Comparative Study of LCA between Disposable Single Use Mask and Reusable Cloth Mask

1. Executive Summary

This report is a comparative study between the Life cycle Assessment of Disposable 3 Layered Masks and Reusable 3 Layered Masks. The study is performed using OpenLCA with ReCiPe Midpoint (H) characterization model. With the recent outbreak of COVID-19, masks were mandatory to control the spread. With a significant increase in the usage of masks across the world, it becomes of great importance to estimate the impact of the usage and disposal of masks in our environment.

2. Goal and Scope

Goal:

The goal of this LCA study is to compare the environmental impacts of 3 Layered Disposable Masks and 3 Layered Reusable Cotton Masks during their manufacturing, usage, and disposal. Hence, this comparative study would be useful to help understand the environmental impacts and would give the public a better idea to make their choice of purchasing a safe and environment-friendly mask.

Scope:

The Life Cycle Assessment are analyzed for the masks with reference to their production at Biomed Technologies, NSW Australia. A common 3-layered Disposable mask is compared with BIO SHIELD-05, a 3 Layered reusable cotton mask with reusability over 50 washes. It is assumed that all the raw materials are sourced and available at the manufacturing facility. The scope covers the manufacturing/production of masks, their usage, and disposal. To differentiate between the usage of Disposable and reusable masks, the functional unit for this assessment is chosen to be the **masks used by an ideal person for a week**. Hence this would be equivalent to 7 Disposal Masks (1mask/day) and 1 Reusable Mask (estimated for 50 washes and would last for 50 days). The system diagram and the boundaries have been specified in Figure 1 and Figure 2.

3. Life-Cycle Inventory

Assumptions:

As mentioned, it is assumed that the raw materials for the manufacturing are made available at the manufacturing unit hence, the system boundary presented in Figure 1 and Figure 2 is the gate-to-grave. Processes such as transportation of raw material and distribution of completed masks are excluded, as the estimated impact for both types of masks is all same. The electricity consumed to produce the ear loop and nose wire is excluded considering that the electricity is the same for both types of masks. The electricity estimated for the body-making and ultrasonic welding of the reusable mask is estimated based on the electricity equivalent of the disposable mask as shown in Appendix A.

The Life Cycle Inventory of 7x Disposable Masks(the inventory for 1x Disposable Mask is shown in Appendix B) and Reusable Cotton Mask are shown in Table1 and Table 2 respectively.

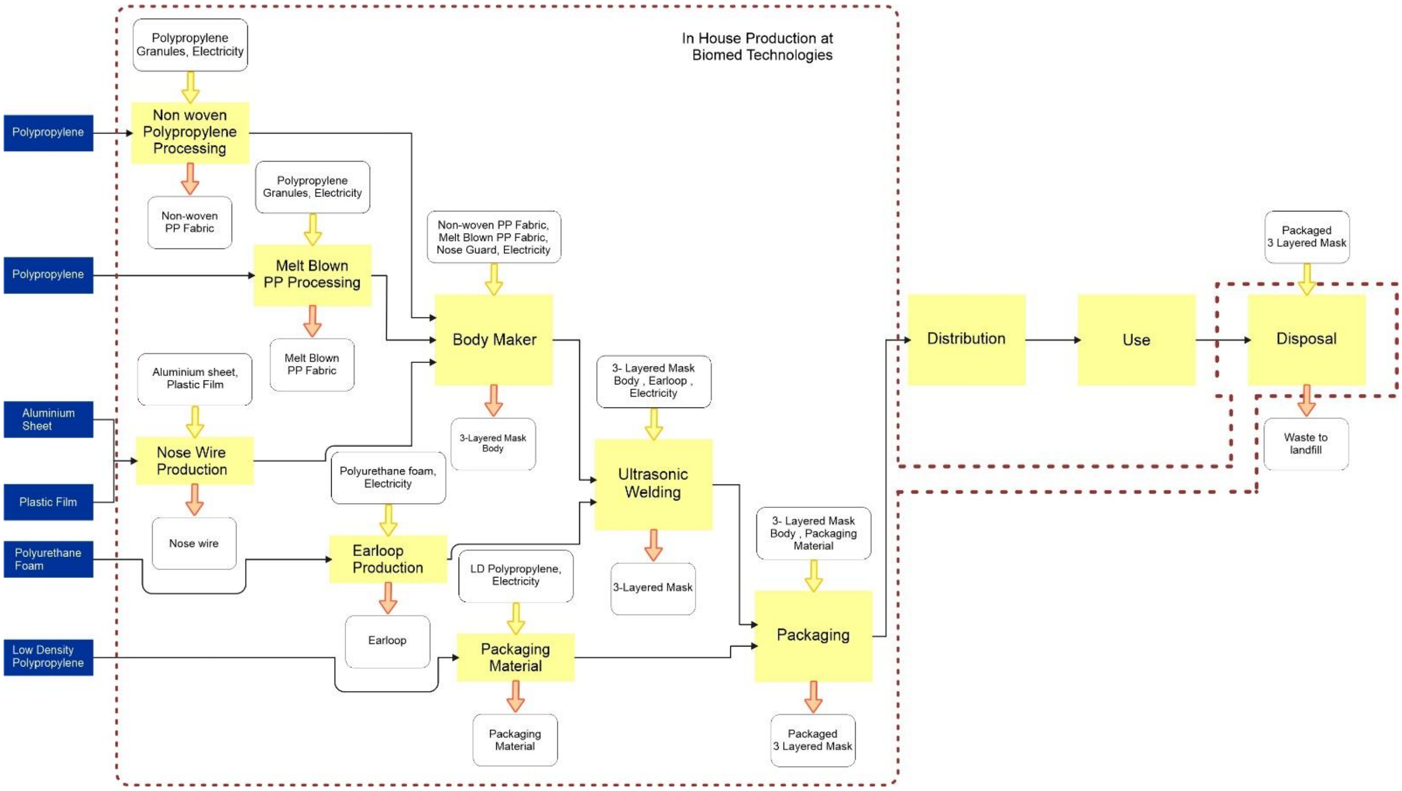


Figure 1 System Process and Boundaries of ***3 Layered Disposable Masks***

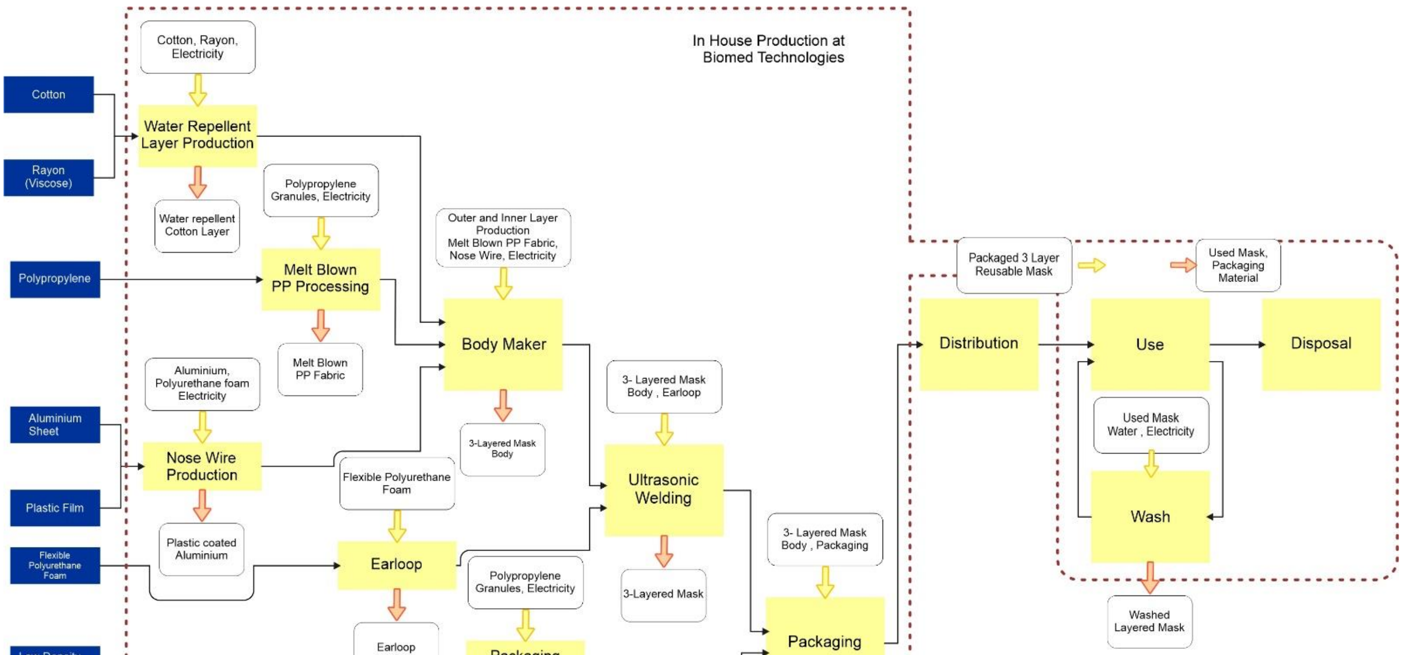


Figure 2 System Process and Boundaries of a ***3-Layered Reusable Mask***

Process 1: Non-Woven Polypropylene Production		
Inputs		
Polypropylene Granulate	10.5	g/FU
Electricity	4.27	kWh/FU
Outputs		
Non-Woven PP Fabric[1]	10.5	g/FU
Process 2: Melt-Blown Polypropylene Production		
Inputs		
Polypropylene Granulate	5.6	g/FU
Electricity[1,5]	1.75	kWh/FU
Outputs		
Melt Blown PP Fabric[1]	5.6	g/FU
Process 3: Nose Wire Production		
Inputs		
Aluminum Sheet[1]	0.7	g/FU
Plastic[1]	1.82	g/FU
Outputs		
Nose Guard[1]	2.52	g/FU
Process 4: Earloop Production		
Inputs		
Flexible Polyurethane Foam – AU	2.24	g/FU
Outputs		
Earloop [1]	2.24	g/FU
Process 5: Packaging Material Production		
Inputs		
Polypropylene LDPE Granulate	12.53	g/FU
Electricity[1]	0.0042	kWh/FU
Outputs		
Packaging Material	12.53	g/FU
Process 6: Body Maker		
Inputs		
Non-woven PP Fabric[1]	10.5	g/FU
Melt-Blow PP Fabric[1]	5.6	g/FU
Nose Wire [1]	2.66	g/FU
Electricity[1]	0.217	kWh/FU
Outputs		
3 Layered Mask Body	1	item/FU
Process 7: Ultrasonic Welding		
Inputs		
3 Layered Mask Body	1	item/FU
Earloop	2.24	g/FU
Electricity[1]	0.0021	kWh/FU
Outputs		
3 Layered Mask	1	item/FU
Process 8: Mask Packaging		
Inputs		
3 Layered Mask	1	item/FU
Packaging Material	12.53	g/FU
Outputs		
Packaged 3 Layered Mask	1	item/FU
Process 9: Disposal		
Inputs		
Packaged 3 Layered Mask	1	item/FU
Outputs		
disposal, Aluminium	0.7	g/FU
disposal, Polypropylene	28.63	g/FU
disposal, Polyurethane	4.06	g/FU

Table 1 LCI of ***7x3 Layered Disposal Mask***

*The Electricity, medium Voltage mix, US is used in standard to account for the electricity consumption in the process

Process 1: Water Repellent Layer Production		
Inputs		
Cotton[2]	7.09	g/FU
Rayon[2]	0.575	g/FU
Electricity[5]	0.32	kWh
Outputs		
Water Repellent Cotton Fabric[2]	7.665	g/FU
Process 2: Melt-Blown Polypropylene Production		
Inputs		
Polypropylene, Granulate, at plant[2]	3.833	g/FU
Electricity[5]	0.25	kWh
Outputs		
Melt Blown PP Fabric[2]	3.833	g/FU
Process 3: Nose Wire Production		
Inputs		
Aluminum Sheet[1]	0.12	g/FU
Plastic Film[1]	0.26	g/FU
Outputs		
Nose Guard[1]	0.38	g/FU
Process 4: Earloop Production		
Inputs		
Flexible Polyurethane Foam – AU[1]	0.32	g/FU
Outputs		
Earloop[1]	0.32	g/FU
Process 5: Packaging Material Production		
Inputs		
Packaging Film, LD polyethylene[1]	1.89	g/FU
Electricity[1,3]	0.0006	kWh/FU
Outputs		
Packaging Material	1.89	g/FU
Process 6: Body Maker		
Inputs		
Water Repellent Cotton Fabric[2]	7.665	g/FU
Melt Blown PP Fabric[2]	3.833	g/FU
Nose Wire	0.38	g/FU
Electricity[1,3]	0.0137	kWh/FU
Outputs		
3 Layered Reusable Mask Body	1	item/FU
Process 7: Ultrasonic Welding		
Inputs		
3 Layered Mask Body	1	item/FU
Earloop	0.32	g/FU
Electricity[1,3]	0.00122	kWh/FU
Outputs		
3 Layered Mask	1	item/FU
Process 8: Mask Packaging		
Inputs		
3 Layered Mask	1	item/FU
Packaging Material	1.89	g/FU
Outputs		
Packaged 3 Layered Mask	1	item/FU
Process 9: Use		
Inputs		
Packaged 3 Layered Mask	1	item/FU
Outputs		
Used Mask	1	item/FU
Disposal, Polypropylene (Package)	1.89	g/FU
Process 10: Wash		
Inputs		
Used Mask	1	item/FU
Water[6]	2100	ml/FU
Electricity[7]	0.0516	kwh/FU
Outputs		
Washed Mask	1	item/FU

Table 2 LCI of 1x***3 Layered Reusable Mask***

[1] Life cycle environmental impacts of disposable medical masks (*Environmental Science and Pollution Research*, 2021) was used to obtain the inventory details of 1-3Layered Disposal mask, the data has been multiplied into 7 to show the usage of 7 Disposable Masks. It is also assumed that the weight of the nose guard and ear loop in the reusable mask is equivalent to that of the Disposable Mask.

[2] Single-use face masks and their alternatives (UNEP, 2022) were used to derive the mass ratio of cotton and rayon (viscose) in the reusable mask. The derivation of layer-wise material categorized weight is shown in Appendix B.

[3] The electricity consumption in the reusable mask manufacturing phase (Mask body Making, Ultrasonic Welding, and Packaging Material Production) is estimated from the reference to Disposable Mask, and the following calculations are shown in Appendix B.

[4] The electricity consumption in the production of Water repellent fabric is estimated as the mean of Electricity consumption of cotton fabric and Rayon fabric with data taken from https://oecotextiles.blog/2009/06/16/what-is-the-energy-profile-of-the-textile-industry/

[5] https://www.geotex.tw/line-meltblown-production.html Machine data is used to estimate the electricity consumption of Melt Blown Polypropylene Processing.

[6] https://biomedtech.com.au/face-masks/ Laundry Guide is used to roughly estimate the amount of water required to wash the BioShield-05 Mask.

[7] Water Footprint and Life Cycle Assessment (Jefferies et al, 2012) was used for the amount of electricity (in kWh) a kettle uses to boil water from 25°C to 90°C

4. Life-Cycle Impact Assessment (LCIA)

4.1 Impact Category Selection

While considering the selection of the impact category, the goal and the scope of the assessment were revisited. The goal of the comparative LCA study is to understand the environmental impacts of the manufacturing, usage, and disposal of 3 Layered Disposable Mask and the 3 Layered Reusable Mask.

Due to the recent outbreak of COVID-19, the usage of masks has skyrocketed, hence the impacts such as human toxicity and terrestrial ecotoxicity due to the production, consumption, and disposal of masks, and other protective equipment have been a concern. On comparing two different masks offering the same level of protection, but manufactured in different processes and with different usability methods, their impact on the **ecosystem** is analyzed. Secondly, since humans are the prime users of these products, the **human toxicity** impact is analyzed for this comparative LCA study.

4.2 Characterization Model Selection

Though the ISO standards have not recommended any preferred characterization methods, the characterization model chosen for this study would need to provide analytics for the two chosen impact categories. On considering the chosen impact categories of Ecotoxicity and Human Toxicity, the ReCiPe Midpoint (H) model was chosen to study a broad set of impact categories over 100 years.

4.3 Open LCA

Open LCA software is an open source and free software used to estimate the sustainability and Life cycle Assessment with fast and reliable estimation. Hence, the processes with input and output flow inventory for two products as shown in Table 1 and Table 2 have been implemented in Open LCA, and the environmental impacts are analyzed using the ReCiPe Midpoint (H) characterization model.

4.4 Results

Open LCA software is an open source and free software used to estimate the sustainability and Life cycle Assessment with fast and reliable estimation. Hence, the processes with input and output flow inventory for two products as shown in Table 1 and Table 2 have been implemented in Open LCA, and the environmental impacts are analyzed using the ReCiPe Midpoint (H) characterization model.

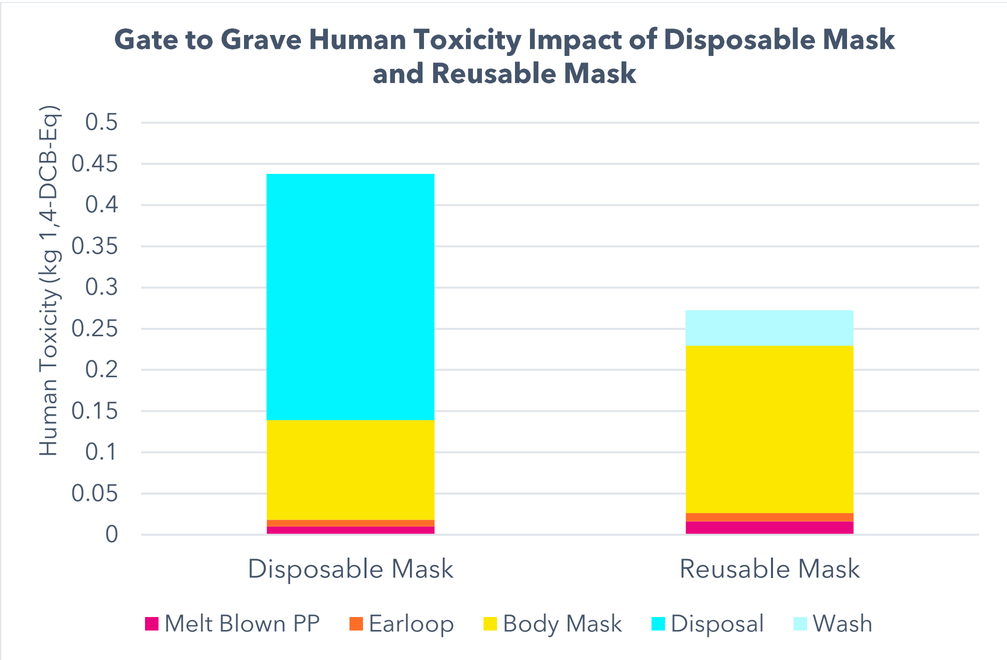


Figure 3 Human Toxicity (HTP 100-H) of Disposable Masks and a Reusable Mask

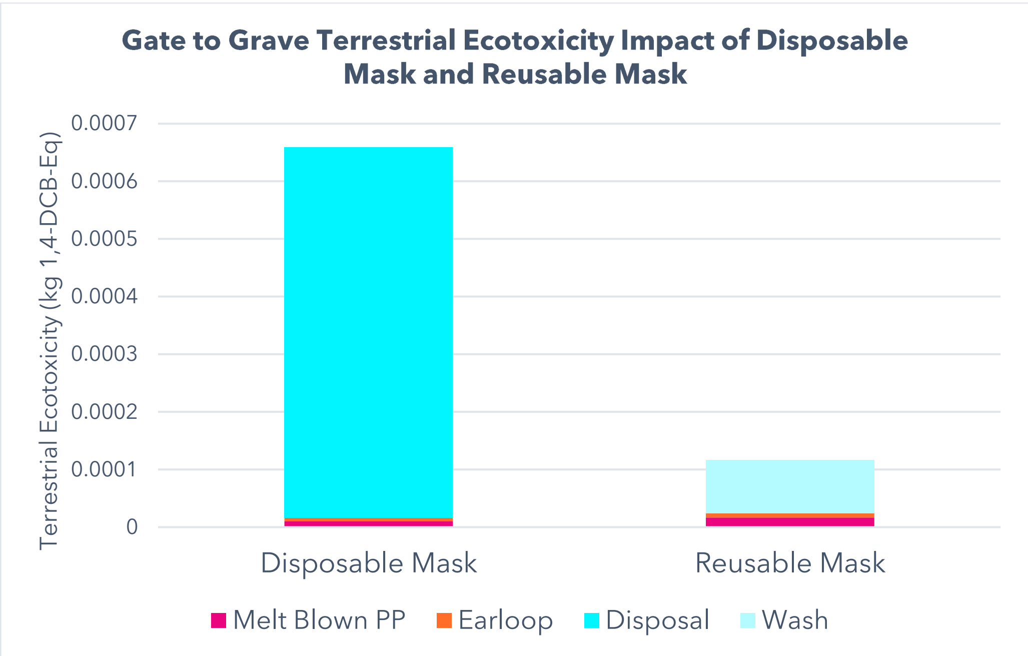
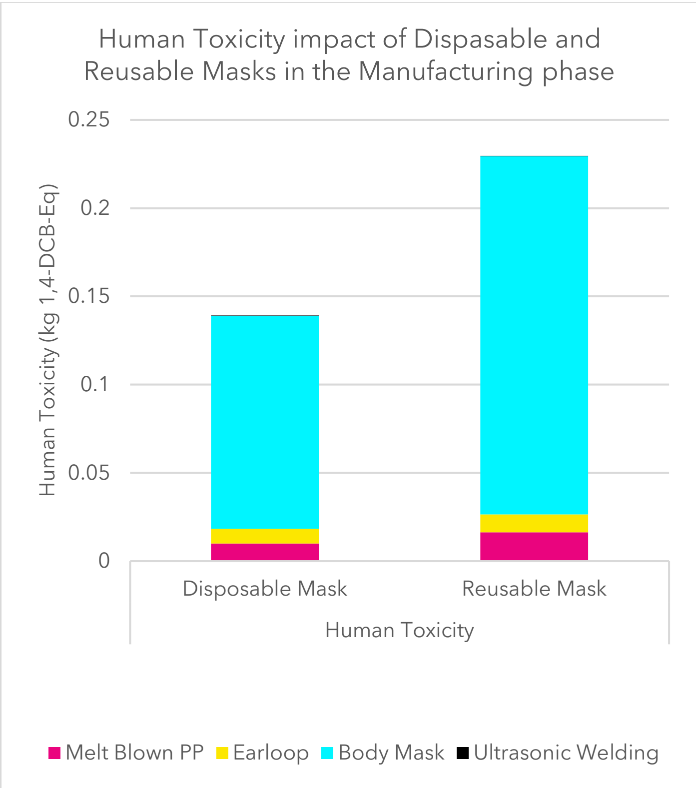


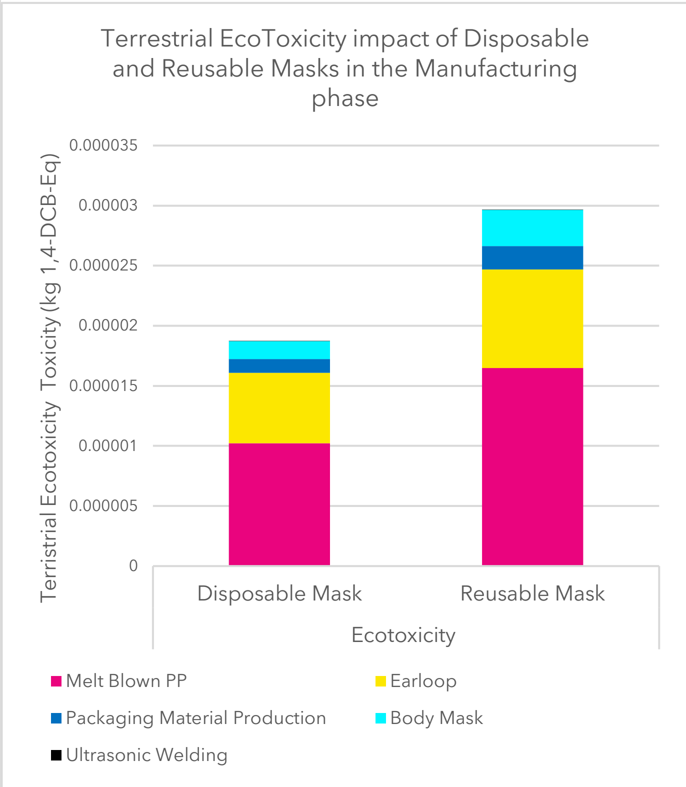
Figure 4 Terrestrial Ecotoxicity impact for 7xDisposable Masks and Reusable Mask

5. Interpretation

5.1 Identification of Significant Issues

On comparing the results of Figure 3 and Figure 4 with the chosen functional unit (ideal usage of masks by a person for a week), it is observed that the disposal process of Disposable Masks shows a major share of human toxicity impact and Terrestrial Ecotoxicity impact. Though the contribution of 1,4-DCB equivalent is high in the manufacturing phase of the reusable mask, the overall impact on human toxicity of terrestrial toxicity is comparatively higher than Disposable Masks as shown in Figure 5





It is observed that the impact created due to Electricity consumption in Mask Body Making and Melt Blown Polypropylene Process is relatively higher in the reusable mask than compared Disposable masks. Table 3 shows the relative increase of impact on human toxicity and Terrestrial Ecotoxicity across the Life Cycle of Disposable Masks and Reusable Mask.

Process Category	**Human Toxicity (%)**		**Terrestrial Ecotoxicity (%)**	
	Disposable Mask	Reusable Mask	Disposable Mask	Reusable Mask
Electricity for Melt Blown PP	2.29	5.95	1.54	**13.50**
Earloop	1.87	3.74	0.89	6.72
Electricity for Body Mask	27.57	**74.25**	0.23	2.47
Disposal of Masks	**68.14**	0.00	**97.15**	0.00
Wash	0.00	**15.62**	0.00	**75.33**

From the above table, the significant impacts on Human Toxicity and Terrestrial Ecotoxicity are caused by the consumption of electricity in key processes and the waste disposal of Surgical Masks. From the above results, it is visible that the disposal of the single-use mask contributes to the major share of the chosen impact analysis.

5.2 Evaluation – Checking Data Quality

The data quality assessment tool in Open LCA was used to check the completeness of the data. However, despite drawing all the inflows and outflows of the process, the Life cycle Inventory data does not account for the emissions that happen during the processes. The above LCI data and the processes have been drawn from a set of referenced papers to ensure consistency over the life cycle of the assessed products; hence the quantitative estimation of the input and output flows of the processes would bring out reliable conclusions on the results. However, there are some limitations in the estimation of the degradation of the Cotton Reusable masks over repeated washes are not accounted to due to a lack of data.

5.3 Conclusion and Limitations

From the above results, we could conclude that the impact on human toxicity and Terrestrial Ecotoxicity is relatively higher in Single Use Disposable Masks. In a further study, setting the usage of the two types of masks over 50 days (gate-to-grave period of BIO SHIELD-05 Mask) would show a greater impact on the human and terrestrial toxicity caused by the usage of 50x single-use masks against 1xCotton Reusable Mask. However, this study is limited to the comparison of 3layered masks with a 75% filtering effect. The results would further change depending on the type of masks compared and the detail of the data (For eg: the estimation of the degradation of Cotton Reusable masks over repeated washes is not accounted for due to lack of data). Obtaining and estimating data for all the inflows and outflows with the consideration of emissions occurring at all the processes would provide an accurate comparison of the products. From the above conclusions, it would be recommended to use a cotton mask over the single-use Disposable Mask to significantly reduce the Toxicity impact on the environment.

6. References

[1] B. Atılgan Türkmen, “Life cycle environmental impacts of disposable medical masks,” *Environmental Science and Pollution Research*, vol. 29, no. 17, pp. 25496–25506, 2021.

[2] “Single-use face masks and their alternatives - life cycle initiative.” [Online]. Available: https://www.lifecycleinitiative.org/wp-content/uploads/2022/03/UNEP-Face-Mask-Report-Final.pdf. [Accessed: 13-Oct-2022].

[3] A. W. Lee, E. R. Neo, Z.-Y. Khoo, Z. Yeo, Y. S. Tan, S. Chng, W. Yan, B. K. Lok, and J. S. Low, “Life cycle assessment of single-use surgical and embedded filtration layer (EFL) reusable face mask,” *Resources, Conservation and Recycling*, vol. 170, p. 105580, 2021.

[4] "What is the energy profile of the textile industry?", *OEcotextiles*, 2022. [Online]. Available: https://oecotextiles.blog/2009/06/16/what-is-the-energy-profile-of-the-textile-industry/. [Accessed: 13- Oct-2022]

[5] P. Giungato, R. Rana, N. Nitti, C. Cavallari and C. Tricase, "Carbon Footprint of Surgical Masks Made in Taranto to Prevent SARS-CoV-2 Diffusion: A Preliminary Assessment", *Sustainability*, vol. 13, no. 11, p. 6296, 2021.

[6] 2022. [Online]. Available: https://www.geotex.tw/line-meltblown-production.html. [Accessed: 13- Oct- 2022]

[7] D. Jefferies, I. Muñoz, J. Hodges, V. King, M. Aldaya, A. Ercin, L. Milà i Canals and A. Hoekstra, "Water Footprint and Life Cycle Assessment as approaches to assess potential impacts of products on water consumption.

Key learning points from pilot studies on tea and margarine", *Journal of Cleaner Production*, vol. 33, pp. 155-166, 2012.

[8] G. Tchana Toffe, S. Oluwarotimi Ismail, D. Montalvão, J. Knight and G. Ren, "A Scale-up of Energy-Cycle Analysis on Processing Non-Woven Flax/PLA Tape and Triaxial Glass Fibre Fabric for Composites", *Journal of Manufacturing and Materials Processing*, vol. 3, no. 4, p. 92, 2019.

7. Appendix

Appendix A – Products for Comparative study

<table>
<tr><td></td><td></td></tr>
<tr><td>Type: Cotton Reusable Mask
Raw Materials: Sourced from China
Design and Production: BioShield-05 Reusable Cotton mask from Biomed Technologies Pty, NSW Belmore, NSW</td><td>Type: SingleUse Disposable Mask
Raw Materials: Sourced from China
Design and Production: Biomed Technologies Pty, NSW Belmore, NSW</td></tr>
<tr><td>Specifications:
<table>
<tr><td>Product Name</td><td>BIOSHIELD-05</td></tr>
<tr><td>Filtering effect (0.075μm)</td><td>75%</td></tr>
<tr><td>PM2.5 Protection</td><td>Good</td></tr>
<tr><td>Air Permeability</td><td>Good</td></tr>
<tr><td>Dust proof</td><td>Yes</td></tr>
<tr><td>Bacterial Protection</td><td>99%</td></tr>
<tr><td>Washing</td><td>Washable: 50 times</td></tr>
<tr><td>Layers</td><td>Outer layer
• 85% cotton
• 9% Rayon
• 6% Silver Fiber
Middle layer
• 100% PET Polyester Fiber
Inside Layer
• 100% Cotton</td></tr>
<tr><td>Laundry guide</td><td>To Correctly clean a face mask
1. Submerge the mask in boiling water for 3-minutes
2. Remove the mask and air dry
3. Be careful not to come in contact with the boiling water to avoid burns.</td></tr>
<tr><td>Sizes</td><td>L: Adult Male, M: Adult Female</td></tr>
</table></td><td>NA</td></tr>
</table>

Appendix B – Excel Calculations for Life Cycle Inventory

Calculated LCI of 7 Single Use masks

Process 1: Non Woven Polypropylene Production			
Inputs			7 Masks
Polypropylene Granulate	1.5	g/FU	10.50
Electricity	0.02916	kWh/FU	0.20
Outputs			
Non Woven PP Fabric	1.5	g/FU	10.50
Process 2: Melt-Blown Polypropylene Production			
Inputs			
Polypropylene Granulate	0.8	g/FU	5.60
Electricity	0.0064	kWh/FU	0.04
Outputs			
Melt Blown PP Fabric	0.8	g/FU	5.60
Process 3: Nose Wire Production			
Inputs			
Aluminium Sheet	0.1	g/FU	0.70
Plastic	0.26	g/FU	1.82
Outputs			
Nose Guard	0.36	g/FU	2.52
Process 4: Earloop Production			
Inputs			
Polyurethane Foam - AU	0.32	g/FU	2.24
Outputs			
Earloop	0.32	g/FU	2.24
Process 4: Packaging Material Production			
Inputs			
Polypropylene LDPE Granulate	1.79	g/FU	12.53
Electricity	0.0006	kWh/FU	0.0042
Outputs			
Packaging Material	1.79	g/FU	12.53
Process 5: Body Maker			
Inputs			
Non-woven PP Fabric	1.5	g/FU	10.50
Melt-Blow PP Fabric	0.8	g/FU	5.60
Nose Wire	0.38	g/FU	2.66
Electricity	0.031	kWh/FU	0.217
Outputs			
3 Layered Mask Body	1	item/FU	7.00
Process 6: Ultrasonic Welding			
Inputs			
3 Layered Mask Body	1	item/FU	7.00
Earloop	0.32	g/FU	2.24
Electricity	0.0003	kWh/FU	0.00210
Outputs			
3 Layered Mask	1	item/FU	7.00
Process 7: Mask Packaging			
Inputs			
3 Layered Mask	1	item/FU	7.00
Packaging Material	1.79	g/FU	12.53
Outputs			
Packaged 3 Layered Mask	1	item/FU	7.00
Process 8: Disposal			
Inputs			
Packaged 3 Layered Mask	1	item/FU	
Outputs			
disposal, Aluminium	0.7	g/FU	
disposal, Polypropylene	28.63	g/FU	
disposal, Polyurethane	4.06	g/FU	

LCI of Reusable Mask

Process 1: Water Repellent Layer Production		
Inputs		
Cotton	7.09	g/FU
Rayon	0.575	g/FU
Electricity	0.32	kWh
Outputs		
Water Repellent Cotton Fabric	7.665	g/FU
Process 2: Melt-Blown Polypropylene Production		
Inputs		
Polypropylene, Granulate, at plant	3.833	g/FU
Electricity	0	kWh
Outputs		
Melt Blown PP Fabric	3.833	g/FU
Process 3: Nose Wire Production		
Inputs		
Aluminium Sheet	0.12	g/FU
Plastic Film	0.26	g/FU
Outputs		
Nose Guard	0.38	g/FU
Process 4: Earloop Production		
Inputs		
Flexible Polyurethane Foam - AU	0.32	g/FU
Outputs		
Earloop	0.32	g/FU
Process 5: Packaging Material Production		
Inputs		
Packaging Film, LD polyethylene	1.89	g/FU
Electricity	0.0006	kWh/FU
Outputs		
Packaging Material	1.89	g/FU
Process 6: Body Maker		
Inputs		
Water Repellent Cotton Fabric	7.665	g/FU
Melt Blown PP Fabric	3.833	g/FU
Nose Wire	0.38	g/FU
Electricity	0.0137	kWh/FU
Outputs		
3 Layered Reusable Mask Body	1	item/FU
Process 7: Ultrasonic Welding		
Inputs		
3 Layered Mask Body	1	item/FU
Earloop	0.32	g/FU
Electricity	0.0012198	kWh/FU
Outputs		
3 Layered Mask	1	item/FU
Process 8: Mask Packaging		
Inputs		
3 Layered Mask	1	item/FU
Packaging Material	1.89	g/FU
Outputs		
Packaged 3 Layered Mask	1	item/FU
Process 9: Use		
Inputs		
Packaged 3 Layered Mask	1	item/FU
Outputs		
Used Mask	1	item/FU
Mask Package	1.89	g/FU
Process 10: Wash		
Inputs		
Used Mask	1	item/FU
Water	300	ml/FU
Electricity	0.0516	kwh/FU
Outputs		
Washed Mask	1	item/FU

Electricity calculation based on Reference

Electricity Consumption	**kWh/Kg**	**g**	**Required Mass (g)**	**kWh/FU**	**Reference**
Spunbound PP	19.44	1000	1.5	**0.02916**	https://www.researchgate.net/figure/Environment-impact-to-produce-flax-tape-compare-to-glass-fibre-42_tbl2_336974762
Melt blow PP	480	60000	0.8	**0.0064**	https://www.geotex.tw/line-meltblown-production.html
Rayon	53.33	1000	0.575	0.031	https://oecotextiles.blog/2009/06/16/what-is-the-energy-profile-of-the-textile-industry/
Cotton	40.83	1000	7.09	0.289	https://oecotextiles.blog/2009/06/16/what-is-the-energy-profile-of-the-textile-industry/
				0.320	