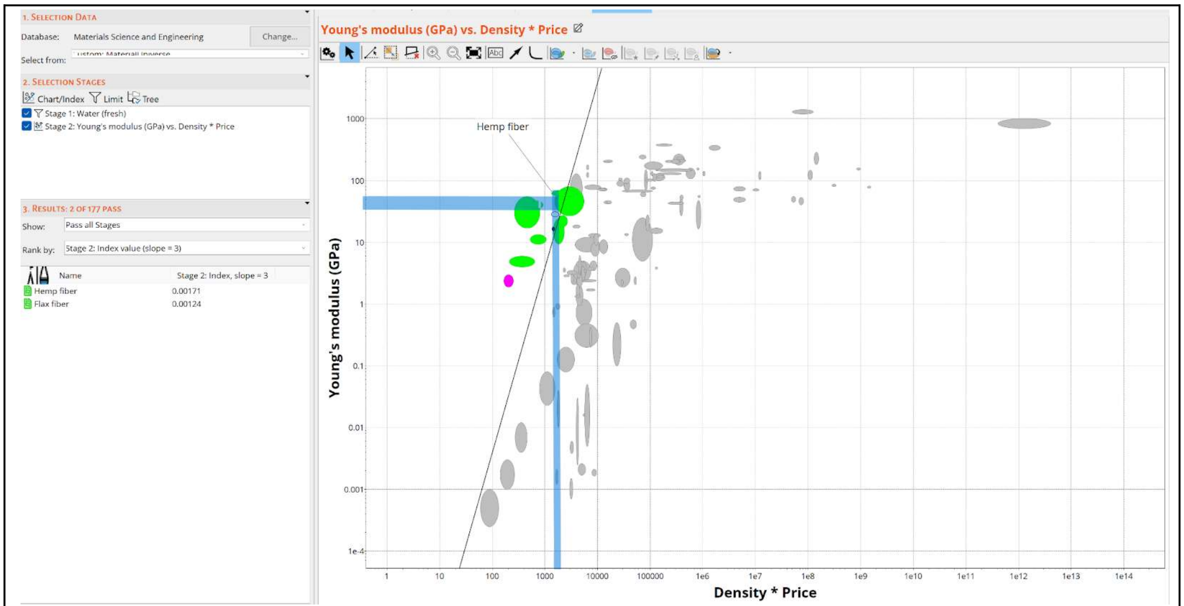
Chosen # pores = 2.00×10^{5} pores

④ $P = \frac{(\#\text{ Pores})(1.307 \times 10^{-12})}{(6.64 \times 10^{-6})}$

$= 0.039$

MILESTONE 4 (STAGE 3) – EFFECTS OF POROUS CONDITIONS

Based on the porosity from Stage 2, is your selected material still a viable option as a wastewater treatment filter? Explain. Provide a graphical justification using a notated Ashby chart from Granta.



Effective Young's Modulus and Yield Strength

$E_{eff} = E(1-P)^n$ $\sigma_{y\,eff} = \sigma_y(1-P)^n$ $n = 2$ (for this project)

① E_{eff} using avg. E

$E_{avg} = 62.5$ GPA

$E_{eff} = (62.5)(1-0.039)^2$

$= 57.7$ GPA

② $\sigma_{y\,eff}$ using avg. σ_y

$\sigma_{y\,avg} = 300$ mPA

$\sigma_{y\,eff} = (300)(1-0.039)^2$

$= 277$ mPA

Based on the ashby chart created in Granta using the MPI for young's modulus, and density and price, our chosen material, hemp fibre is a viable choice. The position of the adjusted data point relative to the index line shows that the material is mechanically viable. The effective modulus still lies above the index line, assuming density and price remain the same. In the decision matrix, hemp fiber scored the highest among cotton fiber and flax fiber. It had consistently strong scores in each of the categories, showing strong material performance, cost efficiency, as well as easy access. The chosen pore size as well as number of pores ensure the correct filtration rate to trap microplastics. In addition to this, hemp fiber can be sourced in Canada, further reducing carbon footprint, correlating to our objective.

MILESTONE 5 (TEAM) – COVER PAGE

Team Number: Tues - 34

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Niyah Miller	millen22
Seher Mian	mians15
Ramil Jiwani	jiwanr4
Qianxiang Sun	sunq55
Jamin Xu	xu826

Any student that is ***not*** present for their scheduled Design Studio session will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their P-2 grade.

Milestone 5 (Stage 2) – Life Cycle Inventory

As a team, fill out the table with the corresponding material information and processes for your life cycle inventory. Provide references for the information and list them below.

Material	Mass (kg)	Process	End of Life
Hemp Fiber	0.0106	Retting	Recycle
Flax Fiber	0.150	Breaking/Hackling	Recycle
Cotton Fiber	0.00983	Spinning	Recycle

References

[1] Alliance Flax Linen Hemp, "All about European linen," *Alliance Flax Linen Hemp*. https://allianceflaxlinenhemp.eu/en/all-about-european-linen. [Accessed: Feb. 4, 2025].

[2] Fehr Graham, "What is a typical wastewater treatment plant life expectancy?" *Fehr Graham*. https://www.fehrgraham.com/about-us/blog/what-is-a-typical-wastewater-treatment-plant-life-expectancy-fg#:~:text=However%2C%20the%20average%20wastewater%20treatment,lasts%2015%20to%2020%20years. [Accessed: Feb. 4, 2025].

[3] A. Bourmaud, W. Dang, J. R. Duflou, and S. González-García, "Environmental impact assessment of end of life options for flax-mapp composites," Industrial Crops and Products, https://www.sciencedirect.com/science/article/pii/S0926669016305854 [Accessed Feb. 7, 2025].

[4] N. Chand and M. Fahim, "Flax fiber," Flax Fiber - an overview | ScienceDirect Topics, https://www.sciencedirect.com/topics/engineering/flax-fiber [Accessed Feb. 7, 2025].

[5] "Raw Cotton," *Coppersmith*, Apr. 27, 2023. https://www.coppersmith.com/industry/raw-cotton/ (accessed Feb. 07, 2025).

[6] "From Raw Cotton to Cotton Fabrics | Toyota Industries Corporation," *www.toyota-industries.com*. https://www.toyota-industries.com/products/relation/textile_process/ (accessed Feb. 07, 2025)

[7] Lemieux, "Lemieux Spinning | Yarn Specialist Since 1906," *Lemieux Spinning*. https://www.lemieuxspinning.com/en/ (accessed Feb. 07, 2025).

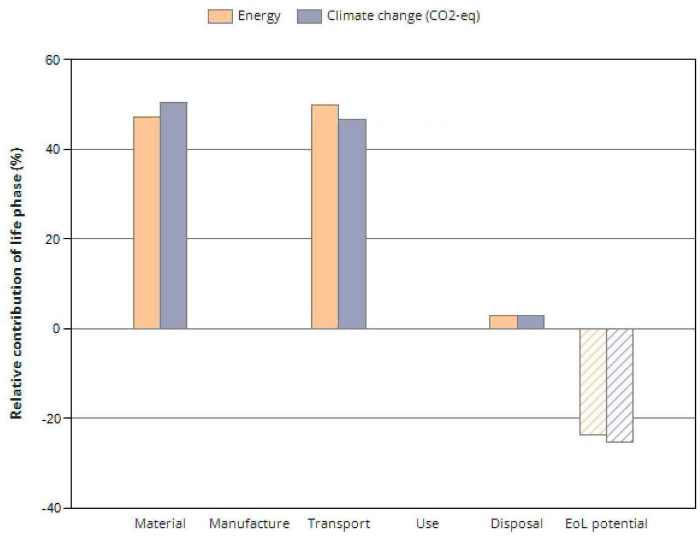
[8] "How Quickly Do Textile Microfibers Degrade in Aquatic Environments? -," Feb. 18, 2019. https://cottontoday.cottoninc.com/how-quickly-do-textile-microfibers-degrade-in-aquatic-environments/ (accessed Feb. 07, 2025)

[9]"Recyclability," *CottonToday*. https://cottontoday.cottoninc.com/our-sustainability-story/circularity/recyclability/ (accessed Feb. 07, 2025)

Milestone 5 (Stage 3) – Eco Audits

As a team, provide a screenshot of your results from performing the Granta Eco-Audit for all three of your top material choices. Include the summary chart as well as the tabular information for the energy cost and CO2 footprint of each material.

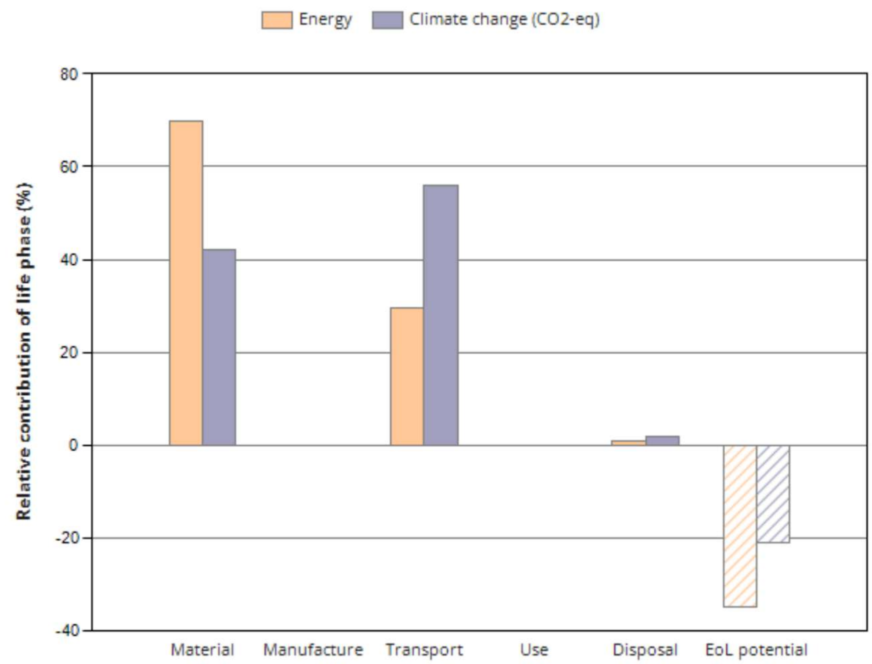
Eco-Audit (Material 1)



Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	0.114	47.2	0.0092	50.5
Manufacture	0	0.0	0	0.0
Transport	0.121	49.8	0.00849	46.6
Use	0	0.0	0	0.0
Disposal	0.00742	3.1	0.000519	2.9
Total (for first life)	**0.242**	**100**	**0.0182**	**100**
End of life potential	-0.0573		-0.00461	

Eco-Audit (Material 2)

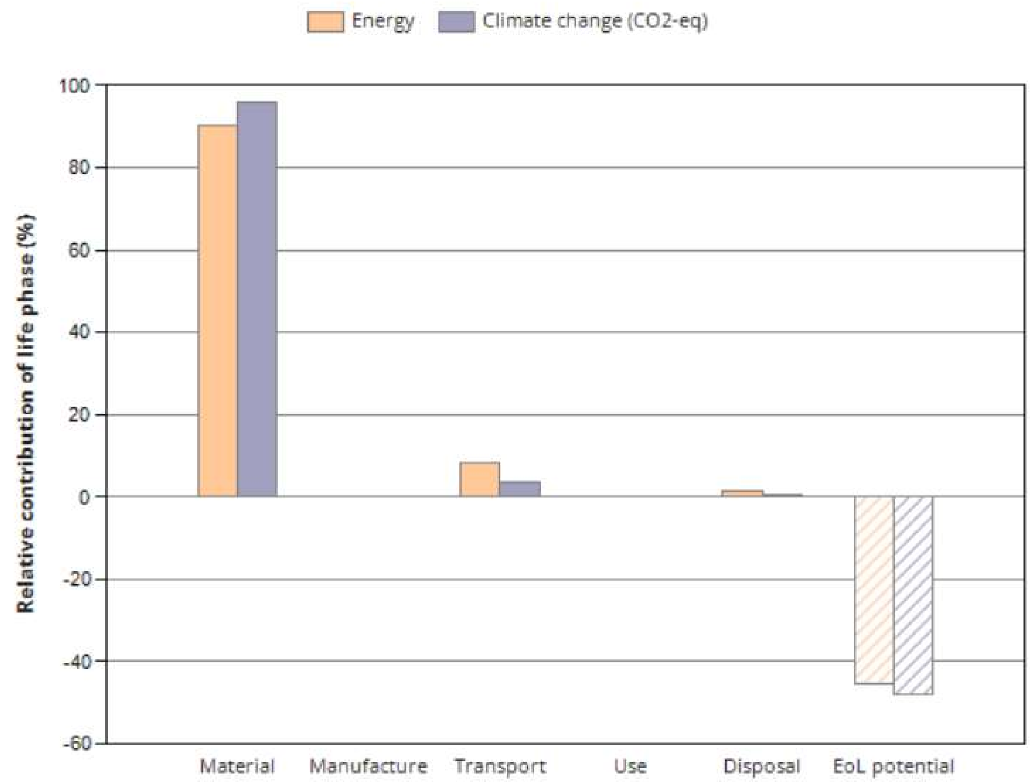
SUMMARY:



Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	8.05	69.7	0.17	42.1
Manufacture	0	0.0	0	0.0
Transport	3.4	29.4	0.226	56.1
Use	0	0.0	0	0.0
Disposal	0.105	0.9	0.00735	1.8
Total (for first life)	**11.5**	**100**	**0.404**	**100**
End of life potential	-4.02		-0.0852	

Note: The processes needed for manufacture are not available in GRANTA, therefore the charts may be slightly inaccurate.

Eco-Audit (Material 3)



Phase	Energy (MJ)	Energy (%)	Climate change (CO2-eq) (kg)	Climate change (CO2-eq) (%)
Material	0.521	90.4	0.0824	95.7
Manufacture	0	0.0	0	0.0
Transport	0.0485	8.4	0.0032	3.7
Use	0	0.0	0	0.0
Disposal	0.00688	1.2	0.000482	0.6
Total (for first life)	**0.577**	**100**	**0.0861**	**100**
End of life potential	-0.261		-0.0412	

Milestone 5 (Stage 4) – Discussion of Eco Audit Implications

As a team, discuss the implications of the results from the Eco-Audit of all three materials. What do you conclude? Be sure to reference any appropriate values from the energy cost and CO2 footprint table.

Based on the results from the Eco-Audit, flax fiber is not a sustainable choice. The manufacturing processes were unable to be displayed in GRANTA, making the summary charts slightly inaccurate however the transportation aspect is accurate. These fibers are grown and processed in Saskatchewan but the usage is necessary in Hamilton, Ontario. Recent studies have found that flax fiber is highly effective at filtering microplastics from water but the impact must be considered in this case. Transporting the filters from Saskatchewan to Ontario is done using a truck which uses a lot of fuel and does not count as an ecological choice for our final material.

The Eco-Audit for cotton fiber also suggests that this material is not a great choice of material. For starters, the manufacturing process of 'spinning' is not available on Grnata, making the Eco-Audit less accurate. Cotton fibers are great for filter microplastics but one major flaw is its lifespan. Even though the summary chart may look appealing, the reality is that cotton fibers do not last very long in water. This means that replacement and maintenance fees will be constant.

Based on the Eco-Audit results, hemp fiber demonstrates a more sustainable profile compared to other materials, particularly when considering its end-of-life (EoL) reuse potential. The total energy consumption is primarily concentrated in the material acquisition (approximately 0.115 MJ) and transportation (around 0.135 MJ) phases, with negligible contributions from manufacturing, use, and disposal stages (Note: manufacturing processes were not available in Granta, however the process to make this fiber has been researched to be field retting which is low energy). Similarly, the CO2 footprint shows that material and transportation phases each contribute about 0.009 kg of CO2 emissions. The most significant environmental benefit arises from the EoL potential, where the reuse of hemp fibers results in a reduction of approximately 0.13 MJ in energy and around 0.01 kg of CO2 emissions. This offsets much of the environmental cost incurred during earlier stages, making hemp a more viable ecological choice. However, transporting the hemp fibers by truck from Alberta to Ontario still contributes significantly to both energy use and CO2 emissions. Taking all of the above information into consideration we can conclude that hemp fiber is the best material out of our top three finalists.

Project Two Milestone (Individual) Worksheets - Jamin Xu

Milestone 1 (Individual) – Cover Page

Team Number: Tues - 34

Please list full name and MacID.

Full Name:	**MacID:**
Jamin	Xu

Team ID: Tues - 34

Stage 1: Initial Problem Statement:

What is your first draft of the problem statement? Keep it brief and to the point. One or two sentences should be enough. **For this initial problem statement, you should be focusing on the main function(s) of the wastewater treatment plant.**

Design and develop a water filtration system that effectively identifies and filters microplastics from a large-scale water plant. The solution should be cost-efficient, sustainable, and energy efficient. Given the nature of a large-scale power plant, the system should also apply to a variety of sources.

Milestone 2 (Individual) – Cover Page

Team Number: Tues - 34

Please list full name and MacID.

Full Name:	MacID:
Jamin Xu	xu826

Milestone 2 (Stage 0) – Research Memo

Team ID: Tues - 34

This is an individual deliverable and should be completed by each team member **prior** to Design Studio 2.

Summary of the current state of filtration technology. You must have 2-4 references from various online sources (following IEEE notation).

Each individual research memo should be ***no more than one page***, excluding references.

Introduction:
Microplastics have become a huge problem in modern society as plastics are integrated into every aspect of our lives. Microplastics are small pieces of plastic from these products that contaminate water sources, produce, soil, etc. Microplastics are harmful to animals, humans, and the environment. Ingesting these micro-particles can cause many diseases and health complications that need to be prevented especially in the biggest source of this problem: drinking water.
Design factors:

- The system must target a range of particle sizes, from microplastics (<5 mm) to nanoplastics (<1 µm).
- Contain multiple filtration stages
- Ensure that membranes are easy to clean
- The system should handle large volumes of water efficiently in industrial or municipal wastewater treatment plants.
- Modular design allows for system expansion based on demand.
- Use biodegradable or recyclable materials in filters and adsorbents.
- Balance high filtration efficiency with affordability.
- Minize energy and maintenance costs.
- Use durable materials to lower replacement frequency.
- Ensure the system can operate under varying conditions

References (adhere to IEEE notation)

***references do not count toward word count / page limit

[1] Dayal, L., Yadav, K., Dey, U., Das, K., Kumari, P., Raj, D., & Mandal, R. R. (2024). Recent advancement in microplastic removal process from wastewater - A critical review. Journal of Hazardous Materials Advances, 16, 100460. https://doi.org/10.1016/j.hazadv.2024.100460

[2] Gao, W., Zhang, Y., Mo, A., Jiang, J., Liang, Y., Cao, X., & He, D. (2022). Removal of microplastics in water: Technology progress and green strategies. Green Analytical Chemistry, 3, 100042. https://doi.org/10.1016/j.greeac.2022.100042

MILESTONE 3 (INDIVIDUAL) – COVER PAGE

Team Number: Tues - 34

Please list full name and MacID.

Full Name:	MacID:
Jamin Xu	xu826

Team ID: Tues - 34

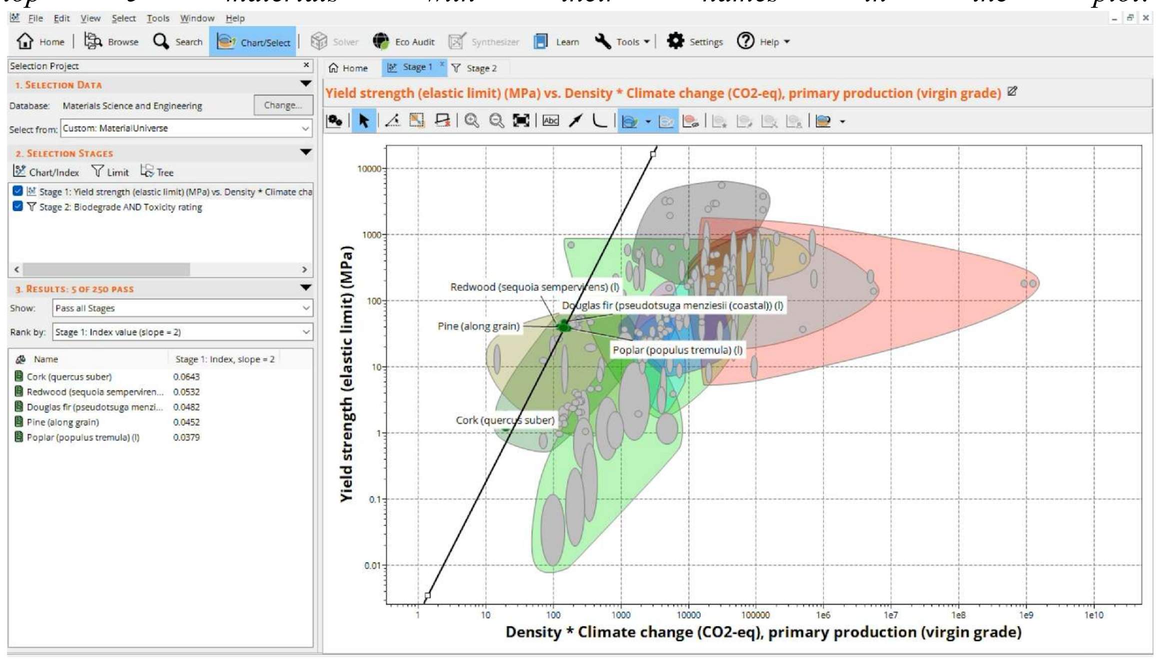
MILESTONE 3 (STAGE 2) – MATERIAL SELECTION: MPI AND MATERIAL RANKING

Document the results of your materials selection and ranking on the following pages.

→ Each team member is required to complete this worksheet

Material Property Chart		
Assigned MPI	**Functional Constraint**	**Objective**
	MPI-strength	Minimize Carbon Footprint

Insert a screenshot of the material property chart with MPI guidelines. Please clearly label the top 5 materials with their names in the plot.



Material Ranking					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Assigned MPI:	Cork	Redwood	Douglas fir	Pine	Poplar

Milestone 5 (Individual) – Cover Page

Team Number: Tues - 34

Please list full name and MacID.

Full Name:	MacID:
Jamin Xu	xu826

Milestone 5 (Stage 1) – Life cycle Diagram

In the space below, copy and paste a life cycle diagram for one of the three top material choices for your filter design. Include citations for each of the process steps within the filter's life cycle.

Life Cycle Diagram

References:
[1] Government of Canada, “Investing in Alberta’s hemp industry,” Canada.ca, Apr. 2022. [Online]. Available: https://www.canada.ca/en/agriculture-agri-food/news/2022/04/investing-in-albertas-hemp-industry.html. [Accessed: Feb. 4, 2025].

[2] Canadian Rockies Hemp, “Sustainable Hemp Products & Agriculture,” Canadian Rockies Hemp, 2025. [Online]. Available: https://www.canadianrockieshemp.com. [Accessed: Feb. 4, 2025].

[3] City of Hamilton, “Community Recycling Centres,” Hamilton.ca, 2025. [Online]. Available: https://www.hamilton.ca/home-neighbourhood/garbage-recycling/waste-recycling-facilities/community-recycling-centres. [Accessed: Feb. 4, 2025].

[4] Care Water Solutions, “The periodic maintenance of the treatment plant,” CareWater Solutions, 2025. [Online]. Available: https://carewater.solutions/en/the-periodic-maintenance-of-the-treatment-plant/#:~:text=Change%20filters%20regularly,quality%20and%20affect%20human%20health. [Accessed: Feb. 4, 2025].

Milestone 1 (Individual) – Cover Page

Team Number: Tues-34

Please list full name and MacID.

Full Name:	MacID:
Ramil Jiwani	Jiwanr4

Milestone 1 (Stage 1) – Individual Problem Statement

Team ID: Tues-34

Stage 1: Initial Problem Statement:

What is your first draft of the problem statement? Keep it brief and to the point. One or two sentences should be enough. **For this initial problem statement, you should be focusing on the main function(s) of the wastewater treatment plant.**

The wastewater treatment plan must remove different sized impurities from the wastewater at a large scale to service a city of 2500 citizens while simultaneously complying with health and environmental regulations.

Milestone 2 (Individual) – Cover Page

Team Number: Tues-34

Please list full name and MacID.

Full Name:	MacID:
Ramil Jiwani	jiwanr4

Milestone 2 (Stage 0) – Research Memo

Team ID: Tues-34

This is an individual deliverable and should be completed by each team member **prior** to Design Studio 2.
Summary of the current state of filtration technology. You must have 2-4 references from various online sources (following IEEE notation).

Each individual research memo should be ***no more than one page***, excluding references.

Introduction:
Plastic pollution in wastewater, particularly the presence of microplastics, has become a significant environmental and health concern. Current wastewater treatment and filtration systems, face a massive challenge in removing these contaminants. This memo discusses the current state of plastic filtration in wastewater treatment systems.
Current challenges include:

- Lack of dedicated treatment processes for microplastics [2]
- Ineffectiveness of existing methods (skimming, sedimentation, tertiary filtration) in targeting microplastics [2]
- High concentrations of microplastics from laundry overwhelming filtration systems

Design factors:
Current devices with microfiltration (MF) are able to remove 78-86% of PVC fragments and 94-100% removal of PET fragments [3]
Devices with smaller nominal pore size (0.2 μm vs. ≥1 μm) result in better performance [3]
Devices using only granular activated carbon (GAC) and ion exchange (IX) are less effective [3]
Devices that use reverse osmosis (RO) systems show efficiency in reducing high levels of microplastics in water. The RO process typically involves:

- Sediment filtration
- Activated carbon filtration
- Reverse osmosis membrane (pore size 0.001 microns)

The reverse osmosis process involves many layers of filtration and can remove microplastics that are very small. Implementing these devices can have a major beneficial impact on the environment and water filtration systems

References (adhere to IEEE notation)

***references do not count toward word count / page limit

[1] D. J. H, “The truth behind RO water filters and microplastics,” Aquatech Water Systems, https://www.aquatechwatersystems.com/blog/the-truth-behind-ro-water-filters-and-microplastics/ (accessed Jan. 13, 2025).

[2] A. G. Cherian, Z. Liu, M. J. McKie, H. Almuhtaram, and R. C. Andrews, “Microplastic removal from drinking water using point-of-use devices,” Polymers, https://pmc.ncbi.nlm.nih.gov/articles/PMC10054062/ (accessed Jan. 13, 2025).

[3] C. and M. Branch, “Government of Canada,” Government of Canada, Innovation, Science and Economic Development Canada, Office of the Deputy Minister, Communications and Marketing Branch, https://ised-isde.canada.ca/site/innovative-solutions-canada/en/plastics-challenge-filtration-microplastics-ship-greywater (accessed Jan. 13, 2025).

[4] V. Jani, S. Wu, and K. Venkiteshwaran, “Advancements and regulatory situation in microplastics removal from wastewater and drinking water: A comprehensive review,” MDPI, https://www.mdpi.com/2673-8929/3/1/7 (accessed Jan. 13, 2025).

Milestone 3 (Individual) – Cover Page

Team Number: Tues-34

Please list full name and MacID.

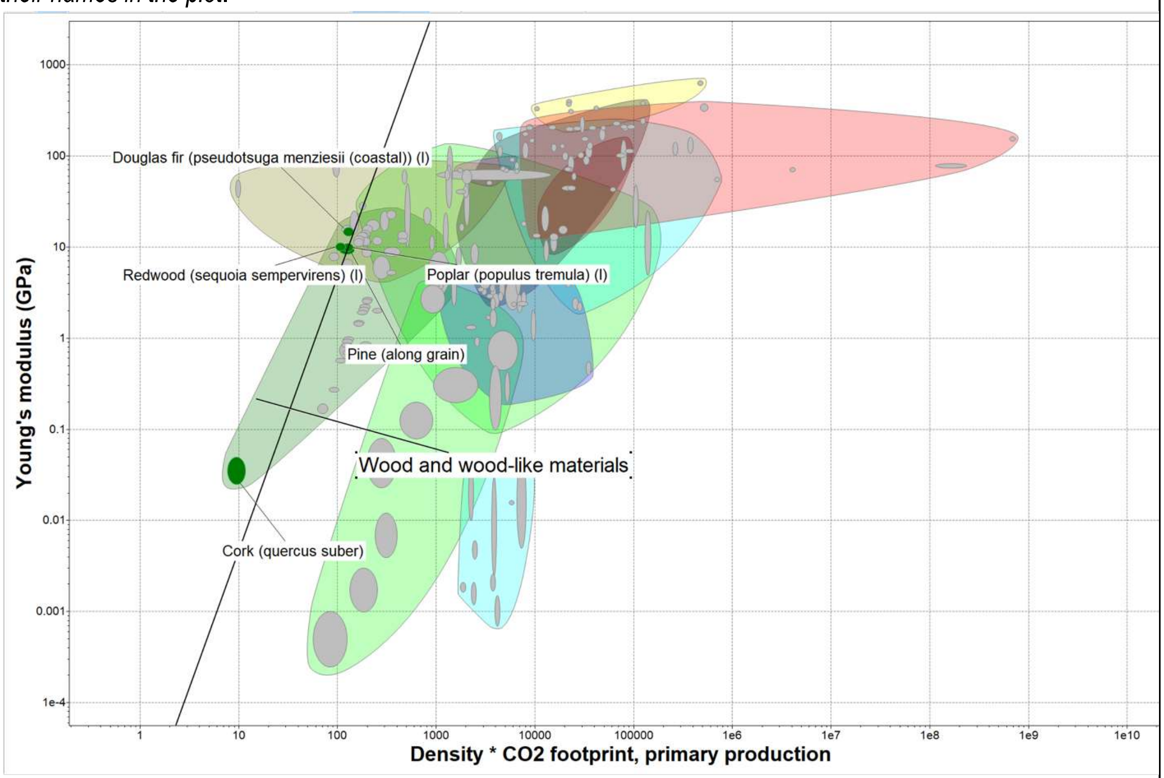
Full Name:	MacID:
Ramil Jiwani	Jiwanr4

Milestone 3 (Stage 2) – Material Selection: MPI and Material Ranking

Document the results of your materials selection and ranking on the following pages.

→ Each team member is required to complete this worksheet

Material Property Chart		
Assigned MPI	**Functional Constraint**	**Objective**
MPI – stiffness	Must be biodegradable Must be non-toxic	Minimize Carbon Footprint
Insert a screenshot of the material property chart with MPI guideline. Please clearly label the top 5 materials with their names in the plot.		



Material Ranking					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5

Assigned MPI: Stiffness (minimize CO_2)	Cork (quercus suber)	Redwood (sequoia sempervirens)	Pine (along grain)	Poplar (populus tremula)	Douglas Fir (Pseudotsuga menziesii (coastal))

Milestone 5 (Individual) – Cover Page

Team Number: Tues-34

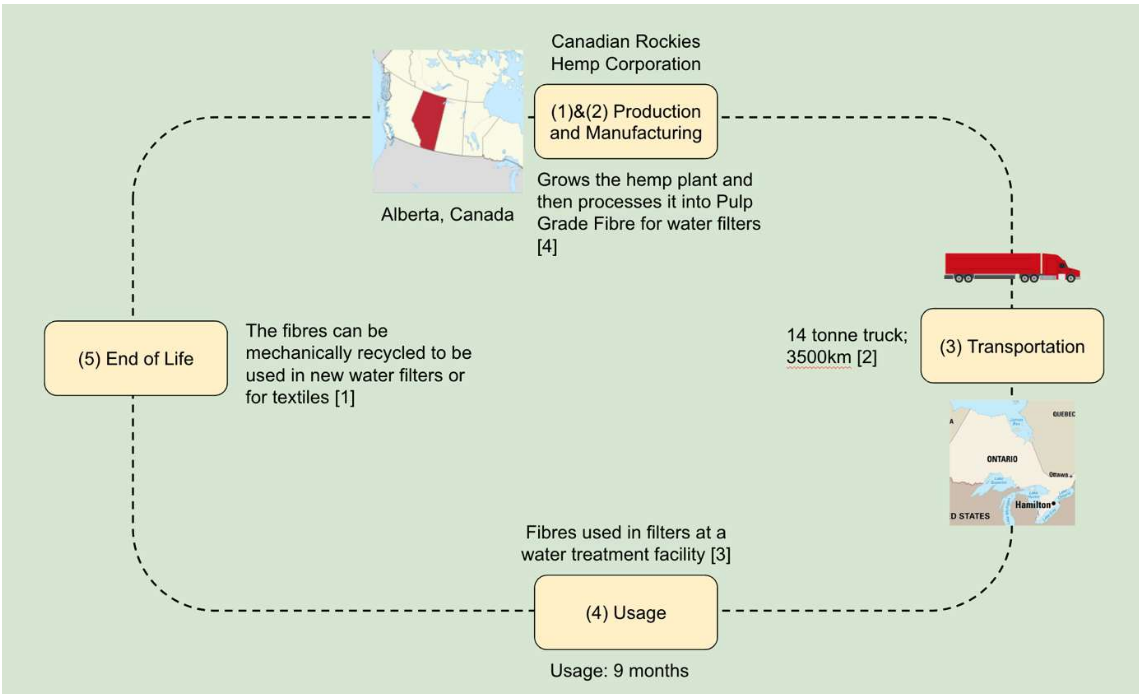
Please list full name and MacID.

Full Name:	**MacID:**
Ramil Jiwani	Jiwanr4

Milestone 5 (Stage 1) – Life cycle Diagram

In the space below, copy and paste a life cycle diagram for one of the three top material choices for your filter design. Include citations for each of the process steps within the filter's life cycle.

Life Cycle Diagram



References
[1] "The recyclability of Hemp Fabric," Hemp Gallery, www.hempgallery.com.au. (accessed Feb. 4, 2025).

[2] "Produce," ET Transport, www.ettransport.ca (accessed Feb. 4, 2025).

[3] H. Campbell, "How long will your water treatment system last?," Secondwind Water, www.secondwindwater.com. (accessed Feb. 4, 2025).

[4] "Our Products," CRHC, www.canadianrockieshemp.com(accessed Feb. 4, 2025).

Milestone 1 (Individual) – Cover Page

Team Number: Tues-34

Please list full name and MacID.

Full Name:	**MacID:**
Qianxiang Sun	Sunq55

Milestone 1 (Stage 1) – Individual Problem Statement

Team ID: Tues-34

Stage 1: Initial Problem Statement:

What is your first draft of the problem statement? Keep it brief and to the point. One or two sentences should be enough. **For this initial problem statement, you should be focusing on the main function(s) of the wastewater treatment plant.**

Design wastewater filtration system that is able to remove contaminants from large-scale plants, including organic, microplastic and metals. It must meet Canadian Health regulation and should be sustainable and durable enough to be cost effective.

Milestone 2 (Individual) – Cover Page

Team Number: Tues-34

Please list full name and MacID.

Full Name:	**MacID:**
Qianxiang Sun	Sunq55

Milestone 2 (Stage 0) – Research Memo

Team ID: Tues-34

This is an individual deliverable and should be completed by each team member **prior** to Design Studio 2.

Summary of the current state of filtration technology. You must have 2-4 references from various online sources (following IEEE notation).

Each individual research memo should be ***no more than one page***, excluding references.

Introduction:

Microplastic is always an important part of water pollution for its potential effect on people's health. This memo focus on current filtration technologies aimed at removing microplastic from wastewater.

Design factors:

To remove microplastic, the mechanical filters are the eldest filter we widely use today. The simplest filter are mesh filters. These filters use a fine mesh to physically trap microplastics based on their size. Although they are relatively versatile, the limitation on catching smaller plastics and problem of being clogged can't be ignored. Another chemical filter based on density This method helps isolate the microplastic by removing the denser sediments when adding common chemicals like zinc chloride, sodium chloride, and sodium iodine due to their inexpensiveness, which makes this filter cost effective.[1] In modern wastewater treatment plant, Various treatment technologies applied, including primary treatment processes (primary settling treatment, grit, and grease treatment), secondary treatment processes (A2O, biofilters, and other bioreactors), and tertiary treatment processes (UV, O_3, chlorination, biologically active filters (BAFs), disc filters (DFs), and rapid sand filters (RSFs)). These treatment can remove most of microplastics in wastewater, but problem of hard to remove smaller plastic still exists. [2]

References (adhere to IEEE notation)

***references do not count toward word count / page limit

[1]. WPI edu: Filtering microplastics using semipermeable membrane filters

(https://users.wpi.edu/~ndxiang/Docs/LitReview.pdf)

[2]. ScienceDirect: Membrane and filtration processes for microplastic removal

(https://www.sciencedirect.com/science/article/pii/B9780443191800000195#s0045)

Milestone 3 (Individual) – Cover Page

Team Number: Tues-34

Please list full name and MacID.

Full Name:	MacID:
Qianxiang Sun	Sunq55

MILESTONE 3 (STAGE 2) – MATERIAL SELECTION: MPI AND MATERIAL RANKING

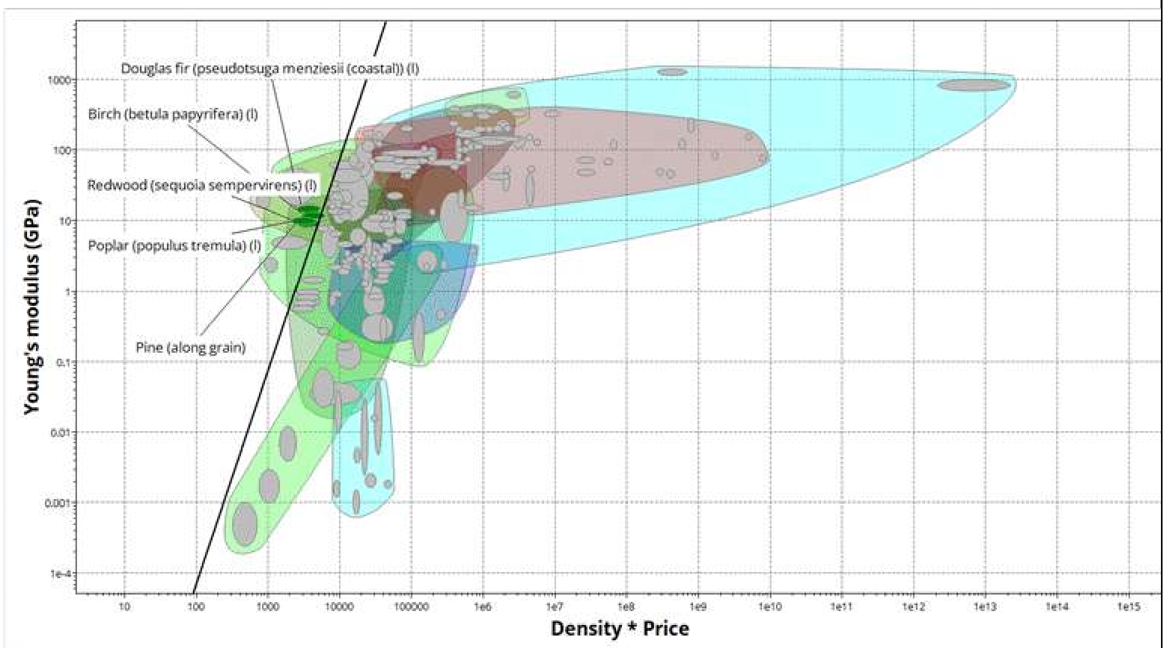
Document the results of your materials selection and ranking on the following pages.

® Each team member is required to complete this worksheet

Material Property Chart		
Assigned MPI	**Functional Constraint**	**Objective**

stiffness	Biodegradable, non toxic	Minimize cost

Insert a screenshot of the material property chart with MPI guideline. Please clearly label the top 5 materials with their names in the plot.



Material Ranking					
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5

Assigned MPI: Stiffness(minimize cost)	Birch (betula papyrifera) (l)	**Name** Douglas fir (pseudotsuga menziesii (coastal)) (l)	**Name** Pine (along grain)	**Nam** Poplar (populus tremula) (l)	Redwood (sequoia sempervirens) (l)

Milestone 5 (Individual) – Cover Page

Team Number: Tues-34

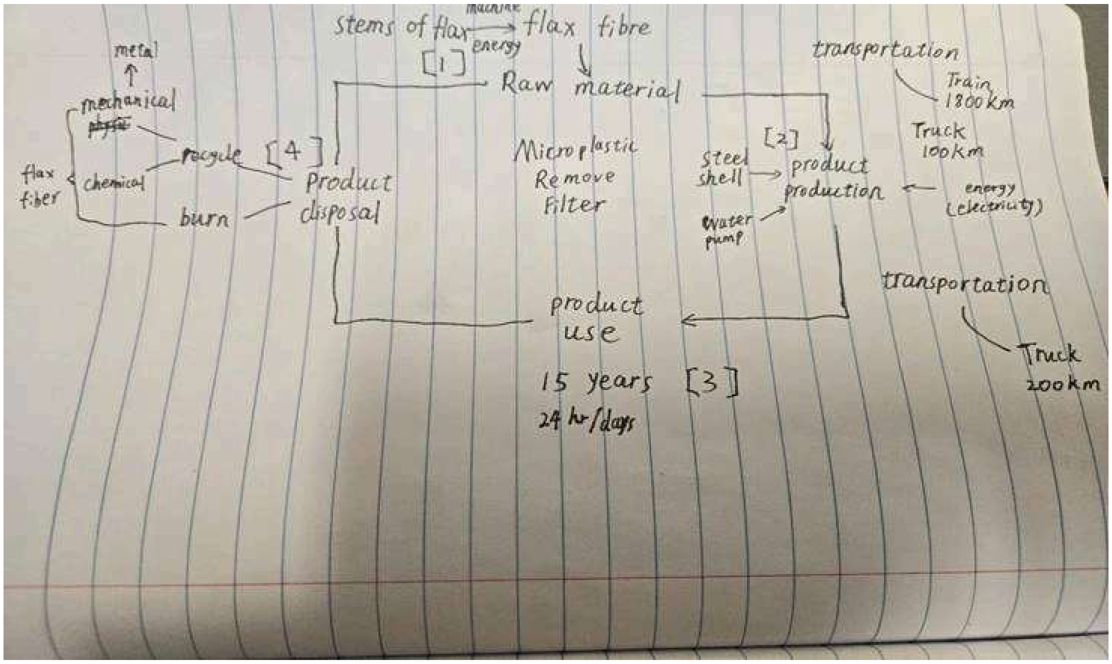
Please list full name and MacID.

Full Name:	**MacID:**
Qianxiang Sun	sunq55

Milestone 5 (Stage 1) – Life cycle Diagram

In the space below, copy and paste a life cycle diagram for one of the three top material choices for your filter design. Include citations for each of the process steps within the filter's life cycle.

Life Cycle Diagram



References

[1] “Everything you need to know about European flax” https://allianceflaxlinenhemp.eu/en/all-about-european-linen

N. Chand and M. Fahim, “Flax fiber,” Flax Fiber - an overview | ScienceDirect Topics, https://www.sciencedirect.com/topics/engineering/flax-fiber

[2] “What Are Industrial Filters Made From?” https://advancedfiltration.com/what-are-industrial-filters-made-from/

[3] “What is a typical wastewater treatment plant life expectancy?” Matthew Johnson https://www.fehrgraham.com/about-us/blog/what-is-a-typical-wastewater-treatment-plant-life-expectancy-fg#:~:text=However%2C%20the%20average%20wastewater%20treatment,lasts%2015%20to%2020%20years

[4] Farida Bensadoun, Bart Vanderfeesten, Ignaas Verpoest, Aart W. Van Vuure, Karel Van Acker Environmental impact assessment of end of life options for flax-MAPP composites https://www.sciencedirect.com/science/article/pii/S0926669016305854