Appendix

Contents

Appendix A: LCA inventory unit process data tables

A1 Disposable A and B unit process data

Disposable top sheet production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Market for textile, nonwoven polypropylene	G / nf	GLO	FTIR		
1	kg	Market for bleaching, textile	G / nf	GLO		Bleaching is not in process of nonwoven PP	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Disposable top sheet	G / f				

Disposable bottom sheet production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.025	kg	Market for polyethylene, linear low density, granulate	G / nf	GLO	FTIR	1.025 to match extrusion process	
1.025	kg	Market for extrusion, plastic film	G / nf	GLO		1kg of this process corresponds to 0.976kg of extruded film.	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Disposable bottom sheet	G / f				

Disposable soaker production

Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Sulfate pulp production, from softwood, bleached	G / nf	RER	FTIR		
1	unit	Transport: market for sulfate pulp	G / nf	RER	Translated process	See translated processes	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Disposable soaker	G / f				

Disposable A material production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
3.31	kg	Disposable top sheet	G / nf		Measurements		
5.24	kg	Disposable bottom sheet	G / nf		Measurements		
31.54	kg	Disposable soaker	G / nf		Measurements		
0.1	kg	Market for polyurethane adhesive	G / nf	GLO	Literature: [1,2]	No data for hot-melt adhesive used in personal care products. PU adhesive can also be used as hot-melt adhesives. Calculated from literature on disposable diapers (2.78 g/kg diaper), see appendix	
	kg	Production of SAP	G / nf				
Economic flow out							
	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable A materials for 1000 mats	G / f				

Disposable B material production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
3.31	kg	Disposable top sheet	G / nf		Measurements		
5.24	kg	Disposable bottom sheet	G / nf		Measurements		
19.78	kg	Disposable soaker	G / nf		Measurements		
0.1	kg	Market for polyurethane adhesive	G / nf	GLO	Literature: [1,2]	No data for hot-melt adhesive used in personal care products. PU adhesive can also be used as hot-melt adhesives. Calculated from literature on disposable diapers (2.78 g/kg diaper), see appendix	
Economic flow out							
	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable B materials for 1000 mats	G / f				

Disposable A manufacturing							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.0425	Unit	Disposable A materials for one mat	G / nf		Literature: [2,3]	1.0425 due to 4.25% solid waste generation during manufacturing	
38.28	kWh	Market for electricity, high voltage	G / nf	PL	Literature: [2,3]	1.07 kWh/kg (average weight of 1000 Disposable A and B	

						mats 34.32 kg is used)	
3.76	m^3	Market for natural gas, high pressure	G / nf	PL	Literature: [2,3]	0.105 m^3/kg (average weight of 1000 Disposable A and B mats 34.32kg is used)	
8.98	kg	Market group for tap water	G / nf	RER	Literature: [2]	0.251/kg (average weight of 1000 Disposable A and B mats 34.32kg is used)	
46.23	Metric tonnes *km	Market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RER		From Torun, PL to LUMC 1150km (Weight of 1000 Disposable A mats is used 40.2kg)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	1000 manufactured disposable high mats	G / f				
0.00898	m^3	Treatment of wastewater, average, wastewater treatment	W / nf	Europe without CH		Corresponding to water input	
0.23	kg	Market for waste polyethylene	W / nf	PL		For disposable bottom sheet	
0.15	kg	Market for waste polypropylene	W / nf	PL		For disposable top sheet	
0.00443	kg	Market for waste polyurethane	W / nf	PL		For disposable adhesive	
1.40	kg	Market for waste paperboard	W / nf	PL		For disposable pulp	

Disposable B manufacturing							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.0425	Unit	Disposable B materials for one mat	G / nf		Literature: [2,3]	1.0425 due to 4.25% solid waste	

						generation during manufacturing	
38.28	kWh	Market for electricity, high voltage	G / nf	PL	Literature: [2,3]	1.07 kWh/kg (average weight of 1000 Disposable A and B mats 34.32kg is used)	
3.76	m^3	Market for natural gas, high pressure	G / nf	PL	Literature: [2,3]	0.105 m^3/kg (average weight of 1000 Disposable A and B mats 34.32kg is used)	
8.98	kg	Market group for tap water	G / nf	RER	Literature: [2]	0.251/kg (average weight of 1000 Disposable A and B mats 34.32kg is used)	
32.70	Metric tonnes *km	Market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RER		From Torun, PL to LUMC 1150km (Weight of 1000 Disposable B mats is used 28.44 kg)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	1000 manufactured Disposable B mats	G / f				
0.00898	m^3	Treatment of wastewater, average, wastewater treatment	W / nf	RER		Corresponding to water input	
0.23	kg	Market for waste polyethylene	W / nf	PL		For disposable bottom sheet	
0.15	kg	Market for waste polypropylene	W / nf	PL		For disposable top sheet	
0.00443	kg	Market for waste polyurethane	W / nf	PL		For disposable adhesive	
0.88	kg	Market for waste paperboard	W / nf	PL		For disposable pulp	

Study	[3]	[2]	**Conversion**	**Average**
Electricity	2.4MJ/kg diaper	5.3MJ/kg diaper	1kWh=3.6MJ	1.07 kWh/kg
Gas energy	0.18MJ/kg diaper	0.56MJ/kg diaper	$1m^3$=35.17MJ	0.105 m^3/kg
Water	0.44 L/kg diaper	0.063 L/kg diaper	1000l=1000kg	0.251 kg//kg
Solid waste	0.045kg/kg diaper	0.04 kg/kg diaper		0.0425 kg/kg
Wastewater	0.44 L/kg diaper		1000l=$1m^3$	0.44 L/kg

Disposable A packaging							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.12	kg	Market for polyethylene, high density, granulate	G / nf	GLO	FTIR	There are 30 mats in one plastic package of 32g (times 1.025 to match process of extrusion).	
1.12	kg	Market for extrusion, plastic film	G / nf	GLO			
5.5	kg	Market for corrugated board box	G / nf	RER		Standard board box of 500g for three plastic packages of 30 mats	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable A packaging for 1000 mats	G / f				
1.1	kg	Market for waste polyethylene	W / nf	NL			
5.5	kg	Market for waste paperboard	W / nf	NL			

Disposable B packaging							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
0.53	kg	Market for polyethylene, high density, granulate	G / nf	GLO	FTIR	There are 50 mats in one plastic package 26g (times 1.025 to match process of extrusion).	
0.53	kg	Market for extrusion, plastic film	G / nf	GLO			
3.5	kg	Market for corrugated board box	G / nf	RER		Standard board box of 500g three plastic	

						packages of 50 mats	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable B packaging for 1000 mats	G / f				
0.52	kg	Market for waste polyethylene	W / nf	NL			
3.5	kg	Market for waste paperboard	W / nf	NL			

Disposable A end of life: incineration							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
5.24	kg	Market for waste polyethylene	W / nf	NL		For disposable bottom sheet	
3.31	kg	Market for waste polypropylene	W / nf	NL		For disposable top sheet	
0.1	kg	Market for waste polyurethane	W / nf	NL		For disposable adhesive	
31.54	kg	Market for waste paperboard	W / nf	NL		For disposable pulp	
1	unit	1000 disposed Disposable A mats	G / f	NL			

Disposable B end of life: incineration							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
5.24	kg	Market for waste polyethylene	W / nf	NL		For disposable bottom sheet	

3.31	kg	Market for waste polypropylene	W / nf	NL		For disposable top sheet	
0.1	kg	Market for waste polyurethane	W / nf	NL		For disposable adhesive	
19.78	kg	Market for waste paperboard	W / nf	NL		For disposable pulp	
1	unit	1000 disposed Disposable B mats	G / f				

Disposable A life cycle							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable A packaging for 1000 mats	G / nf				
1	unit	1000 manufactured Disposable A mats	G / nf				
1	unit	1000 disposed Disposable A mats	G / nf				
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	FU: 1000 use cycles for Disposable A mat	G / f				

Disposable B life cycle							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable B packaging for 1000 mats	G / nf				
1	unit	1000 manufactured Disposable B mats	G / nf				
1	unit	1000 disposed Disposable B mats	G / nf				
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	FU: 1000 use cycles for Disposable B mat	G / f				

A2 Disposable C unit process data

Disposable C soaker production (viscose, nonwoven)							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Textile production, nonwoven viscose, needle punched	G / nf	GLO	FTIR	From translated process	
1	kg	Market for bleaching, textile	G / nf	GLO		Bleaching is not included in the textile production process	
1.8	Metric tonnes *km	Market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RER	Industry	Transport of viscose from Lenzing, AU to Stockholm (1800km)	
Economic flow out							
	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Disposable C soaker	G / f				

Disposable C wax production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.7	Metric tonnes *km	Market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	GLO	Literature: [4,5]	Transport of beeswax at the farming stage and to the customer is 1700km	
0.5	MJ	Market group for electricity, low voltage	G / nf	GLO	Literature: [4,5]	Electricity required for processing the raw beeswax. Is 1.8MJ/kg	
Economic flow out							
	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-	Location	Data source	Note	Number

			functional (nf)				
1	kg	Disposable C beeswax	G / f		Industry		

Disposable C bottom sheet production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.025	kg	Market for polylactide, granulate	G / nf	GLO	FTIR	1.025 to match process of extrusion	
1.025		Market for extrusion, plastic film	G / nf	GLO			
2.7	Metric tonnes *km	Market for transport, freight train	G / nf	Europe without CH	Industry	From Italy, Rome to Stockholm, SE (2700km)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Disposable C bottom sheet	G / f				

Disposable C material production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
11.68	kg	Disposable C soaker	G / nf		Industry		
3.04	kg	Disposable C bottom sheet	G / nf		Industry		
0.16	kg	Disposable C beeswax	G / nf		Industry		
1.12	kg	Market for polyurethane adhesive	G / nf	GLO	Literature: [1,2]	No data for hot-melt adhesive used in personal care products. PU adhesive can also be used as hot-melt adhesives. Amount provided by Industry	
Economic flow out							
	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable C materials for 1000 mats	G / f				

Disposable C manufacturing							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.0425	Unit	Disposable C materials for 1000 mats	G / nf		Literature: [2]	1.0425 due to 4.25% solid waste generation during manufacturing	
50	kWh	Market for electricity, high voltage	G / nf	SE	Industry	3.125kWh/kg	
24	Metric tonnes *km	Market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RER	Industry	From Sweden (Stockholm) to LUMC 1500km	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	1000 Disposable C mats	G / f				
0.135	kg	Market for waste plastic, mixture	W / nf	SE		For polylactic acid top sheet	
0.517	kg	Market for waste yarn and waste textile	W / nf	GLO		For viscose soaker	
0.0496	kg	Market for waste polyurethane	W / nf	SE		For adhesive	
7.089E-3	kg	Market for municipal solid waste	W / nf	SE		For bees wax	

Study	[3]	[2]		**Average**
Electricity	2.4MJ/kg diaper	5.3MJ/kg diaper	1kWh=3.6MJ	1.07 kWh/kg
Gas energy	0.18MJ/kg diaper	0.56MJ/kg diaper	1m^3=35.17MJ	0.105 m^3/kg
Water	0.44 L/kg diaper	0.063 L/kg diaper	1000l=1000kg	0.251 L
Solid waste	0.045kg/kg diaper	0.04 kg/kg diaper		0.0425 kg/kg
Wastewater	0.44 L/kg diaper		1000l=1m^3	0.44 L/kg

Disposable C packaging							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
0.185	kg	Market for polyethylene, high density, granulate	G / nf	GLO		There are 400 mats in one standard plastic package of 60g	
0.185	kg	Market for extrusion, plastic film	G / nf	GLO			

1.5	kg	Market for corrugated board box	G / nf	RER		Standard board box of 500g for 400 mats	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable C packaging	G / f				
0.18	kg	Market for waste polyethylene	W / nf	NL			
1.5	kg	Market for waste paperboard	W / nf	NL			

Disposable C end of life: incineration							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
3.04	kg	Market for waste plastic, mixture	W / nf	NL		For polylactic acid top sheet	
11.68	kg	Market for waste yarn and waste textile	W / nf	GLO		For viscose soaker	
1.12	kg	Market for waste polyurethane	W / nf	NL		For adhesive	
0.16	kg	Market for municipal solid waste	W / nf	NL		For bees wax	
1	unit	1000 incinerated Disposable C mats	G / f				

Disposable C life cycle							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Disposable C packaging	G / nf				
1	unit	1000 manufactured Disposable C mats	G / nf				
1	unit	1000 incinerated Disposable C mats	G / nf				
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	FU: 1000 use cycles for Disposable C mat with incineration	G / f				

A3 Reusable A unit process data

Reusable Top Sheet Production:							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.015	kg	Market for fibre, polyester	G / nf	GLO	FTIR	1.015 used so that it matches with weaving process	
1	kg	Market for weaving, synthetic fibre	G / nf	GLO	Literature: [6]	Weaving is used as there is no knitting process (Weaving uses up to two times more energy than knitting, therefore this data is overestimated)	
1	kg	Market for bleaching, textile	G / nf	GLO		The process “Polyester fibre production, finished” is without bleaching	
0.08	Metric tonnes *km	market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RoW	Industry	Transport to manufacturer (80km)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Reusable polyester top sheet	G / f				

Reusable Bottom Sheet Production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.015	kg	Market for fibre, polyester	G / nf	RoW	FTIR	1.015 used so that it matches with	

						weaving process	
1	kg	Market for weaving, synthetic fibre	G / nf	GLO	Literature: [6]	Weaving is used as there is no knitting process (Weaving uses up to two times more energy than knitting, therefore this data is overestimated)	
1.015	kg	Market for bleaching and dying, yarn	G / nf	GLO		The process “Polyester fibre production, finished” is without bleaching and dying	
0.08	Metric tonnes *km	market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RoW	Industry	Transport to manufacturer (80km)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Reusable polyester bottom sheet	G / f				

Reusable PU film production for bottom sheet							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.025	kg	Polyurethane production, flexible foam, TDI-based, high density	G / nf	GLO	Literature [7]	Polyurethane films are made of thermoplastic PU (TPU). TPU is made from the same ingredient but during the process a defoamer is added. TPU is not available in ecoinvent and therefore TDI-based (results in clear foam)	

						PU foam is used. 1.025kg to match extrusion process.	
1.025	kg	Market for extrusion, plastic film	G / nf	GLO		1kg of this process corresponds to 0.976kg of extruded film.	
0.350	Metric tonnes *km	market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RoW	Industry	Transport to manufacturer (355km)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Reusable PU film for bottom sheet	G / f				

Reusable Soaker production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
0.8	kg	Market for textile, nonwoven polyester	G / nf	GLO	FTIR, Industry	Polyester nonwoven is used as there is no process for only needle-punching (nonwoven process)	
0.2	kg	Textile production, viscose, needle punched	G / nf	GLO	FTIR, Industry	This process is from the ‘Translated’ processes’	
1		Market for bleaching, textile	G / nf	GLO		Market for fibre and textile production do not include bleaching	
0.19	Metric tonnes *km	market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RoW	Industry	Transport to manufacturer (190km)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Reusable soaker	G / f				

Reusable Stitch production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Market for polyester fibre	G / nf	RoW	FTIR, Industry		
0.1	Metric tonnes *km	market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RoW	Industry	Transport to manufacturer (100km)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Reusable polyester stitch for stepping	G / f				

Reusable label production							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.015	kg	Market for fibre, polyester	G / nf	RoW	Industry	1.015 used so that it matches with weaving process	
1	kg	Market for weaving, synthetic fibre	G / nf	GLO	Literature: [6]	Weaving is used as there is no knitting process (Weaving uses up to two times more energy than knitting, therefore this data is overestimated)	
1.015	kg	Market for bleaching and dying, yarn	G / nf	GLO		The process “Polyester fibre production, finished” is without bleaching	
0.08	Metric tonnes *km	market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RoW	Industry	Transport to manufacturer (80km)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-	Location	Data source	Note	Number

			functional (nf)				
1	kg	Reusable label	G / f				

Reusable Aerial production for 10 mats							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
0.36	kg	Reusable polyester top sheet	G / nf		Industry		
0.31	kg	Reusable polyester bottom sheet	G / nf		Industry		
0.25	kg	Reusable PU film for bottom sheet	G / nf		Industry		
0.83	kg	Reusable Soaker	G / nf		Industry		
0.057	kg	Reusable polyester stitch	G / nf		Industry		
0.05	kg	Reusable label	G / nf		Industry		
0.001	kg	Market for polyurethane adhesive	G / nf	GLO	Literature: [1,2]	To bond the PU film to the bottom sheet. Calculated from literature on disposable diapers (2.78 g/kg diaper), see appendix	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Reusable Aerials for 10 mats	G / f				

Reusable manufacturing for 10 mats							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.07	unit	Reusable Aerials for 10 mats	G / nf		Industry	1.07 due to 7% solid waste during manufacturing	
2.90	kWh	Market group for electricity, high voltage	G / nf	CN	Industry	Electricity required for manufacturing is 1.5 kWh/kg (high to match industry demand)	
37.14	metric ton*km	Market for transport, freight, sea, container ship	G / nf	GLO	Industry	From China to	

						Rotterdam (20000km)	
0.390	metric ton*km	Market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RER	Industry	From Rotterdam to the Laundry in Tiel, NL (210km)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	10 manufactured Reusable A mats	G / f				
0.1079	kg	Market for waste polyethylene	W / nf	RoW	Industry	For top and bottom sheet, stitch, label and 80% of the soaker. For polyester there is no waste treatment activity. In literature polyethylene is used instead [8] . 7% waste during manufacturing.	
0.0197	kg	Market for waste polyurethane	W / nf	RoW	Industry	For the PU bottom sheet lamination and adhesive. 7% waste during manufacturing.	
0.0124	kg	Market for waste yarn and waste textile	W / nf	GLO	Industry	For the 20% viscose in the soaker. There is no specific treatment for viscose. 7% waste during manufacturing.	

Reusable use for 1000 mats							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Washing process for 1000 Reusable A mats	G / nf				

1	unit	Distribution for 1000 Reusable A mats	G / nf				
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	1000 use cycles for Reusable A	G / f				

Reusable washing for 1000 mats							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.7	kg	Market for non-ionic surfactant	G / nf	GLO	Literature: [3,9,10]	Average amount of detergent for reusable diapers is 9.43g/kg	
27.65	kWh	Market for electricity, high voltage	G / nf	NL	Industry	0.153 kWh/kg	
20.96	m^3	Market for natural gas, high pressure	G / nf	NL	Industry	0.116m^3/kg	
0.81	m^3	Market group for tap water	G / nf	RER	Industry	4.5L/kg (1000L= 1m^3)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
0.81	m^3	Treatment of wastewater, average, wastewater treatment	W / nf	Europe without Switzerland			
1	unit	Washing process for 1000 Reusable A mats	G / f				

Study	[11]	[12]	[13]	[9]	[3]	[10]
Product	Incontinence pad	Textile clean room garments	Surgical gowns	Reusable diaper	Reusable diaper	Reusable diaper
Total water used	11 L/kg		11 L/kg	9.36 L/kg	43 L/kg	
Electricity	0.94 MJ/kg (of plant)	1 MJ/kg (of plant)			3.2 MJ/kg	
Gas	4.1 MJ/kg (of plant)	5.75 MJ/kg (of plant)			10.6 MJ/kg	
Total energy	5 MJ/kg	6.75 MJ/kg		112 kJ/kg	13.8 MJ/kg	
Detergent				5.9 g/kg	16.5 g/kg	5.9 g/kg

Reusable Distribution Use for 1000 mats							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-	Location	Data source	Note	Number

			functional (nf)				
44.57	metric ton*km	Market for transport, freight, lorry 7.5-16 metric ton, EURO5	G / nf	RER	Industry	LUMC-Tiel 240 km bottom and km forth	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Distribution for 1000 Reusable A mats	G / nf				

Reusable packaging							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
0.5	kg	Market for corrugated board box	G / nf	RoW	Industry	Packaging from CN to NL. 50 mats in one box of 500g (assumption of whole box)	
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Reusable packaging	G / f				
0.5	kg	Market for waste paperboard	W / nf	NL	Ecoinvent		

Reusable End of Life: Incineration							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.441	kg	Market for waste polyethylene	W / nf	NL	Literature: [8]	For bottom and top sheet and 80% soaker. For polyester there is no	

						waste treatment activity. In literature polyethylene is used instead [8]	
0.25	kg	Market for waste polyurethane	W / nf	NL		For PU bottom sheet film and adhesive	
0.166	kg	Treatment of waste textile, soiled, municipal incineration	W / nf	RoW		For 20% viscose part of the soaker	
1	unit	10 incinerated Reusable A mats	G / nf				

Reusable life cycle with incineration							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	10 incinerated Reusable A mats	G / nf				
1	unit	10 manufactured Reusable A mats	G / nf				
1	unit	1000 use cycle for Reusable A mats	G / nf				
1	Unit	Reusable packaging	G / nf				
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	FU: 1000 use cycles for Reusable A with incineration	G / f	NL			

A4 Translated processes:

Translated process: Textile production, nonwoven polyester, needle punched, RoW

Used for process: Disposable C soaker production (viscose, nonwoven), and Reusable soaker production

Goal:

The above process is translated so that it matches an identical process where viscose is needle punched instead of polyester. This process is used for the alternative Reusable A. The soaker of the mat consists of 80% nonwoven polyester and 20% nonwoven viscose. For the latter there is no process like in ecoinvent like there for polyester ‘Textile production, nonwoven polyester, needle punched, RoW’

This translated process is also used for the alternative Disposable C. Transport data (provided by industry) for the viscose is added. The process can be found in the inventory table of Disposable C, namely ‘Disposable C soaker production (viscose, nonwoven)’.

Textile production, nonwoven viscose, needle punched, RoW							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
2.088E-3	m2	Market for building, hall	G / nf	GLO	Ecoinvent	.	
0.41	kWh	Market group for electricity, low voltage	G / nf	GLO	Ecoinvent		
1.035	kg	Market for fibre, viscose	G / nf	GLO	Ecoinvent		
2.95	kg	Market for tap water	G / nf	RoW	Ecoinvent		
Economic flow out							
	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	kg	Disposable C soaker	G / f	SE	FTIR		
3.5E-2	kg	Market for waste yarn and waste textile	W / nf	GLO	Ecoinvent		
5.0E-5	m3	Market for wastewater, average	W / nf	RoW	Ecoinvent		

Translated process: Market for sulfate pulp, bleached

Used for process: soaker production

Goal:

The soaker of the mat is made of softwood pulp. There is no market activity for softwood pulp but only a production process. The production process does not account for transport and therefore, the transport data from the process ‘Market for sulfate pulp’, which is a combination of hardwood, softwood and eucalyptus pulp, is used.

Transport: Market for sulfate pulp, bleached, RER							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional	Location	Data source	Note	Number

			(f) or non-functional (nf)				
2.5279E-2	Metric ton*km	market group for transport, freight train - RER	G / nf	RER	Ecoinvent		
1.9302E-3	Metric ton*km	market for transport, freight, inland waterways, barge - RER	G / nf	RER	Ecoinvent		
1.8663E-1	Metric ton*km	market for transport, freight, lorry, unspecified - RER	G / nf	RER	Ecoinvent		
Economic flow out							
	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1	unit	Transport for 1kg pulp	G / f	RER			

A5 Processes for Interpretation

Material production SAP							
Economic flow in							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
0.006	kg	Market for sulfuric acid	G / nf	RER	Literature: [10,14]		
0.002	kg	Market for ammonium sulfate	G / nf	RER	Literature: [10,14]		
0.78	kg	Market for acrylic acid	G / nf	RER	Literature: [10,14]		
0.46	kg	Market for sodium hydroxide	G / nf	GLO	Literature: [10,14]		
2.187	kWh	Market group for electricity, high voltage	G / nf	RER	Literature: [10,14]		
1700	kg	Water production, deionised	G / nf	RER	Literature: [10,14]		
Economic flow out							
Amount	Unit	Activity	Waste (W) or Good (G) / functional (f) or non-functional (nf)	Location	Data source	Note	Number
1.9	m^3	Treatment of wastewater, average, wastewater treatment	W / nf	RER	Literature: [10,14]		
1	kg	Production of SAP	G / f				

[10,14] **Production for 1kg sodium acrylate (acrylic SAP)**	**Amount**
Sulfuric acid	0.006 kg
Ammonium sulfate	0.002 kg
Acrylic acid	0.780 kg
Sodium hydroxide	0.460 kg
Water	1.700 kg
Wastewater	- 1.900 l
Electricity, high voltage	2.187 kWh

Appendix B: LCA detailed modelling choices and assumptions

B1 Ecoinvent geography selection

In the Ecoinvent database a distinction is made between transforming and transferring unit processes called transforming activities and transferring activities. Transforming activities involve processes that change the physical or chemical nature of materials, while transferring activities involve the movement or conveyance of materials or products without altering their essential properties and can be regarded as consumption mixes for a specific region. Each process has a reference product as an output. It is the reason for carrying out the activity and can either be a good or a waste [15].

For the production of semi-finished products, generic data, represented by global transferring activities from Ecoinvent, were used. ‘Global’ is the geography coverage of the activity representing the average global production [16]. If the geography ‘Global’ was not available, the geography ‘RoW’ (Rest of World) or ‘RER’ (Europe) was selected depending on the production location of the semi-finished product. If no transferring activity was available a transforming activity was selected, and it was assumed that the missing transport data was negligible. For the processes ‘Manufacturing’ specific quantified data, represented by Ecoinvent transferring activities with specific geographies were selected. For incineration generic data, represented by Ecoinvent transferring activities, were used. For the unit process ‘Washing’ of the alternative Reusable A specific quantified data, represented by country specific transferring activities from the Ecoinvent database, were used. For water and detergent European and global activities were selected, respectively. For the unit process ‘Distribution use’ a European transferring activity was used as there was no country specific activity available.

B2 Detailed assumptions for the alternatives

B2.1 Disposable A and B data collection and assumptions

Material production

The alternatives Disposable A mat and Disposable B mat are from the same producer and have equal dimensions. For these alternatives data about the material composition of the products and associated packaging were not provided by industry. Therefore, measurements were done to identify and quantify the different materials of the mats. It was assumed that the top sheet, bottom sheet, and the adhesive of both mats were equal in both quality (type of material) and quantity (amount of material). Qualitative material composition was determined by testing samples of the top sheet, the bottom sheet and the soaker of the Disposable A mat and the soaker of the Disposable B mat by Fourier Transform Infrared Spectroscopy (FTIR), for details see appendix C. It was not possible to prepare a sample of the adhesive and therefore literature was used to determine the material of the adhesive. For the adhesive it was assumed that it was made from polyurethane of which a process was readily available in Ecoinvent database. Quantitative material composition was determined by measurements and literature [1,2]. The different layers of the mat were inseparable and therefore, a special method was applied to quantify the material composition, as outlined in appendix B. It was assumed that the materials of the soaker and the top sheet were bleached.

Manufacturing

Data about the manufacturing process of the two disposable alternatives was not provided by industry and there was also no data available from literature for the specific mats. Data was gathered from LCAs on disposable diapers. Absorbent mats and diapers are both absorbent hygiene products (AHPs) which need to fulfil the same function of collecting and retaining body fluids. Inventory data from two different studies were used to determine the economic flows during the manufacturing stage [2,3]. In the studies inventory data were presented for the average weight of disposable diapers. From this data for each economic flow data was quantified per kilogram of disposable diaper. This calculated data was scaled to the average weight of the Disposable A mat and the Disposable B mat. It was assumed that for manufacturing (lamination of the different layers) the energy flows were equal for both mats and therefore, the average weight of both mats was used. Furthermore, during manufacturing of disposable diapers on average 4.25% solid waste is generated [2,3]. It was assumed that during manufacturing of the disposable mats solid waste generation was equal to 4.25%. Specific waste treatment processes were selected for each material of the product. The geography of specific economic inputs and outputs of the unit process 'Manufacturing' was assumed to be the same location as the producer's headquarter (Torun, Poland).

Incineration

At the end of life, the alternatives were disposed of in regular municipal waste which is incinerated in the Netherlands. Specific waste treatment processes from the Ecoinvent database were used for each material of the mat.

Packaging

The plastic package of the Disposable A mats contains 30 mats, and the plastic package of the Disposable B mat contains 50 mats. The packaging material was identified by FTIR measurements and the amount (weight) of the packaging was measured, see appendices B and C. Additionally, it was assumed that a cardboard box of 500 grams was used for transport between the producer and the hospital. This assumption was made based on industry data provided for the alternative Reusable A. The assumption was made that for both alternatives three plastic packages were packed into the cardboard box.

Transportation

For the transport of the semi-finished products top sheet and bottom sheet no transport data was available and therefore it was set to zero. For the semi-finished product soaker, the transportation was estimated based on the Ecoinvent process 'Market for sulfate pulp, bleached, RER'. This process includes the average transport of sulphate pulp from producer to customer within Europe. It was assumed that the transport data of softwood pulp to the manufacturer was equal to the transport data of the sulphate pulp process from Ecoinvent database. Transportation of the finished products were calculated from the distance between the assumed manufacturing location (Torun, Poland) and the hospital.

B2.2 Disposable C data collection and assumptions

Material production

For the alternative Disposable C data about the material composition of the product was provided by industry. To verify the data a qualitative material analysis was performed by FTIR measurements of the soaker and the bottom sheet, for details see appendix C. For the soaker material the assumption was made that it was made from standard viscose of which a process was available in Ecoinvent. However, data provided by industry determined that the soaker was made from Lenzing viscose produced in Austria [17]. According to literature the single score environmental impact of the viscose process of Ecoinvent is approximately 3 times higher than the impact of Lenzing viscose [18]. However, no inventory data was available and therefore the standard Ecoinvent process was used. For the manufacturing process (needle-punching) of the soaker no background data was available on the economic inputs and outputs. Therefore, the Ecoinvent process 'Textile production, nonwoven polyester, needle punched, RoW' was translated so that it matches an equivalent process that needle punches the material of the soaker. It was assumed that the material of the soaker was bleached. It was not possible to prepare a sample of the adhesive and the fluid barrier and therefore industry data was used. No detailed data was provided by industry on the exact composition of the adhesive and no other data sources yielded any usable data. Therefore, it was assumed that the adhesive was made from polyurethane, a non-Disposable C adhesive. This data was readily available in the Ecoinvent database. Quantitative material composition was determined by solely industry data as the different material layers were inseparable.

Manufacturing

The electricity used to produce the mat and the manufacturing location was provided by industry. It was assumed that the manufacturing process (lamination) did not consume any gas or water as no data was provided although it was asked. Furthermore, it was assumed that the manufacturing process also produced 4.25% solid waste for which specific waste treatment processes were selected [2,3].

Incineration

In practice there are no specific waste flows for Disposable C waste in the Dutch hospitals and therefore it was assumed that the Disposable C absorbent mat was disposed of in regular municipal waste which is incinerated in the Netherlands. For the soaker, bottom sheet, and the fluid barrier no specific waste treatment process suitable for the material were available in the Ecoinvent database. Therefore, waste treatment processes were chosen for similar materials or material groups.

Packaging

By industry data was provided that 400 absorbent mats were packed into one plastic package. It was assumed that the material of the package was the same material as the package of the Disposable A and Disposable B mats. For the quantification it was assumed that the weight of the package was equal to the weight of a standard plastic garbage bag of 60 grams. Additionally, it was assumed that one cardboard box of 500 grams was used for transport between the producer and the hospital for 400 mats.

Transportation

For the transport of the finished product and the semi-finished products soaker and bottom sheet manufacturing locations were provided by industry from which the distance was determined with the help of Google maps. For the fluid barrier transport data from literature were used [4,5].

B2.3 Reusable A data collection and assumptions

Material production

Data on the composition of the products and associated packaging of the Reusable A was provided by industry. To verify the data a qualitative material analysis was performed by FTIR measurements of the soaker and the top sheet, for details see appendix C. The top sheet, bottom sheet, and the label were made from the same material with the distinction that the bottom sheet was laminated with a plastic film. It was assumed that the top sheet, bottom sheet, and the label were woven fabric and that the top sheet and soaker were bleached and that the bottom sheet and the label were bleached and dyed. The soaker was made from two different needle-punched materials but for the manufacturing process (needle-punching) of one of the materials no background data was available on the economic inputs and outputs. Therefore, the same translated Ecoinvent process ‘Textile production, nonwoven polyester, needle punched, RoW’ from the alternative Disposable C was used. The material of the Disposable C soaker and one of the soaker materials of the Reusable A were the same. The quality (type of material) and quantity (amount of material) of the adhesive was not provided by industry and it was not possible to prepare a sample. Therefore, it was assumed that the adhesive was made from polyurethane of which a process was readily available in Ecoinvent database. Literature was used to quantify the amount of the adhesive [1,2]. Quantitative material composition was determined by solely industry data as the different material layers were inseparable.

Manufacturing

Data about the manufacturing process of the *Reusable A* was provided by industry. The amount of electricity used to produce the mat and the manufacturing location was provided. It was assumed that the manufacturing process (lamination) did not consume any gas or water as no data was provided although it was asked. Furthermore, data on the solid waste generation was provided by industry which was 7%. Specific waste treatment processes were selected for each material of the product.

Use

The unit process use of the *Reusable A* includes the washing and the transport of the mat between the LUMC and the laundry service provider. It was assumed that one mat could be used 100 times after which it was discarded. Data about the electricity and gas consumption for the washing process was provided by industry. Data on the amount and type of surfactant used was gathered from literature [3,9,10]. For the transport between the LUMC and the laundry service provider it was assumed that the weight of rolling containers (clean and dirty mats are stacked into rolling containers for transport) was negligible. Additionally, it was assumed that the weight of dirty (after use) reusable absorbent mats was equal to the weight of clean absorbent mats.

Incineration

In the European Union 87% of textile waste is incinerated and therefore it was assumed that the reusable absorbent pad was incinerated [19]. No recycling was modelled for the End-of-life stage as only 1% of used textile is recycled in the European Union [19]. Additionally, this was a result of the lack of data regarding the recycling process. The disposed reusable absorbent mats were thus modelled as specific waste treatments in the Netherlands. For materials of the soaker, top sheet, and bottom sheet no specific waste treatment process suitable for the material were available in the Ecoinvent database. Therefore, waste treatment processes based on literature data were chosen [8].

Packaging

By industry data was provided that for transport of the finished product from the manufacturer to the laundry 50 mats were packed into one cardboard box of 500g. For the functional unit of 1000 uses ten mats are used. However, the package of 500 grams was fully attributed to ten mats and it was assumed that the added environmental impact was negligible. During use it was assumed that no packaging was needed for the transport between the laundry and the hospital.

Transportation

For the transport of the finished product from manufacturer to the laundry service and the semi-finished products to the manufacturer data were provide by industry. For the transportation during the use phase the distance between the hospital and the location of the laundry service was determined with the help of Google maps.

Appendix C: Supplementary LCA results

C1 Characterised results

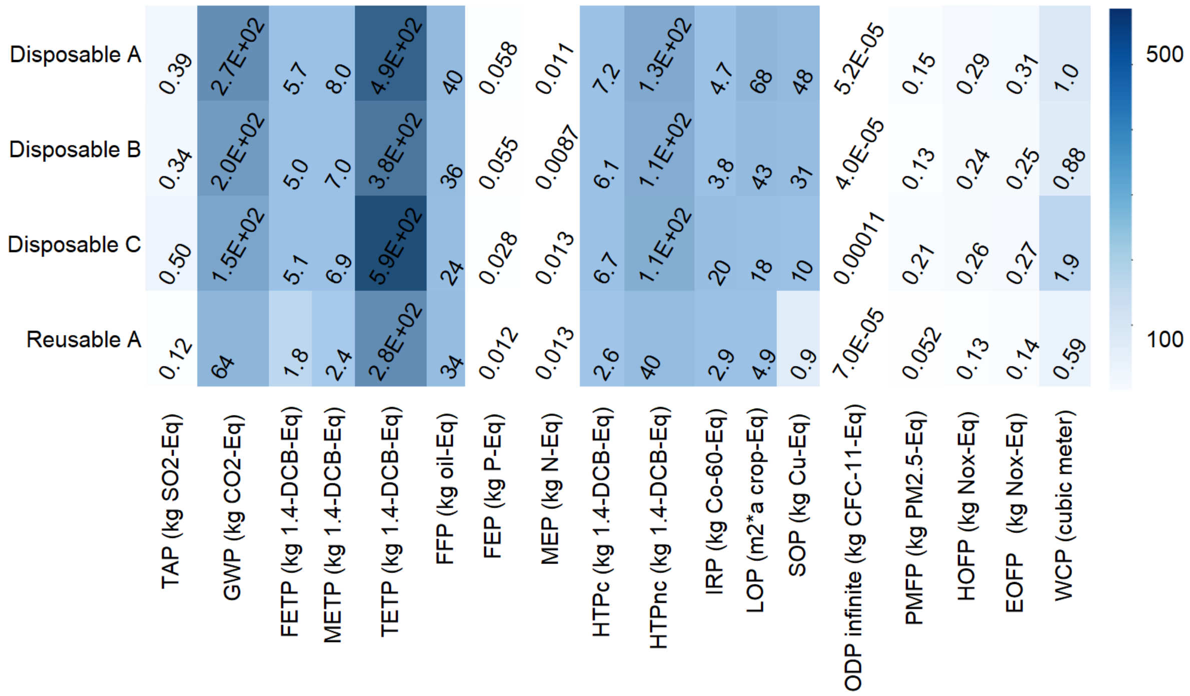


Figure C1: Characterised results for the four absorbent mats. The gradient from dark to light blue gives an indication of the magnitude of the impact score. The impact scores should not be compared across impact categories.

C2 Normalised results

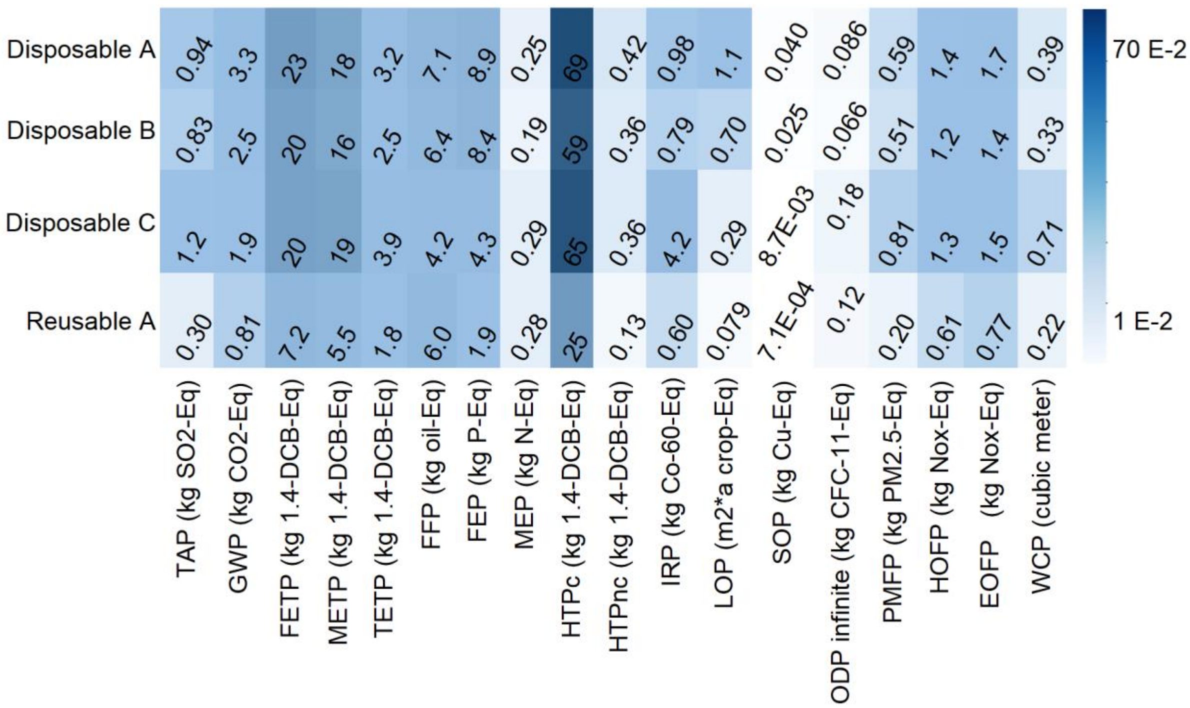


Figure C2: Normalised results for the four absorbent mats. The gradient from dark to light blue gives an indication of the magnitude of the impact score. The impact scores should not be compared across impact categories.

C3 Scenario analysis: worst- and best-case

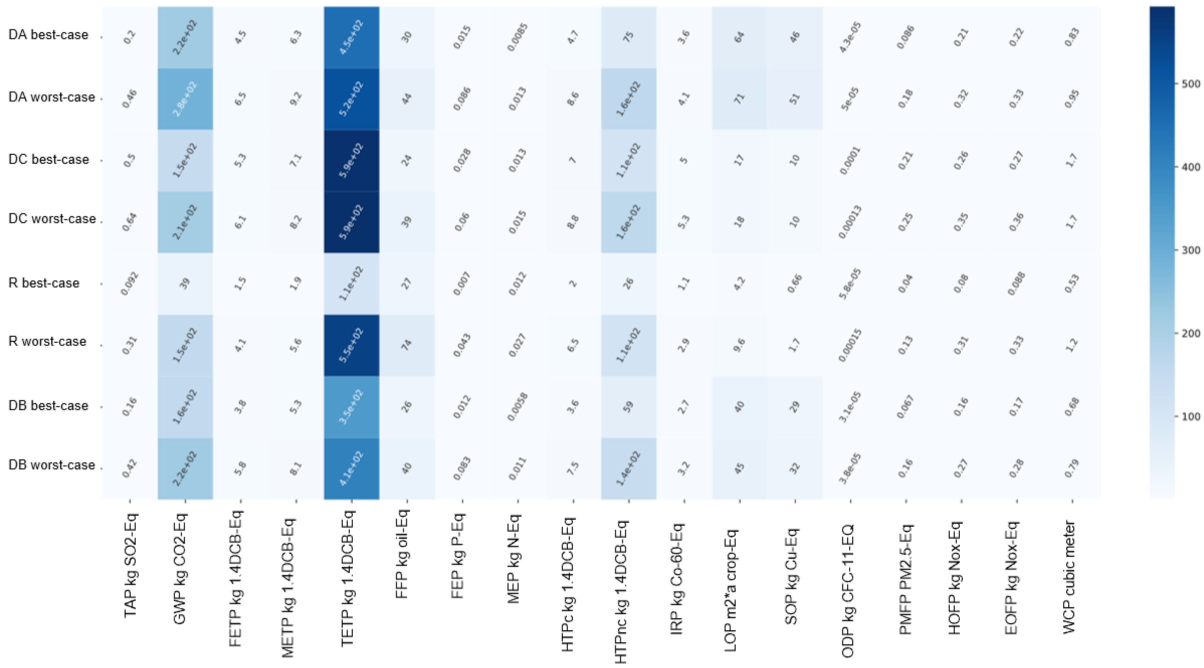


Figure C3: Characterised results for the worst- and best-case scenario for the four absorbent mats. The gradient from dark to light blue gives an indication of the magnitude of the impact score. The impact scores should not be compared across impact categories. DA=Disposable A, DB=Disposable B, DC=Disposable C, R=Reusable A.

Appendix D: Supplementary LCA results for the sustainable redesign

D1 Relative carbon footprint material contributions

To aid product design, the carbon footprint contributions of materials of Disposable A, B, and C, and Reusable A in relation to their mass were determined.

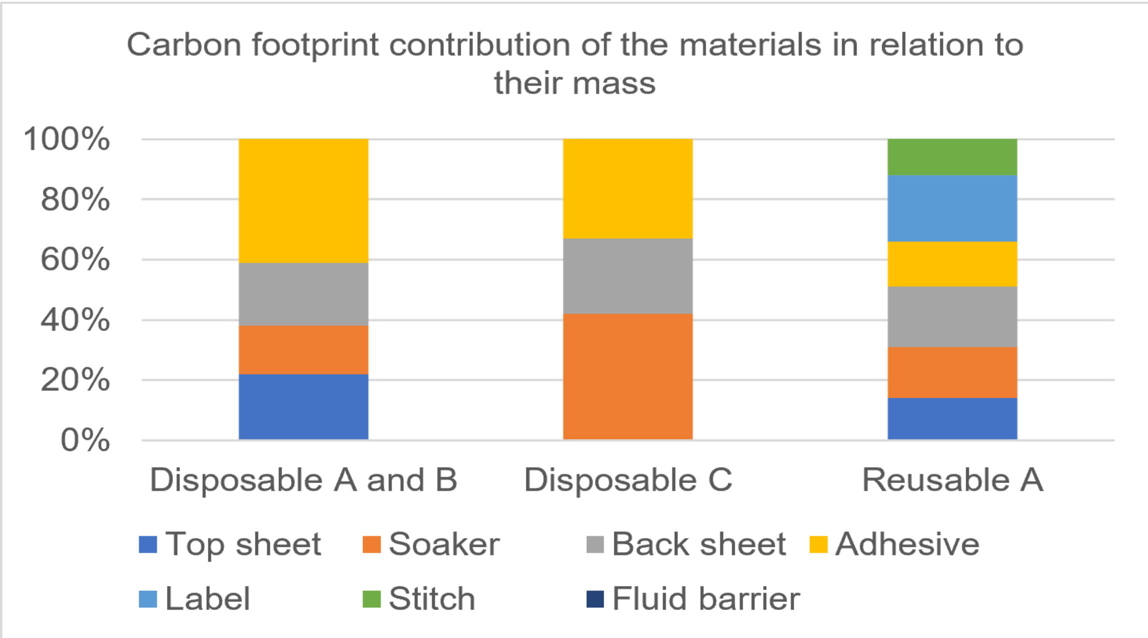


Figure D1: Relative carbon footprint material contributions

D2 Carbon footprint of alternative materials

Absolute carbon footprint of alternative disposable and reusable materials

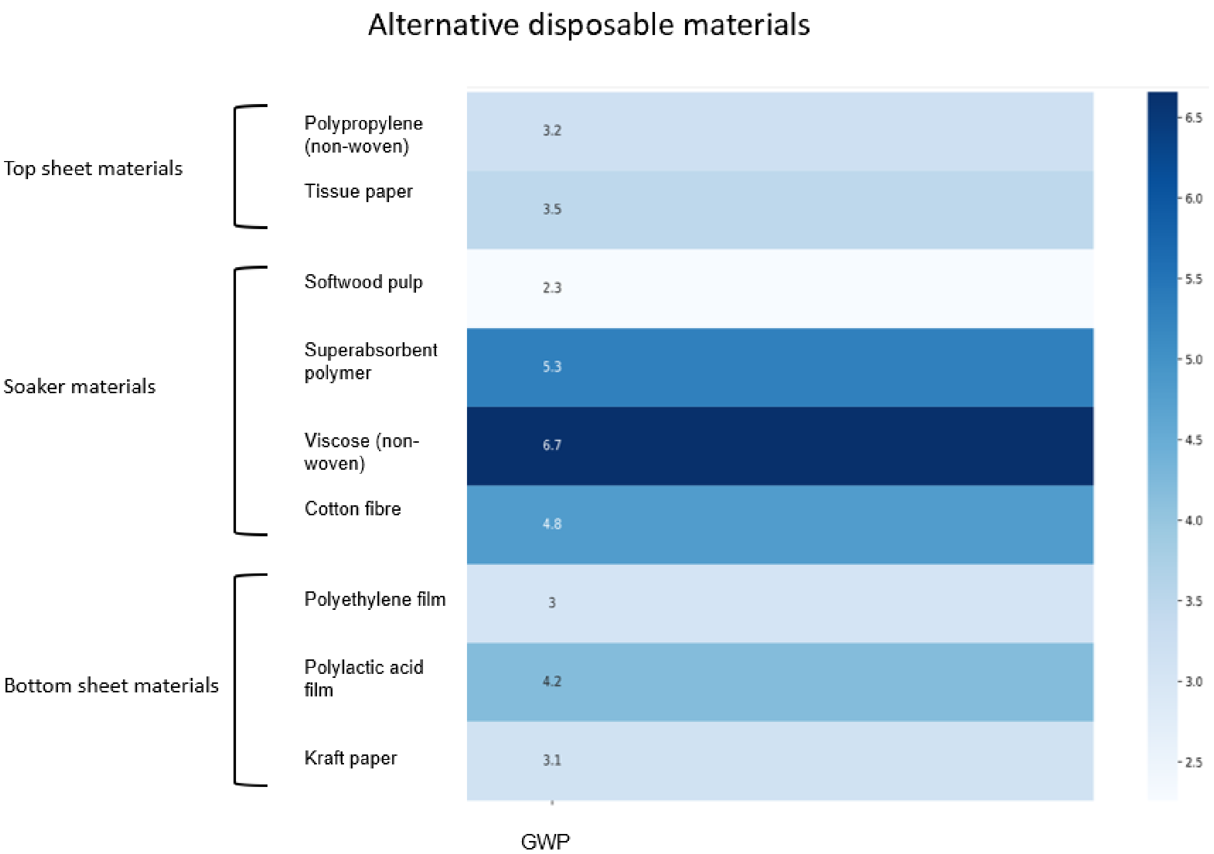


Figure D2: Characterised GWP results for disposable alternative materials.

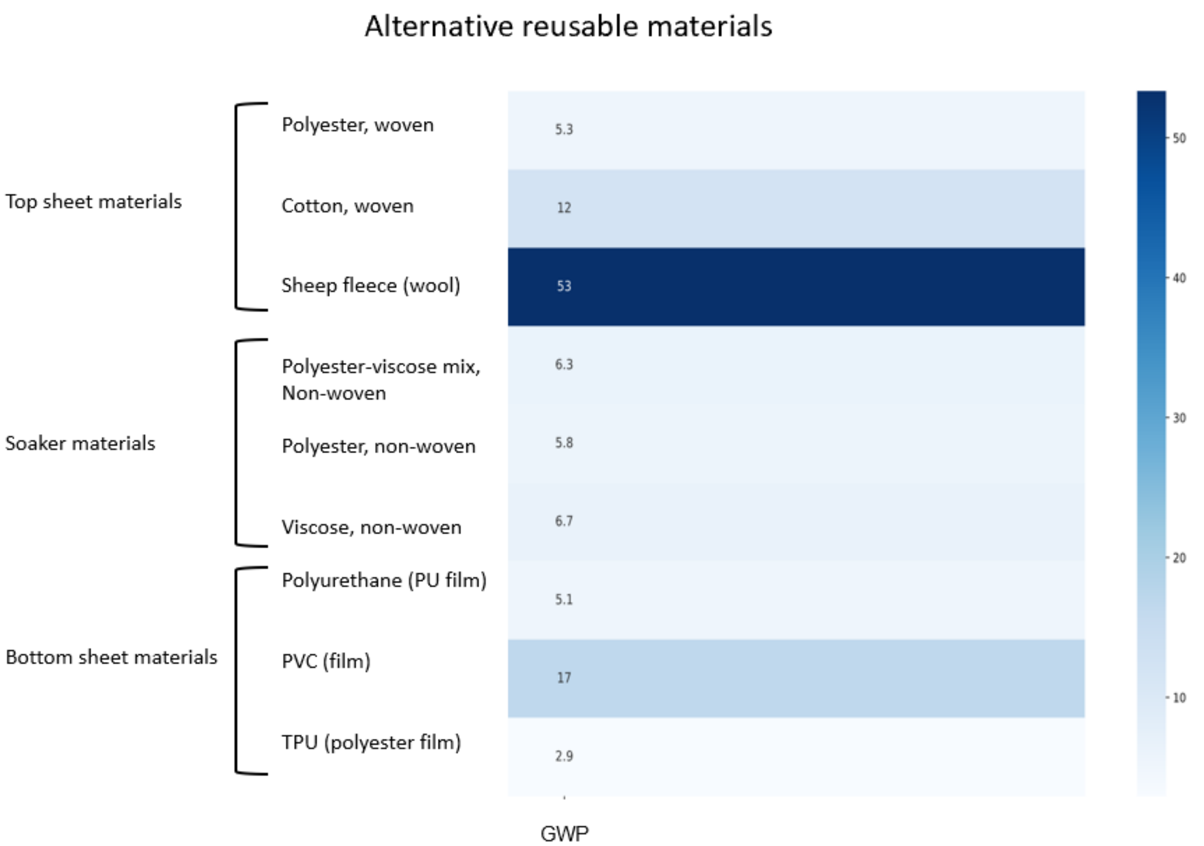


Figure D3: Characterised carbon footprint results for reusable alternative materials.

Carbon footprint of alternative soaker materials per kilogram of absorbed fluid

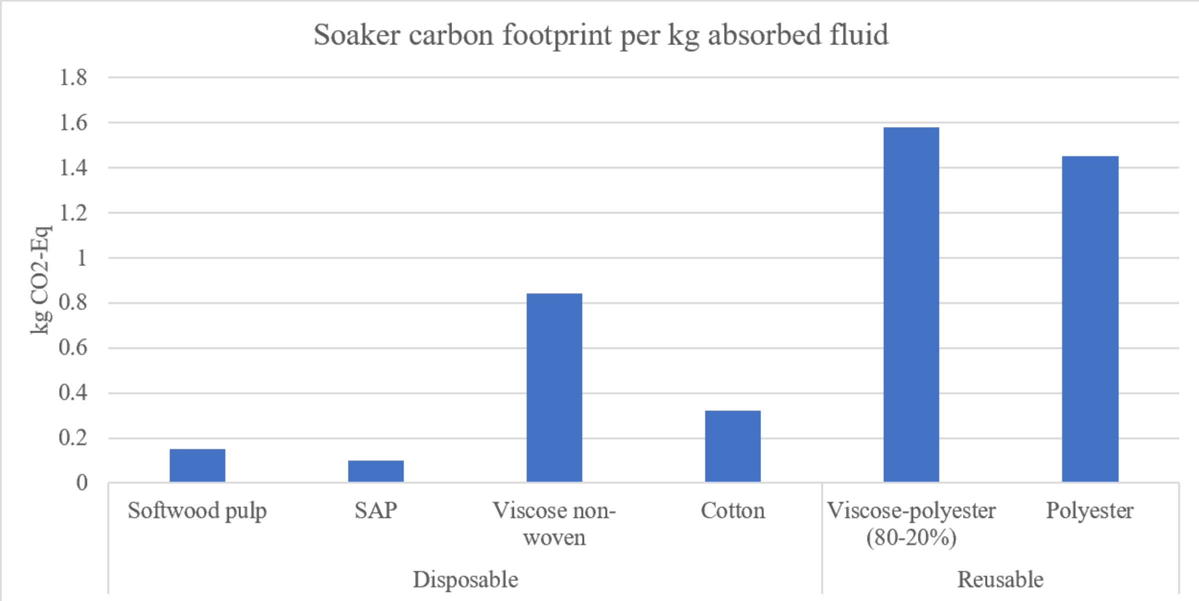


Figure D4: Carbon footprint of alternative soaker materials per kilogram of absorbed fluid. The absorption capacity of softwood pulp, viscose non-woven, and viscose-polyester are determined in Appendix G. It is assumed that the absorption capacity of polyester is approximately equal to the viscose-polyester mix. The absorption capacity of SAP is 60 g/g and that of cotton is 15 g/g [20,21].

Adding superabsorbent polymer to the soaker of disposable absorbent mats

For both alternatives Disposable A and Disposable C, the material SAP was added to the soaker. Literature on absorbent hygiene products showed that the addition of SAP led to a decrease of the total mass of the absorbent hygiene products which in turn resulted in a lower overall environmental impact [2]. The composition of initial soaker material and SAP was chosen according to literature as 47% SAP and 53% initial soaker [2]. The total quantity of soaker was chosen in such a way that the total absorption capacity of the mats remained constant. Figure D5 shows the outcomes of adding SAP to the soakers. The results show that by changing the composition of the soaker to 47% SAP and 53% initial soaker while maintaining the total absorption capacity decreased the carbon footprint by 14% for the Disposable A and 47% for the Disposable C mat. This is mainly due to the reduction of raw material usage caused by the high absorption capacity of SAP. For other impact categories the addition of SAP has an overall negative impact for the Disposable A mat and a positive impact for the Disposable C mat. For the Disposable A mat, the addition of SAP leads to an increase for fourteen out of eighteen impact categories. For the Disposable C mat, the addition of SAP leads to a decrease of impact for all impact categories.

The redesign of absorbent mats has an absorption capacity of 400 grams, which is closest to that of Disposable A, compared to that of Disposable C. Therefore, it is expected that the addition of SAP leads to a lower carbon footprint. However, it is recommended that SAP is not utilized in the redesign because the overall impact is expected to be worse compared to leaving out SAP.

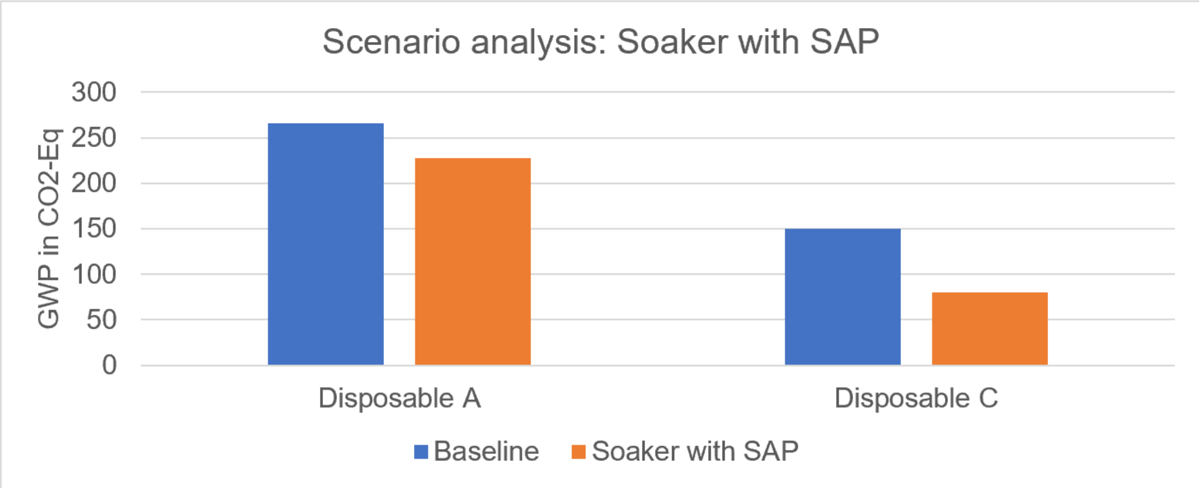


Figure D5: Adding SAP to the soaker of Disposable A and C while keeping the total absorption capacity constant.

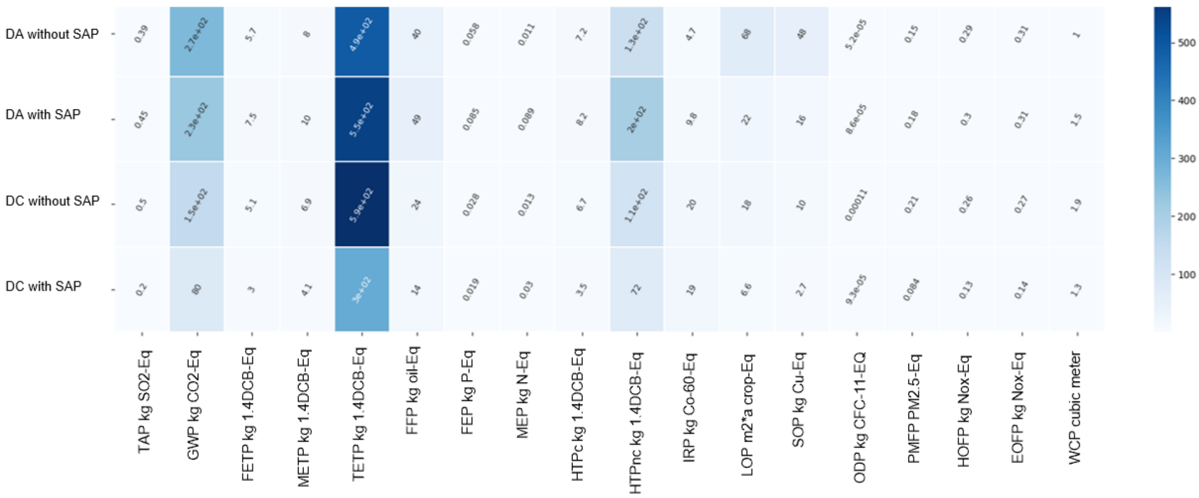


Figure D4: Characterised results for adding SAP to the soaker of the disposable mats. The gradient from dark to light blue gives an indication of the magnitude of the impact score. The impact scores should not be compared across impact categories. DA=Disposable A and DC=Disposable C.

D3 Concept evaluation: Characterised results for the final concepts

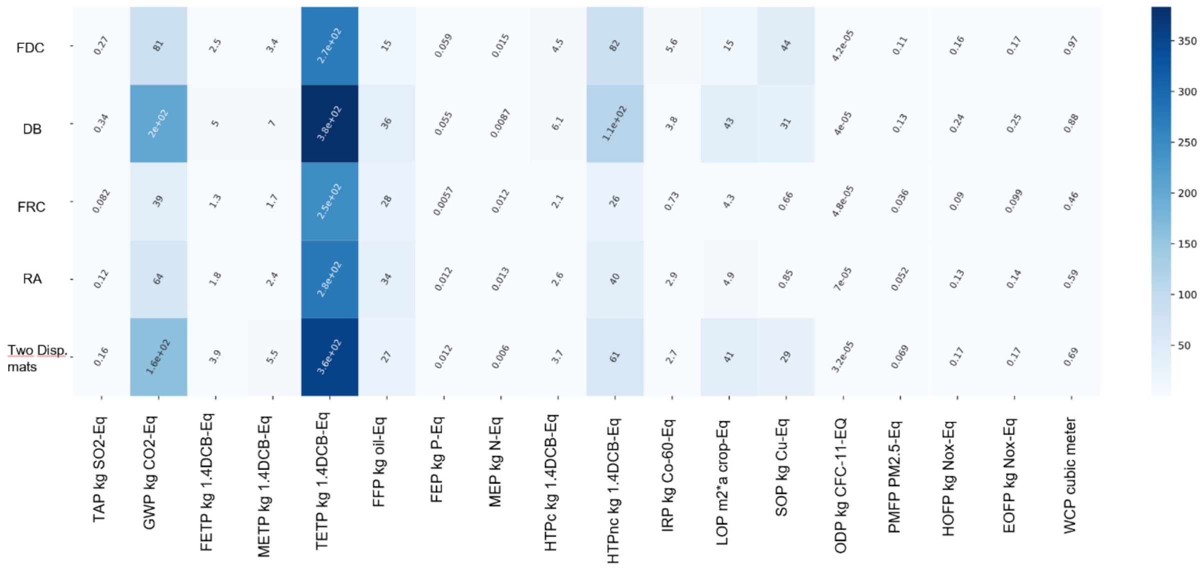


Figure D5: Characterised results for the final disposable concept (FDC) and final reusable concept (FRC) compared to the Disposable B (DL), standard Reusable A (R), and two disposable absorbent mats (one with an absorption capacity of 400 grams and the other with 175 grams).

Appendix E: Quantitative material identification Disposable A and Disposable B mat

Disposable A and B: Determining the weight of the different material layers

Objective

The objective of this experiment is to determine the weights of four different materials, namely the top sheet, the absorbent core, the bottom sheet, and the adhesive. of the Disposable A and B mats, as there are no data available from the industry. The data gathered from this experiment will be utilized in the life cycle assessment.

Materials

-Electronic scale (precision of 0.001 grams)
-Measuring tape (metric with a precision of +-0.5mm)
-Three Disposable A mats

Procedure

1. Visual inspection of Disposable A and B
2. Determine the total weight of the mats
3. Separate the materials from each other
4. Determine the weight of the PU film bottom sheet
5. Determine the weight of the PE nonwoven top sheet
6. Determine the weight of the adhesive
7. Determine the weight of the absorbent core

1. Visual inspection of Disposable A and B mat

A visual inspection by eye of the Disposable A and B mats revealed that the materials did not differ.

2. Determine the total weight of the mats and the dimensions of the mat

Three Disposable A mats and three Disposable B mats were weighted with the electronic scale. For each of the mat types the average was calculated.

Table E1: Weight of the disposable and B mats.

Mat type	Mat 1	Mat 2	Mat 3	Average
Disposable A	40.39g	40.35g	39.83g	40.19g
Disposable B	28.47g	29.08g	27.75g	28.43g
Average of A and B	/	/	/	34.31g

Three Disposable A mats were measured with measuring tape. As the packaging of both Disposable A and B mats displayed 60x60 cm only the Disposable A mats were used for checking the dimensions. The dimension of the mat was measured to the nearest millimetre. Measurements were done in the middle of the mats.

Table E2: Dimensions of the Disposable A mat.

	Mat 1	Mat 2	Mat 3	Average
length	593	597	596	595
width	595	592	594	594

3. Separate the materials from each other

Efforts were made to separate the top sheet from the remaining materials; however, the materials were inseparable, see figure 1. It was observed that, on one edge of the mat, the top sheet was not glued to the bottom sheet, see figure 2. This area was used to determine the weight of the PU film bottom sheet and nonwoven top sheet.

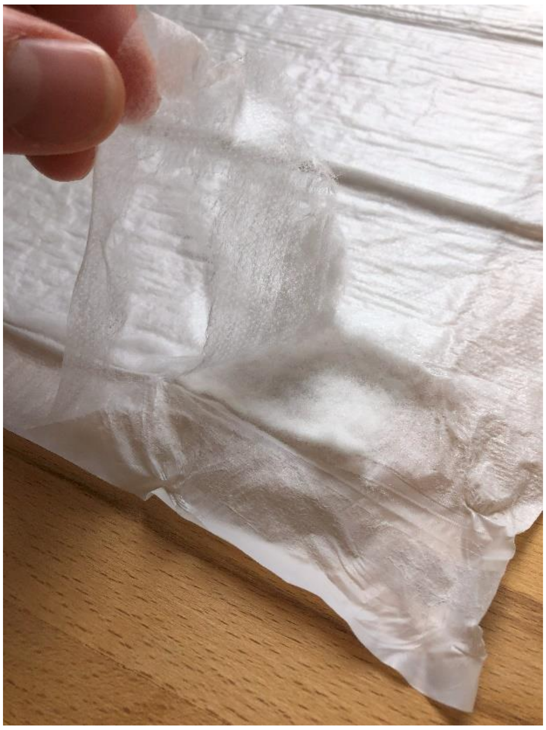


Figure E1: Inseparable materials Figure E2: Unglued edge

4. Determine the weight of the PU film bottom sheet

Three samples for three different Disposable A mats were prepared by cutting along the edge of glued top and bottom sheet and unglued top and bottom sheet. The samples were used to determine the total weight of the bottom sheet by multiplying the weight of the sample with respect to the total area of each mat. To determine the width of the samples each sample width was measured at three points along the longitudinal edge, namely in the middle and at the outer edges. The dimension was rounded to the nearest millimetre.

Figure E3: Bottom sheet samples for determining the weight of the bottom sheet.

Table E3: Determine the width of the bottom sheet samples.

	Measurement 1	Measurement 2	Measurement 3	Average
Sample 1	10	10	10	10
Sample 2	11	10	11	11
Sample 3	12	11	12	12
Total average	/	/	/	11±0.5

After determining the average width of the bottom sheet samples the weight was determined with the electronic scale.

Table E4: Determine the weight of the bottom sheet samples.

	Sample 1	Sample 2	Sample 3	Average
Weight	0.091g	0.102g	0.098g	0.097g

To determine the total weight of the bottom sheet the weight of the samples was multiplied with a multiplications factor so that the width of the sample multiplied by the multiplication factor covers the width of the mat.

Table E5: Determine the total weight of the bottom sheet.

	Average width sample	Average width mat	Multiplication factor (width mat / width sample)	Average weight sample	Total weight bottom sheet (average weight sample * multiplication factor)
Values	11mm	594mm	54	0.097g	5.24g

5. Determine the weight of the nonwoven top sheet

Three samples for three different Disposable A mats were prepared by cutting along the edge of glued top and bottom sheet and unglued top and bottom sheet. The samples were used to determine the total weight of the top sheet by multiplying the weight of the sample with respect to the total area of each mat. To determine the width of the samples each sample width was measured at three points along the longitudinal edge, namely in the middle and at the outer edges. The dimension was rounded to the nearest millimetre.

Figure E4: Top sheet samples for determining the weight of the top sheet.

Table E6: Determine the width of the top sheet samples.

	Measurement 1	Measurement 2	Measurement 3	Average
Sample 1	10	7	7	8
Sample 2	7	7	7	7
Sample 3	7	7	8	7
Total average	/	/	/	7

After determining the average width of the top sheet samples the weight was determined with the electronic scale.

Table E7: Determine the weight of the top sheet samples.

	Sample 1	Sample 2	Sample 3	Average
Weight	0.045g	0.032g	0.041g	0.039g

To determine the total weight of the top sheet the weight of the samples was multiplied with a multiplications factor so that the width of the sample multiplied by the multiplication factor covers the width of the mat.

Table E8: Determine the total weight of the top sheet.

	Average width sample	Average width mat	Multiplication factor (width mat / width sample)	Average weight sample	Total weight top sheet (average weight sample * multiplication factor)
Values	7mm	594mm	84.86	0.039g	3.31g

6. Determine the weight of the adhesive
To determine the weight of the adhesive the total weight of the mat was used. According to literature the average weight of adhesive in disposable diapers was 0.1 grams in 2011 and the average weight of diapers was 36 grams [1]. This results in a weight percentage of 0.28 percent. To determine the weight of the adhesive the average weight of the Disposable A and B mat was used, because both mats have the same structure and therefore equal amounts of adhesive.

Table E9: Determine the weight of the adhesive.

Average weight mat	Multiplication factor	Weight adhesive
34.31g	0.0028	0.096g

7. Determine the weight of the absorbent core
To determine the weight of the absorbent core the weight of the top sheet, bottom sheet, and adhesive was subtracted from the total weight of each mat.

Table E10: Determine the weight of the absorbent core.

Mat type	Total weight	Top sheet weight	Bottom sheet weight	Adhesive weight	Absorbent core weight
Disposable A	40.19g	3.31g	5.24g	0.096g	31.54g
Disposable B	28.43g	3.31g	5.24g	0.096g	19.78g

7. Determine the weight of the absorbent core
One packaging was weighted for each mat type. To determine the weight of the absorbent core the weight of the top sheet, bottom sheet, and adhesive was subtracted from the total weight of each mat. Table 11: Determine the weight of the packaging. For Disposable A mats there are 30 mats and for Disposable B mats there are 50 mats in one packaging.

Table E11: Packaging weight for the two mats.

Mat type	Packaging weight
Disposable A	31.32g
Disposable B	26.21g

Results

Table E12: Total weight and weight of each component for the Disposable A and B mats.

	Disposable A	Disposable B	Average
Total weight	40.19g	28.43g	34.31g
Top sheet weight	3.31g	3.31g	3.31g
Absorbent core weight	31.54g	19.78g	25.66g
Bottom sheet weight	5.24g	5.24g	5.24g
Adhesive weight	0.10g	0.10g	0,10g

Packaging	32g/30mats	26g/50 mats	/

Appendix F: FTIR qualitative material identification

Fourier Transform Infrared Spectroscopy (FTIR): identify unknown materials and verify known materials of the absorption mats

Objectives
To identify IR absorption peaks and the corresponding functional groups of different materials samples from the three mats, namely Disposable A, B, and C, and Reusable A. The objective is to identify the unknown materials of the Disposable A and B's top sheet, soaker, and bottom sheet. For the other two mats data was provided by industry, however, FTIR is used to verify the materials. Materials of the Disposable C mat, namely the viscose soaker and the polylactic acid (PLA) bottom sheet, and for Reusable A, namely polyester top and bottom sheet and viscose-polyester mix soaker, are verified by the identification of IR absorption peaks and the corresponding functional groups of different the materials.

Introduction
Attenuated Total Reflectance Fourier-Transform Infrared (ATR-FTIR) spectroscopy is a technique used to analyse the chemical composition and molecular structure of materials. An infrared light beam is directed into a high-refractive-index material, namely a crystal. This creates a transient wave that reaches beyond the outer surface of the optically dense crystal, and then into the sample which is held in contact with it. This wave interacts with the sample's surface, getting absorbed by its unique molecular vibrations. The altered wave is then passed into the spectrometer's detector. The system then uses this data to generate a distinct infrared spectrum of the sample.

Materials and samples
Instrument
Thermo Scientific Nicolet iS50 ATR FT-IR
Materials
Tissue and isopropanol solvent
Samples
Disposable A: Top sheet, soaker, bottom sheet, and packaging.
Disposable C: Soaker and bottom sheet.
Reusable: Top sheet and soaker

Table F1: Sample overview

Mat	Label	File name
Disposable A	1TS	1TS
	1S	1S
	1BS	1BS
	1P	1P
Disposable B	2S	2S
Disposable C	3S	3S
	3BS	3BS
Reusable A	4TS	4TS
	4S	4S

TS=top sheet, S=soaker, BS=bottom sheet and P=packaging

Methods
Instrument settings:

Number of scans: 24, resolution : 4, final format: Absorbance, background handling: Collect background before each sample.

Procedure:

After the background was collected, the sample was placed into the sample compartment and the IR absorbance spectrum was run. The datasheet was saved as .csv file for analysis.

Analysis:

Analysis of the data was done in Omnic (software provided by Thermo Scientific). For each sample the absorbance spectrum was plotted, *automatic baseline correct* was selected, and IR absorption peaks were identified. The graphs and IR absorption peaks of each sample were compared to data from literature to identify the material. If necessary, the plotted absorbance graphs were inverted to be compared to transmittance graphs from literature. To match the samples to materials found in literature, the peaks are compared with each other [22].

Results and analysis Disposable A and B

Top sheet: PP

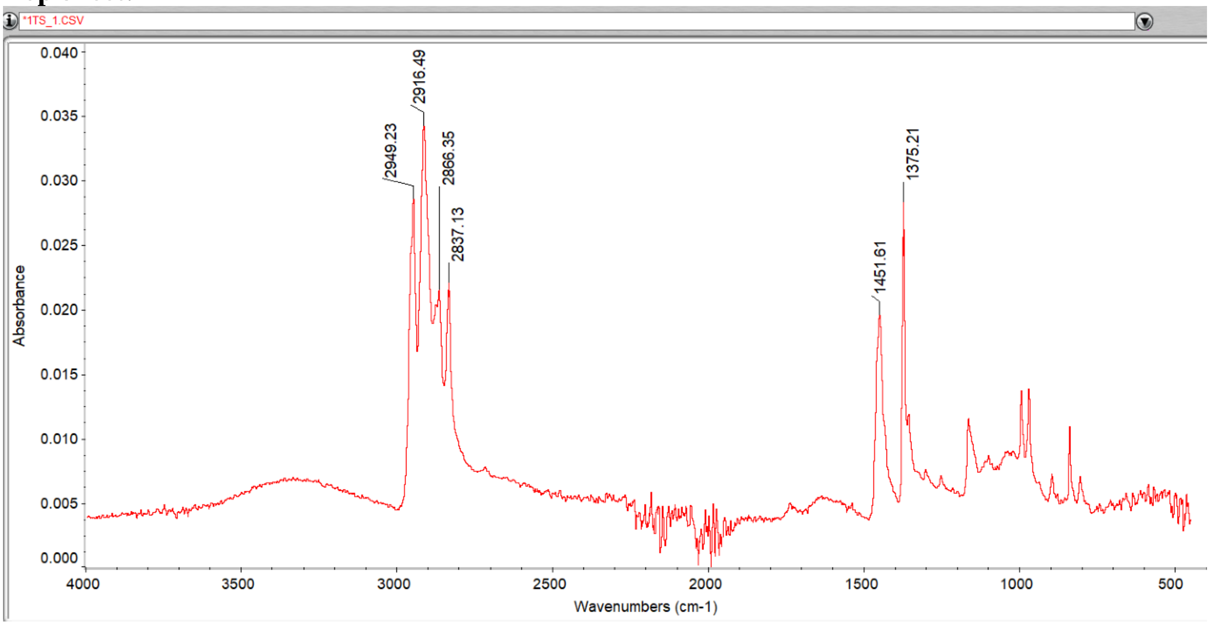
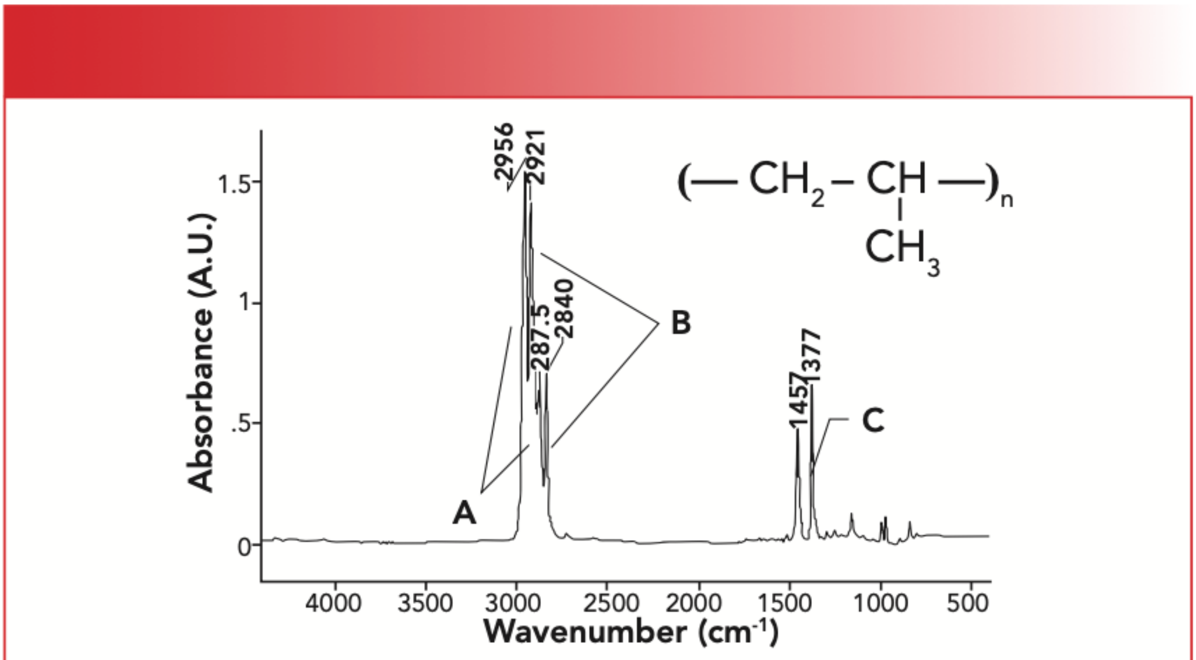


Figure F1: Absorbance spectrum and peaks of the Disposable A top sheet sample.



A	2956, 2875	CH_3 Asymmetric and symmetric stretches
B	2921, 2840	CH_2 Asymmetric and symmetric stretches
C	1377	CH_3 Umbrella mode

Figure F2: Absorbance spectrum and peaks of polypropylene (adapted from [22]).

Soaker: Softwood pulp

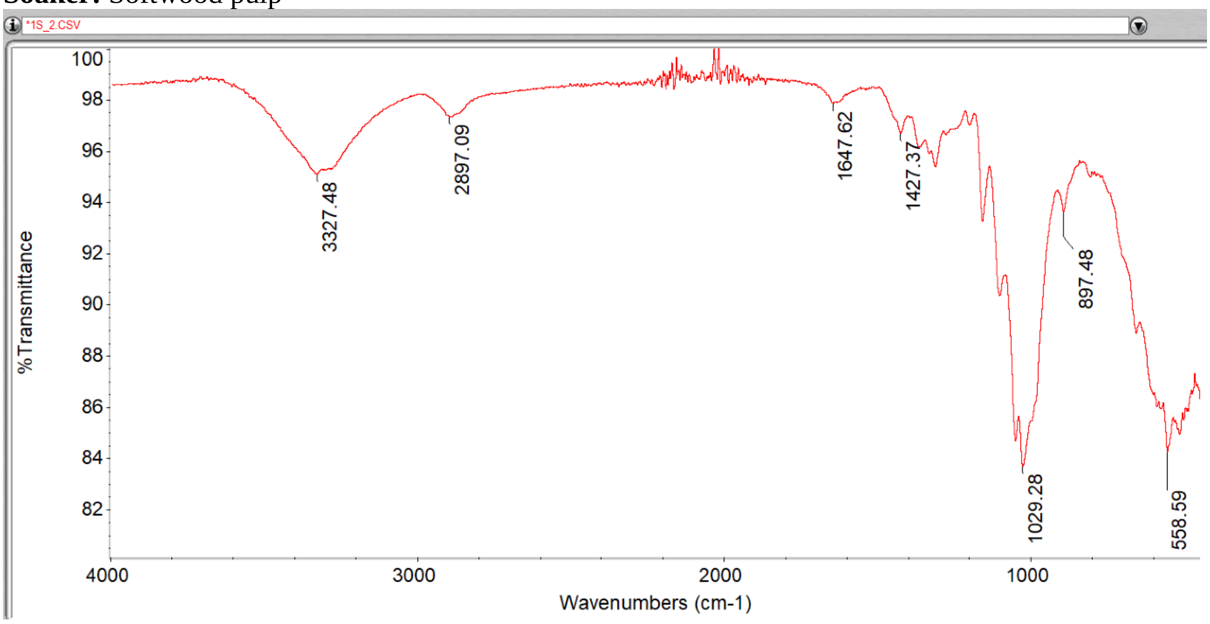


Figure F3: Transmittance spectrum and peaks of the Disposable A soaker sample.

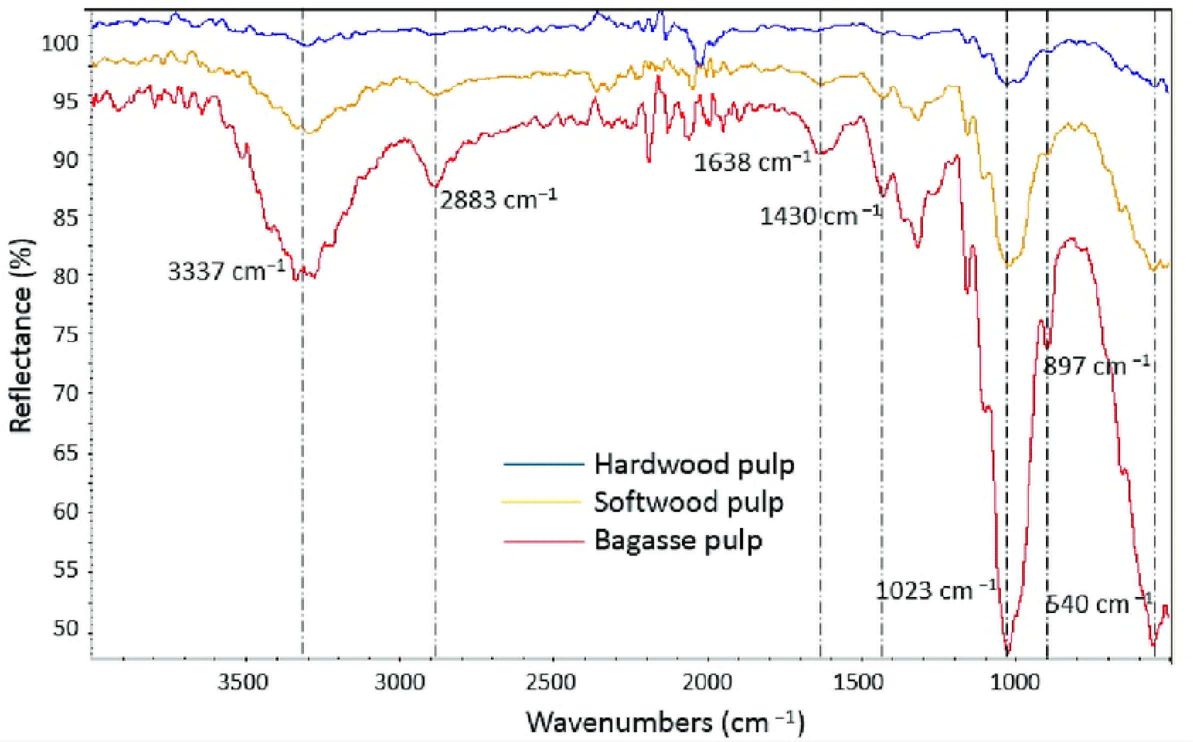


Figure F4: Reflectance spectrum and peaks of different pulp sources (adapted from[23]).

Bottom sheet: LLDPE

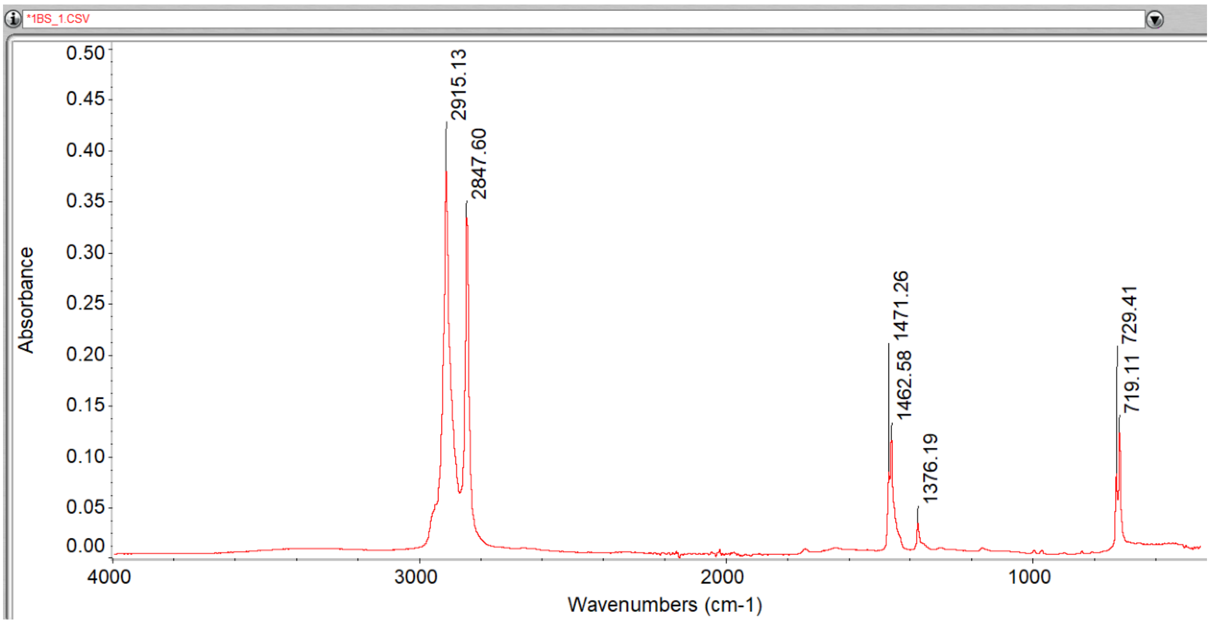
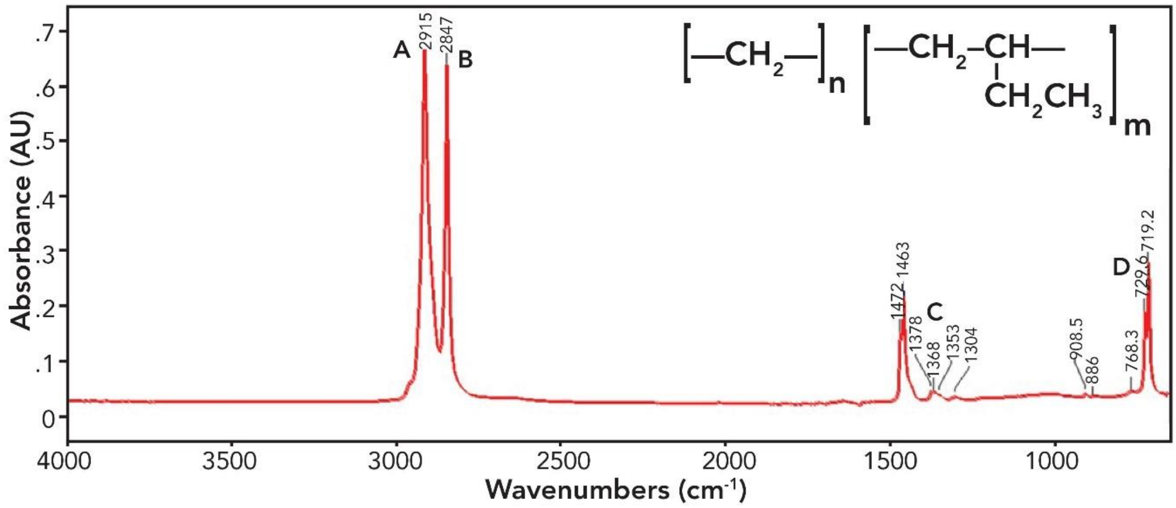


Figure F5: Absorbance spectrum and peaks of the Disposable A bottom sheet sample.



A	2915	CH_2 Asymmetric Stretch
B	2847	CH_2 Symmetric Stretch
C	1378	CH_3 Umbrella Mode
D	729/719	Split CH_2 Rocking Peak

Figure F6: Absorbance spectrum and peaks of linear low-density polyethylene (adapted from [24]).

Packaging: HDPE

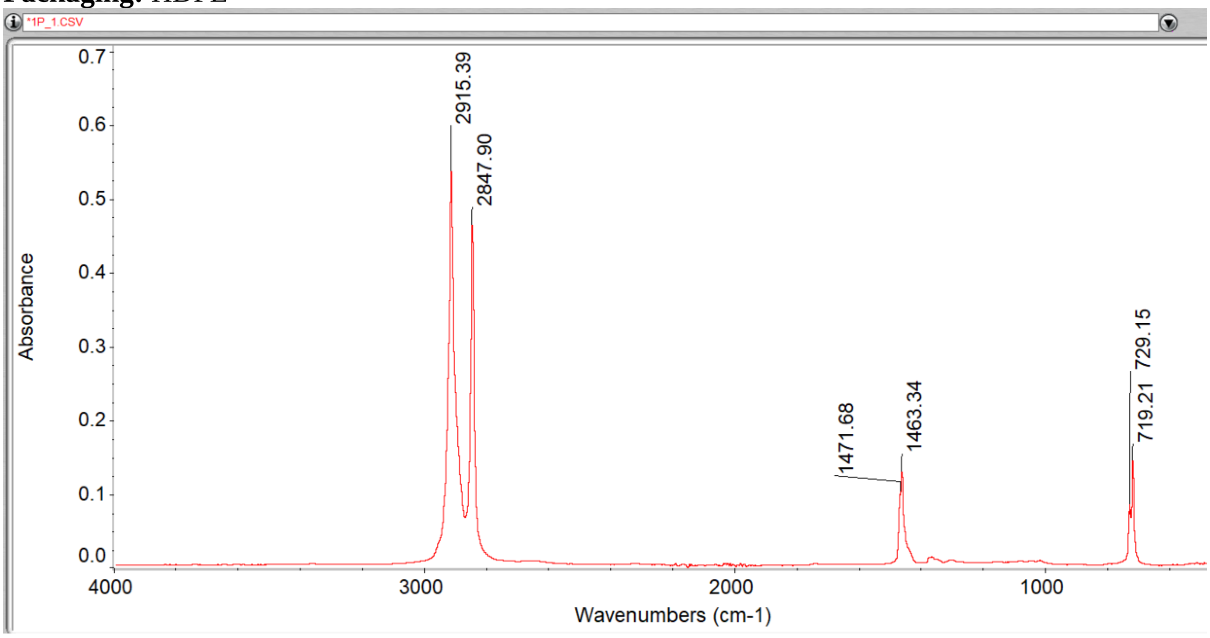
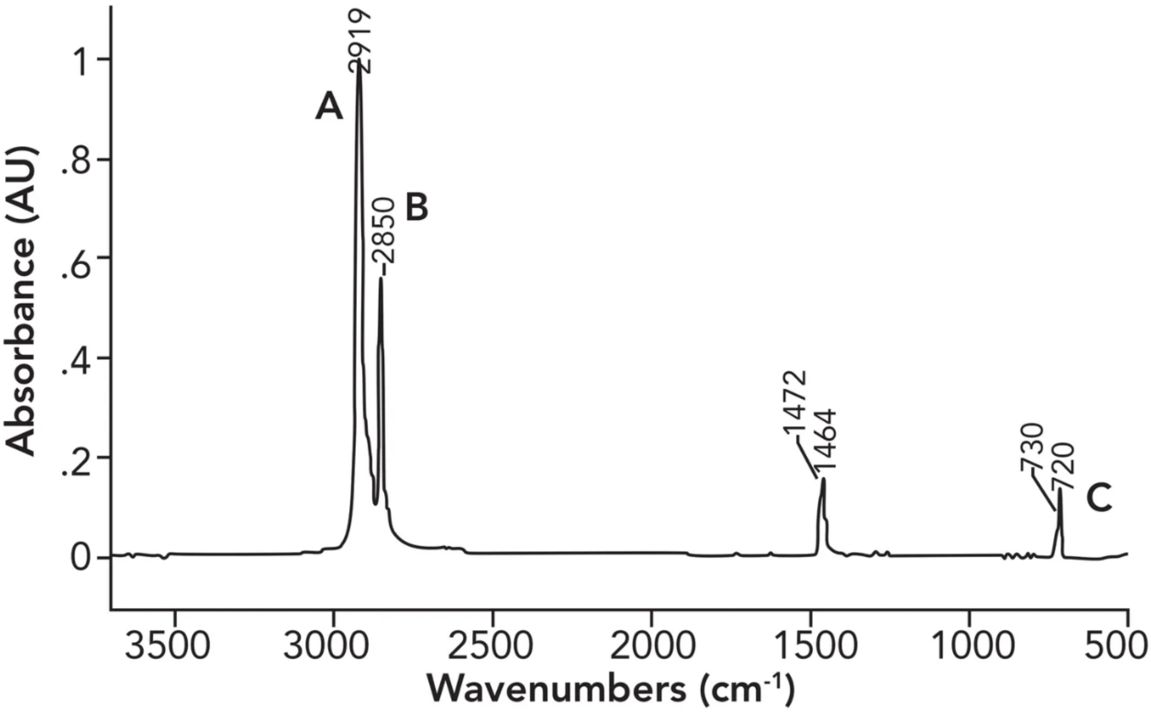


Figure F7: Absorbance spectrum and peaks of the Disposable A packaging sample.



A	2919	CH_2 Asymmetric C-H stretch
B	2850	CH_2 Symmetric C-H stretch
C	730, 720	Split CH_2 rock

Figure F8: Absorbance spectrum and peaks of high-density polyethylene (adapted from [24]).

Table F2: Comparison of sample peaks and literature peaks for Disposable A samples.

Sample	Sample peaks	Literature peaks	Material
Disposable A top sheet	2950, 2866 2916, 2837 1375	2956, 2875 2921, 2840 1377	PP
Disposable A soaker	3327, 2897 1648, 1427 1029, 897, 559	3337, 2883 1638, 1430 1023, 897, 540	Softwood pulp
Disposable A bottom sheet	2915, 2847 1376 729, 719	2915, 2847 1378 729, 719	LLDPE
Disposable A packaging	2915, 2848 729, 719	2919, 2850 730, 720	HDPE

Results and analysis Disposable C

Soaker:

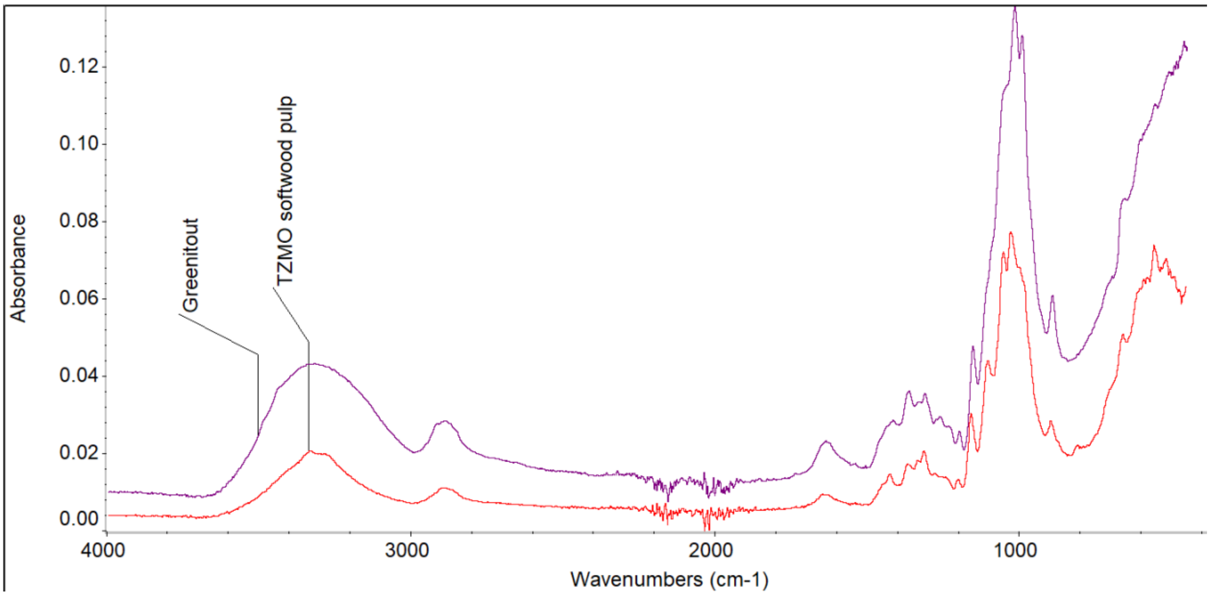


Figure F9: Absorbance spectrum and peaks of Disposable A softwood pulp (cellulose) and Disposable C soaker sample.

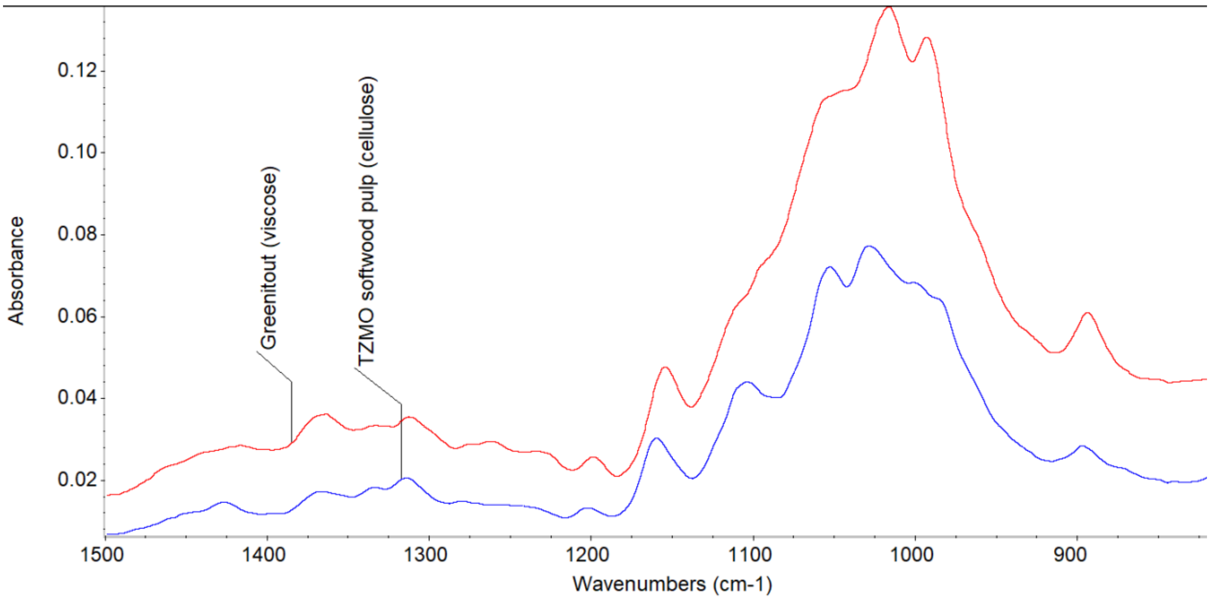


Figure F101: Absorbance spectrum and peaks of Disposable A softwood pulp (cellulose) and Disposable C soaker sample for wavenumbers between 800 and 1500.

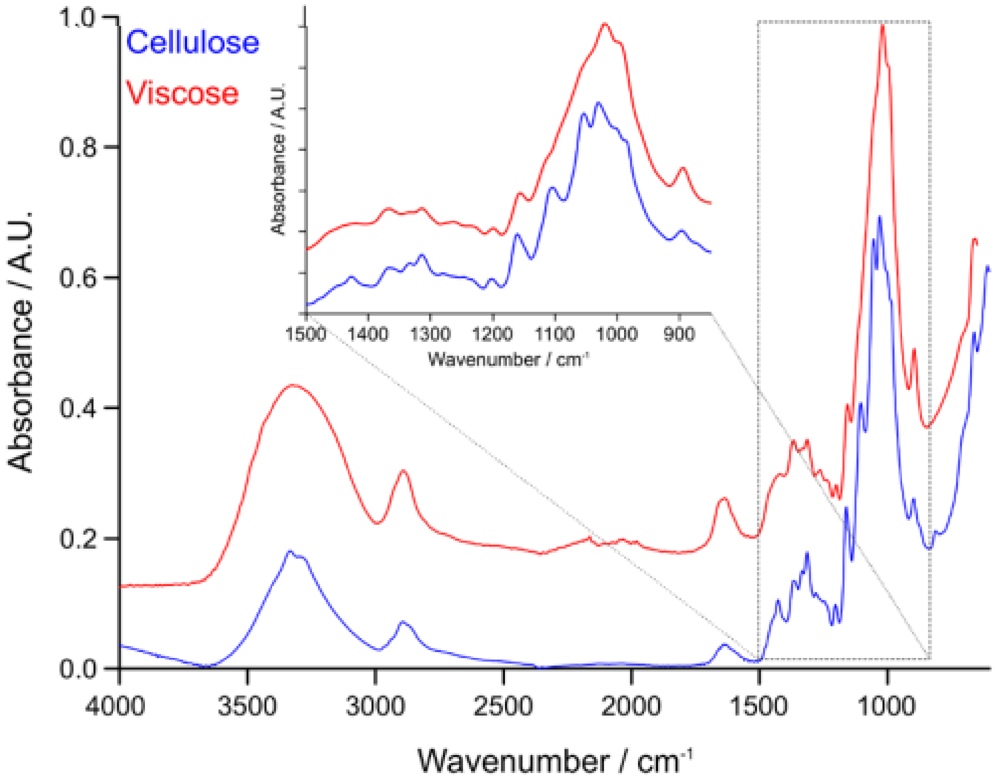


Figure F112: Absorbance spectrum and peaks of cellulose compared to viscose (adapted from [25]).

According to Lendl differentiation of viscose and natural cellulose fibres is possible based on IR-spectra measured with ATR-technique [26]. The natural cellulose has bands which do not appear in the viscose or are only weakly expressed (1425, 1105 and 1051 cm-1).

Bottom sheet:

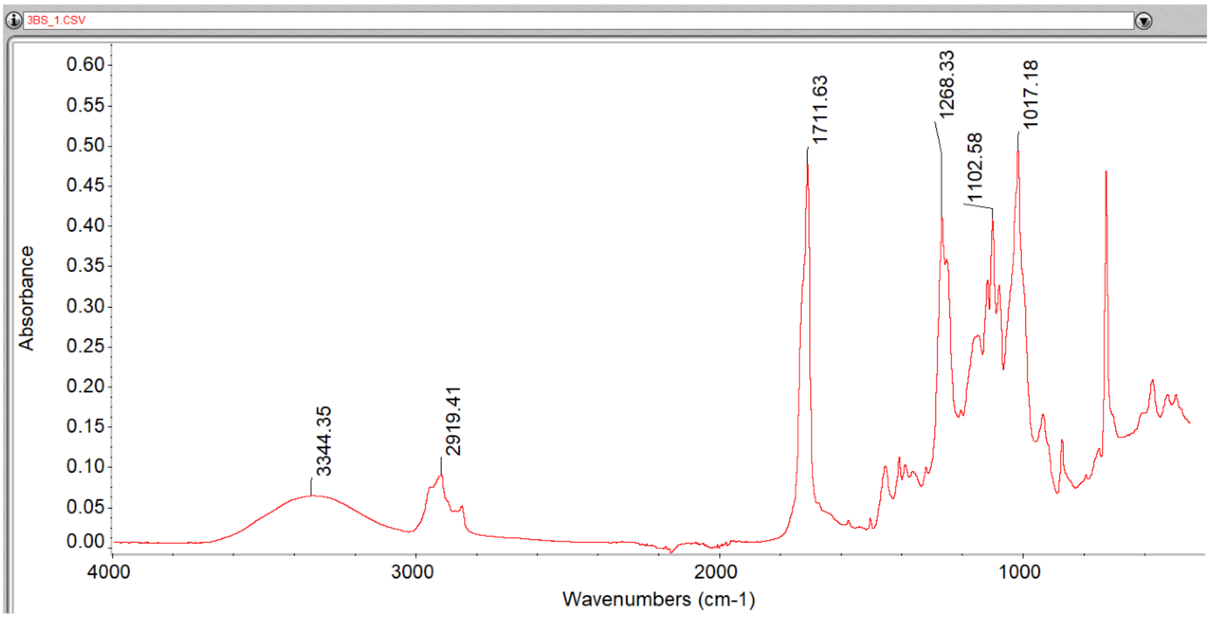


Figure F123: Absorbance spectrum and peaks of Disposable C bottom sheet.

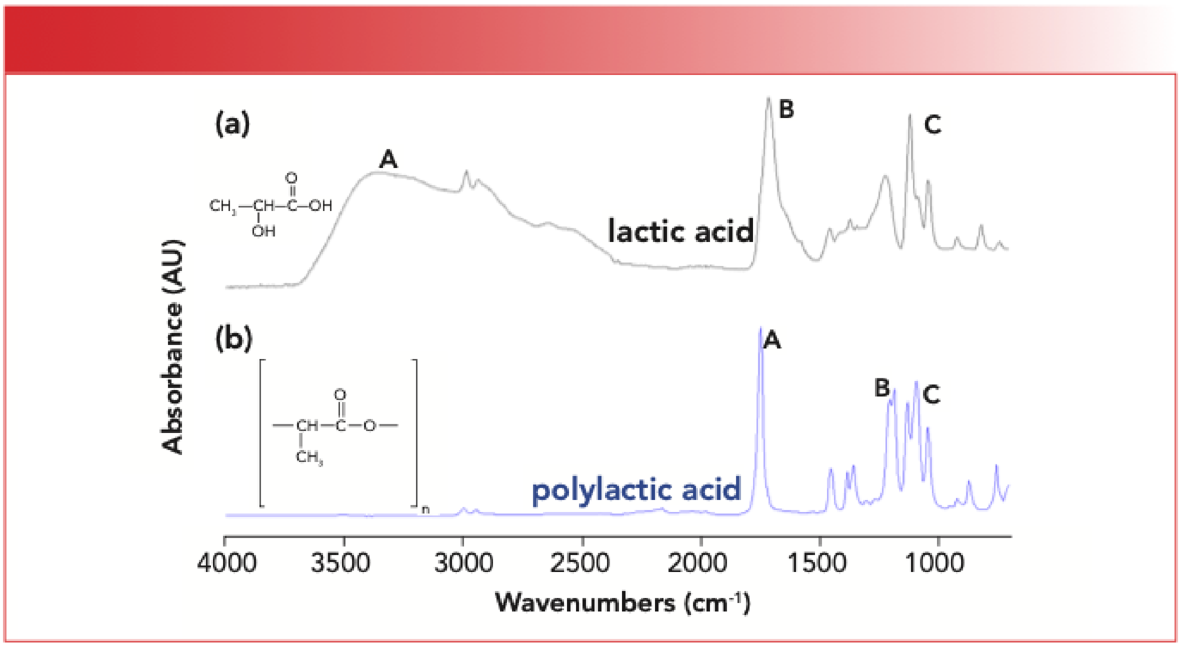


Figure F13: Absorbance spectrum and peaks of lactic acid and polylactic acid (adapted from [27]).

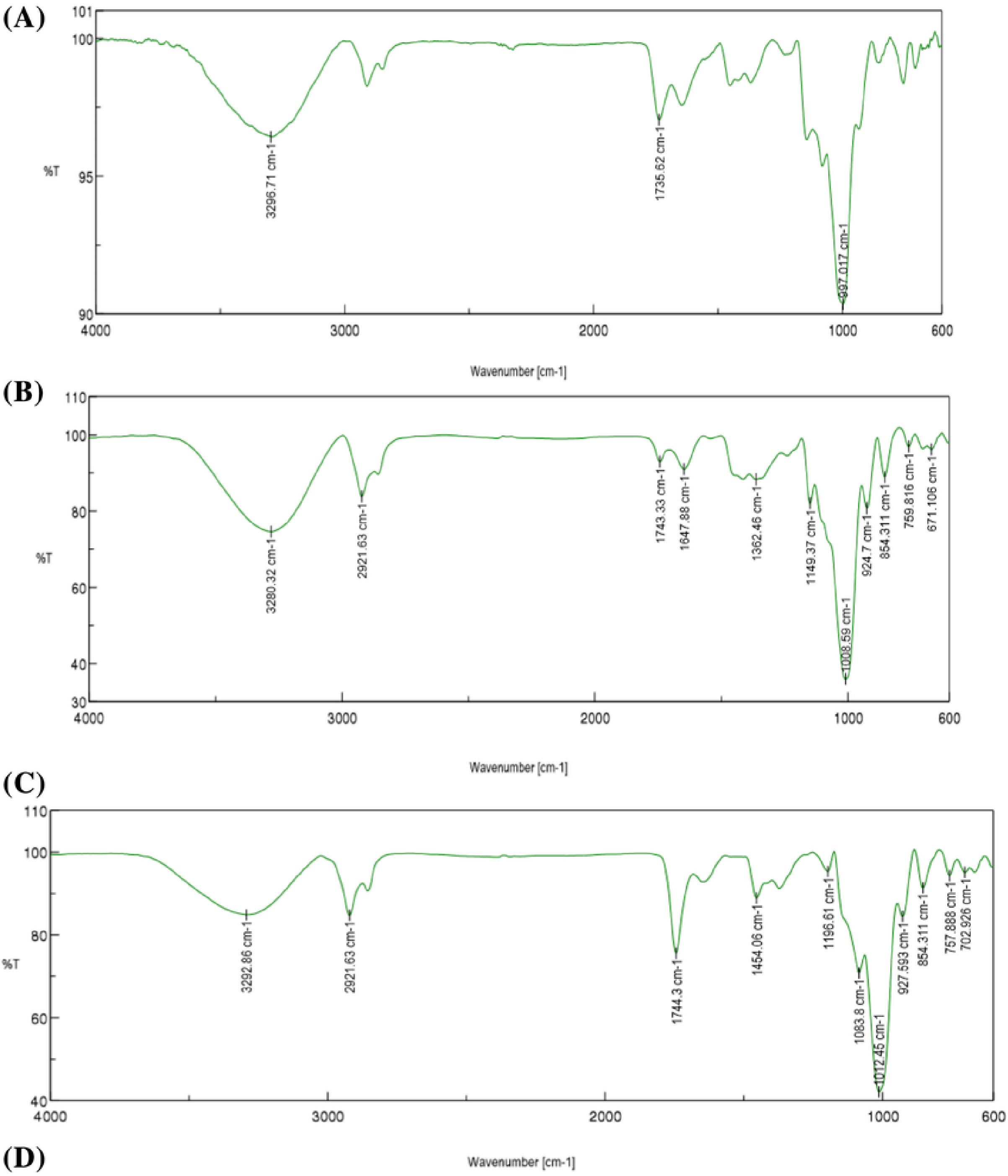


Figure F144: Absorbance spectrum and peaks of bioplastics: a) Polyvinyl alcohol, b) AV film, c) Starch polyvinyl alcohol film (adapted from [28]).

Table F3: Comparison of sample peaks and literature peaks for disposable biodegradable samples.

Sample	**Sample peaks**	**Literature peaks**	**Material**
Disposable C soaker	3327, 2897 1648, 1427 1029, 897, 559 900-1200: weakly expressed peaks compared to softwood pulp (cellulose)	3337, 2883 1638, 1430 1023, 897, 540 900-1200: weakly expressed peaks compared to softwood pulp (cellulose)	Viscose

Disposable C bottom sheet	Broad stretch from 3500 to 2500 and peaks at 1711, 1268	Broad stretch from 3500 to 2500 and peaks around 1700 and 1250	Lactic acid
	3344, 2919 1712, 1017	3292, 2921 1744, 1012	Starch polyvinyl alcohol

The sample material of the Disposable C bottom sheet cannot clearly be attributed to a material found in literature. However, the bottom sheet sample has three clear distinct peaks at 1711, 1268 and 1017 which indicate that the material is a polyester [27]. Furthermore, the broad stretch between 3500 and 2500 are like the stretches of lactic acid and other biopolymers. Therefore, the material of the Disposable C bottom sheet is determined to be a Disposable C polymer.

Results and analysis Reusable A

Soaker:

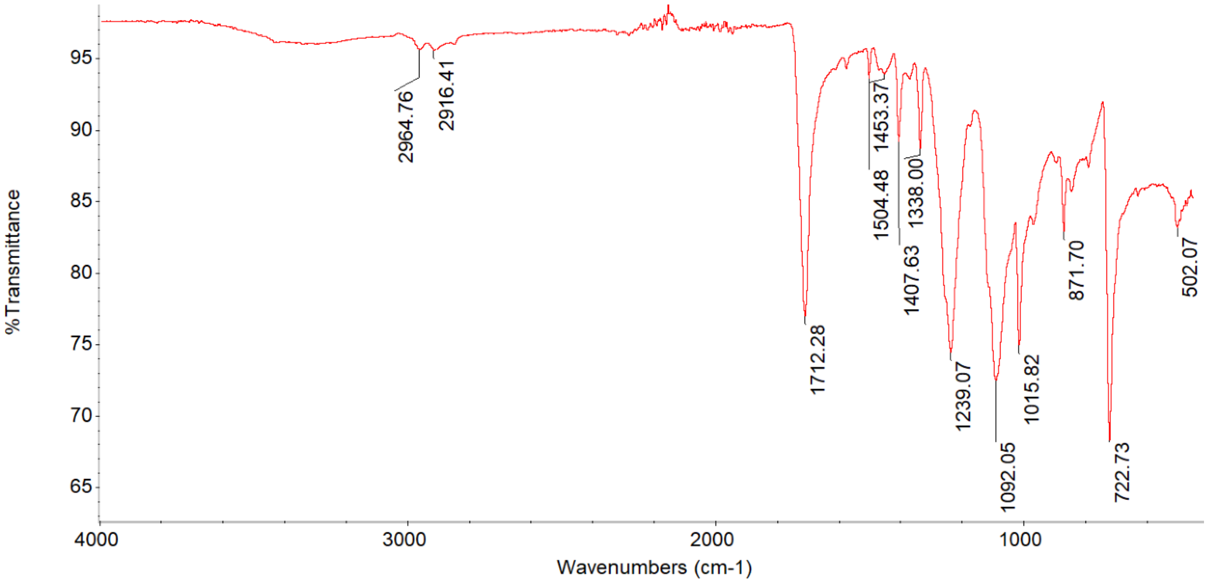


Figure F155: Absorbance spectrum and peaks of Reusable A soaker sample.

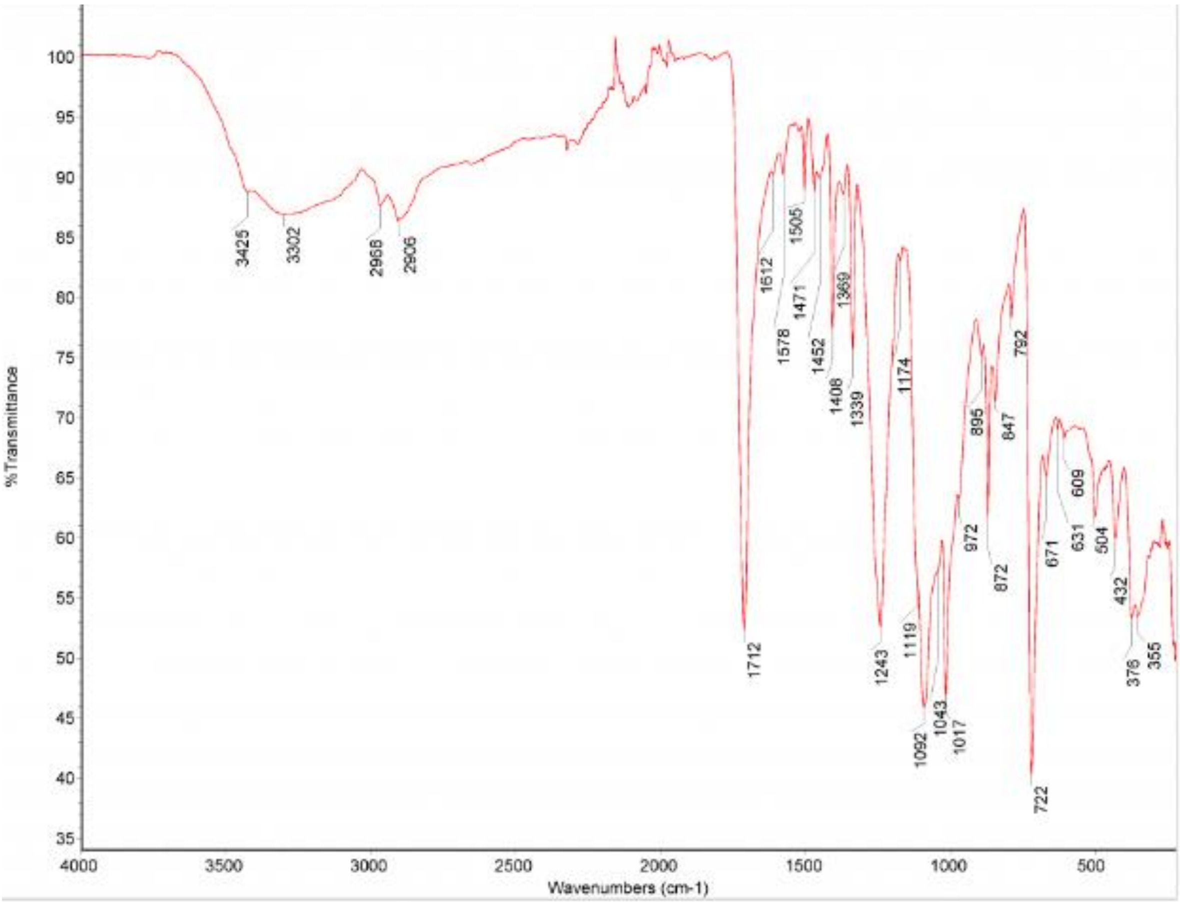


Figure F16: Absorbance spectrum and peaks of polyester-viscose (50%-50%) fibre (adapted from [29]).

Top and bottom sheet:

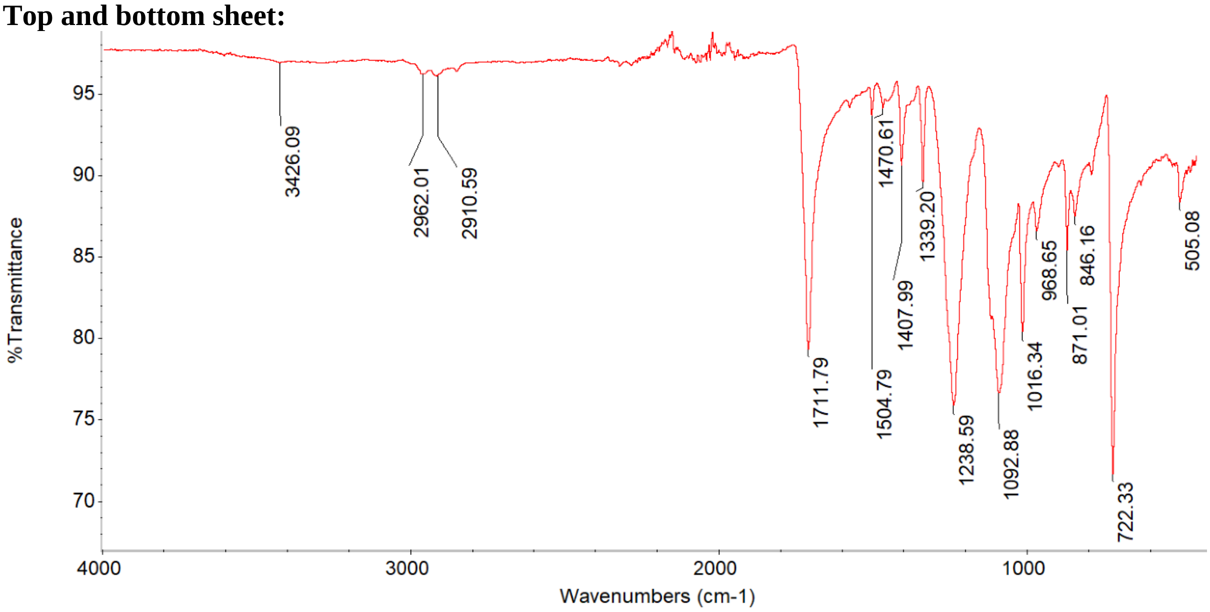


Figure F176: Absorbance spectrum and peaks of Reusable A top sheet sample.

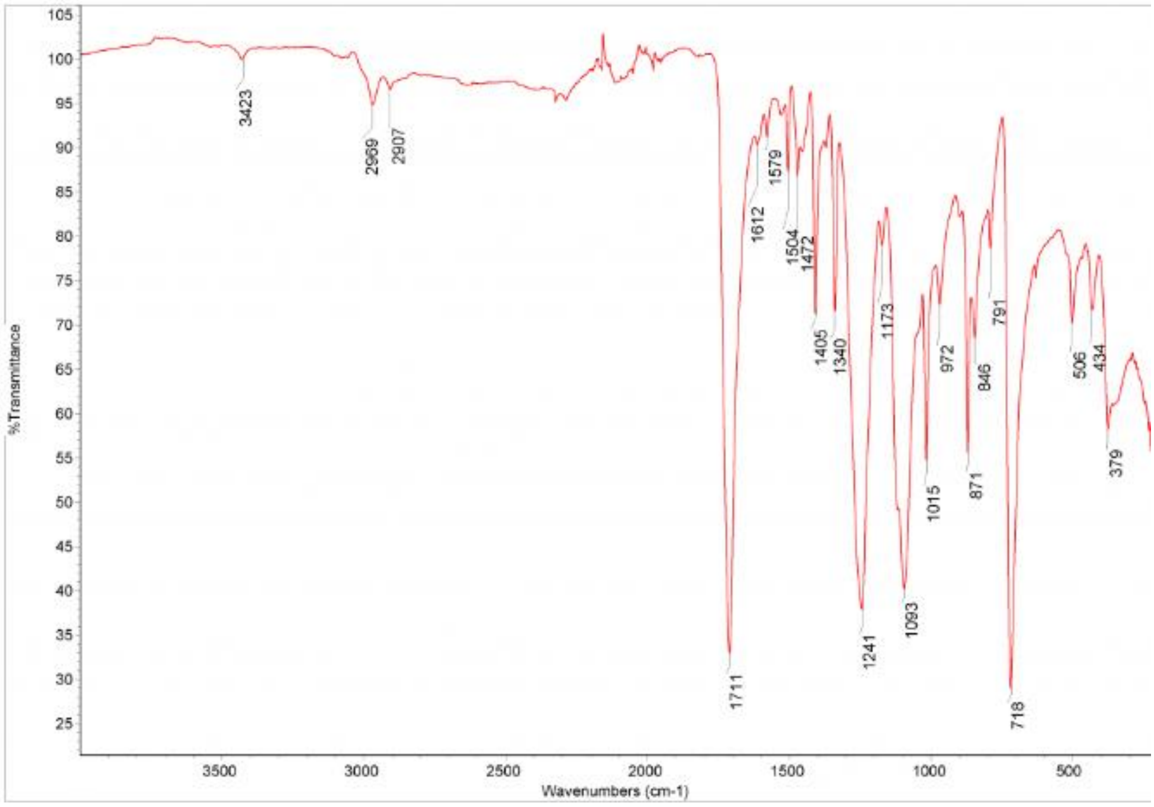


Figure F187: Absorbance spectrum and peaks of polyester fibre (adapted from [29]).

Table F4: Comparison of sample peaks and literature peaks for Reusable A samples.

Sample	**Sample peaks**	**Literature peaks**	**Material**
Reusable A soaker	Mellow stretch from 3000 to 3600 2964, 2916 1712, 1092 722	Broad stretch from 3000 to 3600 2968, 2906 1712, 1093 722	Polyester-viscose (50%-50%)
Reusable A top and bottom sheet	3426 2962, 2910 1712, 1239 722	3423 2969, 2908 1711, 1241 718	Polyester

For the Reusable A soaker sample the amplitude of the stretch from 3000 to 3600 is smaller compared to the one for polyester-viscose (50%-50%). This is due to the increased amount of polyester in the Reusable A sample polyester-viscose (80%-20%).

Appendix G: Absorption capacity determination

Determining the Absorption Capacity of the Absorbent Mats

Objective
The objective of this experiment is to determine the absorption capacity of the four mats, namely Disposable A mat, Disposable B mat, Disposable C mat and the Reusable A. There is data available on the absorption capacity of the Disposable A and B and Reusable A, but different standards and methods were used. Hence, a direct comparison of the absorption capacity of the mats is not possible. The data gathered from this experiment will be utilized in the life cycle assessment. The experiment was conducted following the instructions of ISO 20158:2018 (Textiles-Determination of water absorption time and water absorption capacity of textile fabrics).

Conditioning and testing atmosphere
Deviations from the given procedure of ISO 20158:2018
The relative humidity was not determined for this experiment. Therefore, there is no assurance that the experiment was conducted under standard atmosphere as outlined in ISO 139, Textiles — Standard atmospheres for conditioning and testing. According to ISO 139, the standard atmosphere shall have a temperature of 20,0 °C (±2,0 °C) and a relative humidity of 65,0 % (±4,0 %). The temperature was within the range of 20,0 ±2,0 °C but the relative humidity was not measured. The experiment was conducted at the department of gynaecology of the Leiden University Medical Center.
For testing a different liquid was used than specified in ISO 20158:2018. Grade 3 distilled water containing 9 g/l sodium chloride was used instead of Grade 3 distilled water. Grade 3 distilled water with 9g/l sodium chloride is used, because it better resembles amniotic fluid, urine and blood which are the main fluids that are absorbed by the mats when used in the hospital.
Individual and average water absorption time (s) were not measured in this experiment as they were of no use for the LCA.
For preparation of the Disposable C and Reusable A samples it was not possible to cut the samples with a minimum distance of 150mm from the selvedges. There was only one mat available for preparation of six samples resulting in too few area for cutting out six samples with a minimum distance of 150mm from the selvedges.
Pretreatment, laboratory testing conditions and water temperature
Absorbent mats were removed from their packing, unfolded, and conditioned in an atmosphere of 20 ±2,0 °C for 24 h prior to testing. The relative humidity was not measured as no measuring device was available. After 24 h samples were cut out from the mats as outlined in ISO 20158:2018. The water temperature was 20 ±2,0°C.

Apparatus and materials
Container, with a minimum depth of 100 mm and sufficient surface area to allow the specimen to float freely, analytical balance (Sartorius Laboratory L2200P-*E2), capable of determining mass with an accuracy of ±0,01 g, timer with an accuracy of ±0,1 s, grade 3 water, in accordance with ISO 3696, at a temperature of 20 ± 2 °C with 9 g/l sodium chloride.
Samples
Six samples were prepared for every mat as specified in ISO 20158:2018. Samples of each mat can be seen in figure .


Figure G1: Samples from left to right: Reusable A, Disposable B, Disposable C and Disposable A.

Experiment setup


Figure G2: Experimental setup.

Individual and average water absorption capacity (%) of the specimens

The following formula as outlined in ISO 20158:2018 is used:

$$WAC(\%) = \frac{m2 - m1}{m1} \times 100$$

where

m1 is the mass of test specimen in dry state, in g.

m2 is the mass of test specimen in wet state, in g. The absorption capacity is also displayed in gram / gram.

Procedure

The procedure as outlined in ISO 20158:2018 was followed. Samples were saturated for 120 ± 2s and hang to drain of at its corner for 60 ± 2s.

Results

Table F1: Disposable A mat absorption capacity

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Average

m1	1.33g	1.48g	1.50g	1.41g	1.38g	1.40g	1.42g
m2	21.34g	23.41g	24.65g	19.63g	20.59g	20.22g	21.64g
WAC	1505	1482	1543	1292	1392	1344	1424
g/g	15.05	14.82	15.43	12.92	13.92	13.44	14.24

Table F2: Disposable B mat absorption capacity

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Average**
m1	0.90g	0.81g	0.96g	0.89g	0.95g	0.89g	0.90g
m2	12.13g	10.15g	12.49g	11.05g	12.03g	10.68g	11.42g
WAC	1248	1153	1201	1142	1166	1100	1169
g/g	12.48	11.53	12.01	11.42	11.66	11.00	11.69

Table F3: Disposable C mat absorption capacity

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Average**
m1	0.69g	0.67g	0.70g	0.66g	0.75g	0.66g	0.69g
m2	6.44g	5.86g	5.74g	6.22g	6.83g	5.94g	6.17g
WAC	833	774	720	842	811	800	794
g/g	8.33	7.74	7.20	8.42	8.11	8.00	7.94

Table F4: Reusable A absorption capacity

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Average**
m1	4.93g	4.81g	4.78g	5.04g	5.11g	5.10g	4.96g
m2	22.89g	24.08g	21.61g	24.40g	23.83	24.22g	23.50g
WAC	364	400	352	384	366	375	374
g/g	3.64	4.00	3.52	3.84	3.66	3.75	3.74

Table F5: Total absorption capacity

	Mass mat	**Absorption capacity**	**Total absorption capacity**
Disposable A	40g	14.24 g/g	570g
Disposable B	28g	11.69 g/g	327g
Disposable C	16g	7.94 g/g	127g
Reusable A	186g	3.74 g/g	695g

Date of test
28.08.2023

Calculations for scenario analysis Disposable A and Disposable C

Table F6: Calculation of the SAP and initial soaker amount

	Disposable A	Disposable C
Total mass mat	40 grams	16 grams
Absorption capacity	14.24g/g	7.94g/g
Total absorption capacity	570 grams	127 grams
Absorption capacity SAP [2]	60g/g	
Composition absorbent core of AHPs [1]	54% pulp, 46% SAP	
Mass absorbent core with SAP	16.2 grams	4.0 grams
Mass pulp material	8.7 grams	2.2 grams
Mass SAP	7.5 grams	1.8 grams

References Appendix

[1] Mendoza JMF, D'Aponte F, Gualtieri D, Azapagic A. Disposable baby diapers: Life cycle costs, eco-efficiency and circular economy. J Clean Prod 2019;211:455–67. https://doi.org/10.1016/j.jclepro.2018.11.146.

[2] Cordella M, Bauer I, Lehmann A, Schulz M, Wolf O. Evolution of disposable baby diapers in Europe: life cycle assessment of environmental impacts and identification of key areas of improvement. J Clean Prod 2015;95:322–31. https://doi.org/10.1016/j.jclepro.2015.02.040.

[3] Aumonier Simon, Great Britain. Environment Agency., Collins Michael. Life cycle assessment of disposable and reusable nappies in the UK. Environment Agency; 2005.

[4] Benecke F. Commercial Beekeeping in Australia. 2007.

[5] Maglaya I. Life cycle analysis of non-petroleum based wax. Master Thesis. University of Queensland, 202AD.

[6] Munasinghe P, Druckman A, Dissanayake DGK. A systematic review of the life cycle inventory of clothing. J Clean Prod 2021;320:128852. https://doi.org/10.1016/j.jclepro.2021.128852.

[7] Matyjaszewski K, Möller M. Polymer science : a comprehensive reference. vol. 10. 9th ed. Amsterdam: Elsevier; 2012.

[8] Duhoux T, Maes E, Hirschnitz-Garbers M, Peeters K, Asscherickx L, Christis M, et al. Study on the technical, regulatory, economic and environmental effectiveness of textile fibres recycling Final Report 2021. https://doi.org/10.2873/828412.

[9] O'brien K, Olive R, Hsu Y-C, Morris L, Bell R, Kendall N. Life Cycle Assessment: Reusable and Disposable Nappies in Australia. 2009.

[10] Hoffmann BS, de Simone Morais J, Teodoro PF. Life cycle assessment of innovative circular business models for modern cloth diapers. J Clean Prod 2020;249:119364. https://doi.org/10.1016/j.jclepro.2019.119364.

[11] Griffing E, Overcash M. Reusable and Disposable Incontinence Underpads: Environmental Footprints as a Route for Decision Making to Decarbonize Health Care. J Nurs Care Qual 2023;38:278–85. https://doi.org/10.1097/NCQ.0000000000000697.

[12] Overcash M, Griffing E. National Economic and Environmental Benefit of Reusable Textiles in Cleanroom Industry. PDA J Pharm Sci Technol 2022;76:109–19. https://doi.org/10.5731/pdajpst.2020.012138.

[13] Vozzola E, Overcash M, Griffing E. An Environmental Analysis of Reusable and Disposable Surgical Gowns. AORN J 2020;111:315–25. https://doi.org/10.1002/aorn.12885.

[14] Gontia P, Janssen M. Life cycle assessment of bio-based sodium polyacrylate production from pulp mill side streams: case study of thermo-mechanical and sulfite pulp mills. J Clean Prod 2016;131:475–84. https://doi.org/10.1016/j.jclepro.2016.04.155.

[15] Ecoinvent. Activities & Products n.d. https://ecoinvent.org/the-ecoinvent-database/activities-products/ (accessed September 10, 2023).

[16] Ecoinvent. Geographies n.d. https://ecoinvent.org/the-ecoinvent-database/geographies/ (accessed September 10, 2023).

[17] Lenzing. EcoVero Lenzing n.d. https://www.ecovero.com/ (accessed September 12, 2023).

[18] van der Vreede G, Sevenster M. Lifecycle environmental impact assessment of textiles : For priority streams in Dutch lifecycle-based waste policy . Delft: 2010.

[19] Europees Milieuagentschap. De gevolgen van textielproductie en -afval voor het milieu. Europees Parlament 2023. https://www.europarl.europa.eu/news/nl/headlines/society/20201208STO93327/de-gevolgen-van-textielproductie-en-afval-voor-het-milieu#:~:text=In%20plaats%20van%20ze%20weg,wordt%20gerecycled%20tot%20nieuwe%20kleding. (accessed September 9, 2023).

[20] Dhiman R, Chattopadhyay R. Absorbency of synthetic urine by cotton nonwoven fabric. The Journal of The Textile Institute 2021;112:996–1003. https://doi.org/10.1080/00405000.2020.1802894.

[21] Bartkowiakb G, Frydrych I. Superabsorbents and their medical applications. Handbook of Medical Textiles, Elsevier; 2011, p. 505–46. https://doi.org/10.1533/9780857093691.4.505.

[22] Smith BC. The Infrared Spectra of Polymers III: Hydrocarbon Polymers. Spectroscopy 2021:22–5. https://doi.org/10.56530/spectroscopy.mh7872q7.
[23] Ismaeilimoghadam S, Sheikh M, Taheri P, Maleki S, Resalati H, Jonoobi M, et al. Manufacturing of Fluff Pulp Using Different Pulp Sources and Bentonite on an Industrial Scale for Absorbent Hygienic Products. Molecules 2022;27. https://doi.org/10.3390/molecules27155022.
[24] Smith BC. The Infrared Spectra of Polymers II: Polyethylene. Spectroscopy 2021:24–9. https://doi.org/10.56530/spectroscopy.xp7081p7.
[25] Application Note AN M 144 Analysis of Microplastics using FTIR and Raman-Microscopy, Engineering; 2017.
[26] Comnea-Stancu IR, Wieland K, Ramer G, Schwaighofer A, Lendl B. On the Identification of Rayon/Viscose as a Major Fraction of Microplastics in the Marine Environment: Discrimination between Natural and Manmade Cellulosic Fibers Using Fourier Transform Infrared Spectroscopy. Appl Spectrosc 2017;71:939–50. https://doi.org/10.1177/0003702816660725.
[27] Smith BC. Infrared Spectroscopy of Polymers, VIII: Polyesters and the Rule of Three. Spectroscopy 2022:25–8. https://doi.org/10.56530/spectroscopy.ta9383e3.
[28] Krishnamurthy A, Amritkumar P. Synthesis and characterization of eco-friendly bioplastic from low-cost plant resources. SN Appl Sci 2019;1:1432. https://doi.org/10.1007/s42452-019-1460-x.
[29] Vahur S, Teearu A, Peets P, Joosu L, Leito I. ATR-FT-IR spectral collection of conservation materials in the extended region of 4000-80 cm–1. Anal Bioanal Chem 2016;408:3373–9. https://doi.org/10.1007/s00216-016-9411-5.