Electronic Supplementary Material (ESI) for Environmental Science: Nano.

Gold nanoclusters embedded in antimicrobial keyboard covers: Life Cycle Assessment and environmental sustainability.

Authors: Martina Pucciarelli, Fabio Grimaldi, Gaowei Wu, Paola Lettieri

Department of Chemical Engineering, University College London

Corresponding author: p.lettieri@ucl.ac.uk

ANNEX I: Number of Nurses and Medical Doctors in the European continent and United Kingdom

The main assumption on which all the study is based on is the number of keyboards required in hospitals.
Based on a personal communication on the approximate number of computers at UCL Hospital (London), and on the number of staff it was estimated a ratio of 0.45 computers and thus keyboard for member staff.
Then data on the numbers of hospital doctors and nurses were collected for UK and Europe, in order to estimate the number of keyboard covers required over a period of one year, which is 2.1E+05 and 1.6E+06, respectively.
Europe was considered as a geographical continent, and not as Union.
Data on the number of doctors and nurses were collected from different websites and reports from the NHS England, NHS Wales, NHS Scotland, Department of Health in Northern Ireland, EUROSTAT and ISTAT.
Tables SI 1 and 2 reports the numbers estimated:

Table SI 1 Number of medical doctors in the European continent, estimated for the year 2018.

Medical doctors in Europe, estimated numbers for year 2018			
Belgium	8272	Netherlands	21603
Bulgaria	16732	Austria	22807.83
Czechia	22371.82	Poland	42127
Denmark	17094	Portugal	24003
Germany	170000	Romania	28465
Estonia	2547.7	Slovenia	3548
Ireland	8205.95	Slovakia	9086.69
Greece	23321	Finland	7698.74
Spain	107000	United Kingdom	143595
France	131059.27	Iceland	696
Croatia	8195	Liechtenstein	19.1
Italy	241512	Norway	13931
Cyprus	801	Switzerland	22011.05
Latvia	3623	Montenegro	924
Lithuania	9726	North Macedonia	2179
Luxembourg	NA	Albania	1718
Hungary	17406.65	Serbia	11345
Malta	1177.94	Turkey	112027

Table SI 2 Number of Nurses in the European continent, estimated for the year 2018.

Nurses in Europe, estimated numbers for year 2018			
Belgium	86247	Netherlands	60012
Bulgaria	22752	Austria	51203.43
Czechia	52864.88	Poland	134248
Denmark	37092	Portugal	39670
Germany	350000	Romania	10737
Estonia	4890.9	Slovenia	3935
Ireland	22375.78	Slovakia	21178.38
Greece	23160	Finland	5937
Spain	156772	United Kingdom	312240
France	354504.78	Iceland	1588
Croatia	4702	Liechtenstein	46.9
Italy	263465	Norway	42759
Cyprus	4141	Switzerland	48068.77
Latvia	6317	Montenegro	2173
Lithuania	15478	North Macedonia	5136
Luxembourg	3940	Albania	5782
Hungary	28684.52	Serbia	5697
Malta	2908.37	Turkey	163875

ANNEX II: Main assumptions used to define the system

Based on the data reported by G.B. Hwang and co-authors on the photo-bactericidal activity of encapsulated [$Au^{25}(Cys)_{18}$] and crystal violet in a polymer matrix [1], the quantity of gold required for the production of each antimicrobial keyboard cover was estimated.

For the swell-encapsulation process it is required a volume of around 4.4 litres of solution: 50% acetone, 40% DI water, 10% [$Au^{25}(Cys)_{18}$] sol (12mM) and crystal violet (800 ppm). 33% of AuNCs is encapsulated in the silicone matrix of the keyboard cover, therefore around 8.6E-02 gr of Au. The rest stays in solution and it can be used to produce other 2 keyboard covers.

Table SI 3 reports the quantity of gold required to satisfy the annual demand of keyboard covers in UK and Europe, and two different scenarios based on two assumed yield loss linked to the production of antimicrobial keyboard covers.

Table SI 3 Quantity of gold necessary to produce the number of antimicrobial keyboard cover (a.k.c.) to satisfy the annual demand in UK and Europe, accounting for a faulty loss of 0% (scenario 1), 5% (baseline) and 10% (scenario 2).

		United Kingdom	**Europe**
	Grams of Au/a.k.c.	8.6E-02 gr	
	90% production yield form synthesis [$Au^{25}(Cys)_{18}$]	9.5E-02 gr	
Scenario 1 [0%]	*Num. a.k.c. required in 1 year*	2.1E+05	1.6E+06
Scenario 1 [0%]	*Kilos of Au required to satisfy the annual demand*	2.0E+01 kg	1.5E+02kg
Baseline [5%]	*Num. a.k.c. required accounting a faulty loss of 5%*	2.23E+05	1.70E+06
Baseline [5%]	*Kilos of Au required accounting a faulty loss of 5%*	2.1E+01 kg	1.6E+02 kg
Scenario 2 [10%]	*Num. a.k.c. required accounting a faulty loss of 10%*	2.33E+05	1.78E+06
Scenario 2 [10%]	*Kilos of Au required accounting a faulty loss of 10%*	2.2E+01 kg	1.7E+02 kg

Table SI 4 Number of total reactors and number of production lines considered in this study.

		United Kingdom	Europe
Scenario 1 [0%]	*Number of reactors*	65	495
Scenario 1 [0%]	*Number of lines*	6	45
Baseline [5%]	*Number of reactors, accounting a faulty loss of 5%*	68	520
Baseline [5%]	*Number of lines, accounting a faulty loss of 5%*	6	47
Scenario 2 [10%]	*Number of reactors, accounting a faulty loss of 10%*	7	50
Scenario 2 [10%]	*Number of lines, accounting a faulty loss of 10%*	71	545

Table SI 5 This table reports all the chemical and energy inputs along with the equipment required to run a 11 milli-reactors production system over a period of 1 year, with a yield of 90%.

		Annual value for a system/production line of 11 reactors producing around 3.4 kg AuNCs/yr	Unit
Chemicals	*$HAuCl_4$ (as crystal and lumps)*	5.9	kg
	L-Cysteine	3.2	kg
	NaOH	4.3	kg
	Carbon monoxide (gas)	2.60	kg
	Water	1790	kg
Reactor Equipment	*Borosilicate vessels, 20 litres, life span of 2 years*	1.5	unit
	Spare-Borosilicate vessels, 20 litres, life span of 4 years	0.75	unit
	3 multi-channels pumps, life span of 7 years	0.43	unit
	2 spare-multi-channels pumps, life span of 14 years	0.14	unit
	Milli-reactor tubing, PTFE tubing, life span 1 year	22	m
	Spare Milli-reactor tubing, PTFE tubing, life span 2 years	11	m
	Milli-reactor tubing, Teflon, life span 1 year	22	m
	Spare Milli-reactor tubing, Teflon, life span 2 years	11	m
	T-junction, life span 2 years	11	unit
	Spare T-junction, life span 4 years	5.5	unit
	Temperature controller, life span 2 years	1	unit
	Spare-Temperature controller, life span 4 years	0.5	unit
	Pressure sensor, life span 2 years	5.50	unit
	Spare-Pressure sensor, life span 2 years	2.75	unit
	Back pressure regulator, life span 2 years	0.5	unit
	Spare-Back pressure regulator, life span 4 years	0.25	unit
	Paraffine oil (for oil bath), life span 3 years	4.80	l
	Spare-Paraffine oil (for oil bath), life span 6 years	2.40	l
Energy consumption	*Electricity consumption (heating and pumping)*	8400	kWh

Table SI 6 Quantities of material inputs for the swell-encapsulation-shrink process over a period of 1 year to satisfy both the assumed British and European demands.

		United Kingdom	**Europe**
Scenario 1 [0%]	*Acetone*	1.22E+05 kg	9.34E+05 kg
Scenario 1 [0%]	*Water*	1.24E+05 kg	9.52E+05 kg
Scenario 1 [0%]	*Crystal violet*	249 kg	952 kg
Baseline [5%]	*Acetone*	1.28E+05 kg	9.81E+05 kg
Baseline [5%]	*Water*	1.31E+05 kg	9.99E+05 kg
Baseline [5%]	*Crystal violet*	261 kg	2.00E+03 kg
Scenario 2 [10%]	*Acetone*	1.34E+05 kg	1.03E+06 kg
Scenario 2 [10%]	*Scenario 2 -10%*	1.37E+05 kg	1.05E+06 kg
Scenario 2 [10%]	*Crystal violet*	274 kg	2.09E+03 kg

ANNEX III: environmental impact categories

Further information on the environmental footprint method (EF 2.0) and the calculation models that includes can be found in JRC-EC report: "Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment method"[2].

Environmental Footprint method (EF 2.0)	**Method**	**Indicator**
Acidification terrestrial and freshwater	Accumulated Exceedance [3,4]	Accumulated Exceedance (AE)
Cancer human health effects	USEtox model [5]	Comparative Toxic Unit for humans
Climate Change	IPCC baseline model (100 years) [6]	Radiative forcing as Global Warming Potential (GWP100)
Ecotoxicity freshwater	USEtox model [5]	Comparative Toxic Unit for ecosystems (CTUe)
Eutrophication freshwater	EUTREND model [7]	Fraction of nutrients reaching freshwater (P) or marine (N) end compartment
Eutrophication marine	EUTREND model [7]	Fraction of nutrients reaching freshwater (P) or marine (N) end compartment
Eutrophication terrestrial	Accumulated Exceedance [3,4]	Accumulated Exceedance (AE)
Non-cancer human health effects	USEtox model [5]	Comparative Toxic Unit for humans (CTUh)
Ozone depletion	WMO model [8]	Ozone Depletion Potential (ODP)
Photochemical ozone formation - human health	LOTOS-EUROS [9]	Tropospheric ozone concentration increase
Resource use, energy carriers	CML 2002 [10]	Energy
Resource use, mineral and metals	CML 2002 [10]	Consumption resources and scarcity
Water scarcity	Available WAter REmaining (AWARE) in UNEP, 2016	Deprivation water

ANNEX IV: inventory for gloves and wipes

Table SI 7 reports inputs of nitrile butadiene rubber based on information collected form scientific literature[11]. For the modelling it was assumed an injection moulding process has been used in the GaBi modelling, therefore both electricity and water consumptions are in line with the dataset, *"DE: plastic injection, moulding part (unspecific) – ts"*.

Table SI 7 Material input of nitrile butadiene rubber for manufacturing gloves used in hospitals.

		United Kingdom	**Europe**
Scenario 1 [0%]	*Nitrile butadiene rubber*	3.32E+05 kg	2.56E+06 kg
Baseline [5%]	*Nitrile butadiene rubber*	3.48E+05 kg	1.15E+06 kg
Scenario 2 [10%]	*Nitrile butadiene rubber*	3.64E+05 kg	2.79E+06 kg

Non woven-alcohol wipes have been modelled based on information retrieved on different websites of producers and on the NHS suppliers website, specifically https://my.supplychain.nhs.uk/Catalogue/product/vjt421 , and the producer website, Gama healthcare https://gamahealthcare.com/products/alcohol-wipes-large-100. Both webpages were visited in June 2019.

Table SI 8 Material inputs for non-woven alcohol (70%) wipes.

		United Kingdom	**Europe**
Scenario 1 [0%]	*Non-woven tissue – polypropylene (PP)*	2.73E+05 kg	1.99E+06 kg
Scenario 1 [0%]	*Alcohol (70%)- Isopropanol*	1.03E+07 kg	7.53E+07 kg
Scenario 1 [0%]	*HDPE canister*	3.51E+05 kg	2.56E+06 kg
Baseline [5%]	*Non-woven tissue – polypropylene (PP)*	2.60E+05 kg	2.09E+06 kg
Baseline [5%]	*Alcohol (70%)- Isopropanol*	9.82E+06 kg	7.89E+07 kg
Baseline [5%]	*HDPE canister*	3.35E+05 kg	1.31E+07 kg
Scenario 2 [10%]	*Non-woven tissue – polypropylene (PP)*	2.86E+05 kg	2.19E+06 kg
Scenario 2 [10%]	*Alcohol (70%)- Isopropanol*	1.08E+07 kg	8.28E+07 kg
Scenario 2 [10%]	*HDPE canister*	3.68E+05 kg	2.86E+06 kg

ANNEX V: absolute results concerning both antimicrobial keyboard covers and alcohol wipes plus gloves systems. Tables report absolute results for the 3 faulty rate percentages considered: 0%, 5% and 10%.

LCIA results for the British scenarios of producing antimicrobial keyboard covers

Table SI 9 LCIA results for the life cycle of antimicrobial keyboard covers in the UK. Table shows results for the 3 different scenarios, based on different faulty percentages in the production process.

Environmental Footprint method (EF 2.0)	**Unit**	**UK scenario 0% faulty rate**	**UK scenario 5% faulty rate [baseline]**	**UK scenario 10% faulty rate**
Acidification terrestrial and freshwater	Mole of H+ eq.	4.26E+03	4.48E+03	4.70E+03
Cancer human health effects	CTUh	1.18E-02	1.24E-02	1.30E-02
Climate Change	kg CO2 eq.	4.29E+05	4.54E+05	4.79E+05
Climate Change (fossil)	kg CO2 eq.	4.26E+05	4.50E+05	4.75E+05
Climate Change (biogenic)	kg CO2 eq.	2.97E+03	3.18E+03	3.40E+03
Ecotoxicity freshwater	CTUe	5.29E+06	5.55E+06	5.81E+06
Eutrophication freshwater	kg P eq.	8.96E+03	9.40E+03	9.85E+03
Eutrophication marine	kg N eq.	1.69E+03	1.77E+03	1.86E+03
Eutrophication terrestrial	Mole of N eq.	1.64E+04	1.72E+04	1.81E+04
Non-cancer human health effects	CTUh	8.10E-01	8.51E-01	8.91E-01
Ozone depletion	kg CFC-11 eq.	1.21E-01	1.27E-01	1.34E-01
Photochemical ozone formation - human health	kg NMVOC eq.	3.66E+03	3.85E+03	4.04E+03
Resource use, energy carriers	MJ	7.22E+06	7.65E+06	8.08E+06
Resource use, mineral and metals	kg Sb eq.	9.85E+02	1.03E+03	1.08E+03
Water scarcity	m³ world equiv.	1.51E+05	1.59E+05	1.67E+05
ReCiPe method (2016) – hierarchical	**Unit**			
Metal Depletion	$	9.67E+04	1.02E+05	1.06E+05

LCIA results for the European scenarios of producing antimicrobial keyboard covers.

Table SI 10 LCIA results for the life cycle of antimicrobial keyboard covers in the European continent. Table shows results for the 3 different scenarios, based on different faulty percentages in the production process.

Environmental Footprint method (EF 2.0)	**Unit**	**EU cont. scenario 0% faulty rate**	**EU cont. scenario 5% faulty rate [baseline]**	**EU cont. scenario 10% faulty rate**
Acidification terrestrial and freshwater	Mole of H+ eq.	3.85E+04	4.08E+04	4.31E+04
Cancer human health effects	CTUh	9.26E-02	9.74E-02	1.02E-01
Climate Change	kg CO2 eq.	6.30E+06	6.80E+06	7.31E+06
Climate Change (fossil)	kg CO2 eq.	6.22E+06	6.71E+06	7.21E+06
Climate Change (biogenic)	kg CO2 eq.	8.42E+04	9.22E+04	1.00E+05
Ecotoxicity freshwater	CTUe	4.06E+07	4.26E+07	4.46E+07
Eutrophication freshwater	kg P eq.	6.86E+04	7.20E+04	7.54E+04
Eutrophication marine	kg N eq.	1.46E+04	1.54E+04	1.63E+04
Eutrophication terrestrial	Mole of N eq.	1.44E+05	1.52E+05	1.60E+05
Non-cancer human health effects	CTUh	6.35E+00	6.67E+00	7.00E+00
Ozone depletion	kg CFC-11 eq.	9.27E-01	9.74E-01	1.02E+00
Photochemical ozone formation - human health	kg NMVOC eq.	3.28E+04	3.47E+04	3.66E+04
Resource use, energy carriers	MJ	1.16E+08	1.26E+08	1.36E+08
Resource use, mineral and metals	kg Sb eq.	7.55E+03	7.92E+03	8.30E+03
Water scarcity	m³ world equiv.	1.30E+06	1.37E+06	1.44E+06
ReCiPe method (2016) – hierarchical	**Unit**			
Metal Depletion	$	7.24E+05	7.80E+05	8.17E+05

LCIA results for the British scenarios of producing alcohol wipes and nitrile gloves.

Table SI 11 LCIA results for the life cycle of alcohol wipes (70%) and nitrile gloves in the United Kingdom. Table shows results for the 3 different scenarios, based on different faulty percentages in the production process.

Environmental Footprint method (EF 2.0)	**Unit**	**UK scenario 0% faulty rate**	**UK scenario 5% faulty rate [baseline]**	**UK scenario 10% faulty rate**
Acidification terrestrial and freshwater	Mole of H+ eq.	9.95E+04	1.04E+05	1.09E+05
Cancer human health effects	CTUh	2.85E+00	2.99E+00	3.13E+00
Climate Change	kg CO2 eq.	4.27E+07	4.48E+07	4.69E+07
Climate Change (biogenic)	kg CO2 eq.	7.97E+04	8.36E+04	8.76E+04
Climate Change (fossil)	kg CO2 eq.	4.26E+07	4.47E+07	4.68E+07
Ecotoxicity freshwater	CTUe	5.78E+06	6.06E+06	6.35E+06
Eutrophication freshwater	kg P eq.	7.41E+02	7.77E+02	8.13E+02
Eutrophication marine	kg N eq.	1.78E+04	1.87E+04	1.96E+04
Eutrophication terrestrial	Mole of N eq.	2.01E+05	2.11E+05	2.21E+05
Non-cancer human health effects	CTUh	2.90E+00	3.04E+00	3.18E+00
Ozone depletion	kg CFC-11 eq.	1.38E-01	1.45E-01	1.51E-01
Photochemical ozone formation - human health	kg NMVOC eq.	1.62E+05	1.70E+05	1.78E+05
Resource use, energy carriers	MJ	7.93E+08	8.32E+08	8.71E+08
Resource use, mineral and metals	kg Sb eq.	4.35E+00	4.57E+00	4.78E+00
Water scarcity	m³ world equiv.	1.23E+07	1.29E+07	1.35E+07

LCIA results for the European scenarios of producing alcohol wipes and nitrile gloves.

Table SI 12 LCIA results for the life cycle of alcohol wipes (70%) and nitrile gloves in the European continent. Table shows results for the 3 different scenarios, based on different faulty percentages in the production process.

Environmental Footprint method (EF 2.0)	Unit	EU cont. scenario 0% faulty rate	EU cont. scenario 5% faulty rate [baseline]	EU cont. scenario 10% faulty rate
Acidification terrestrial and freshwater	Mole of H+ eq.	7.63E+05	7.99E+05	8.39E+05
Cancer human health effects	CTUh	2.19E+01	2.29E+01	2.41E+01
Climate Change	kg CO2 eq.	3.27E+08	3.43E+08	3.60E+08
Climate Change (fossil)	kg CO2 eq.	6.11E+05	6.40E+05	6.72E+05
Climate Change (biogenic)	kg CO2 eq.	3.26E+08	3.42E+08	3.59E+08
Ecotoxicity freshwater	CTUe	4.43E+07	4.64E+07	4.87E+07
Eutrophication freshwater	kg P eq.	5.67E+03	5.95E+03	6.24E+03
Eutrophication marine	kg N eq.	1.37E+05	1.43E+05	1.50E+05
Eutrophication terrestrial	Mole of N eq.	1.54E+06	1.61E+06	1.69E+06
Non-cancer human health effects	CTUh	2.22E+01	2.33E+01	2.44E+01
Ozone depletion	kg CFC-11 eq.	1.06E+00	1.11E+00	1.16E+00
Photochemical ozone formation - human health	kg NMVOC eq.	1.24E+06	1.30E+06	1.37E+06
Resource use, energy carriers	MJ	6.08E+09	6.37E+09	6.69E+09
Resource use, mineral and metals	kg Sb eq.	3.34E+01	3.50E+01	3.67E+01
Water scarcity	m³ world equiv.	9.44E+07	9.90E+07	1.04E+08

ANNEX VI: hotspot analysis on the LCIA outcomes for antimicrobial keyboard covers (faulty rate 5%- baseline) European continent geographical reference.

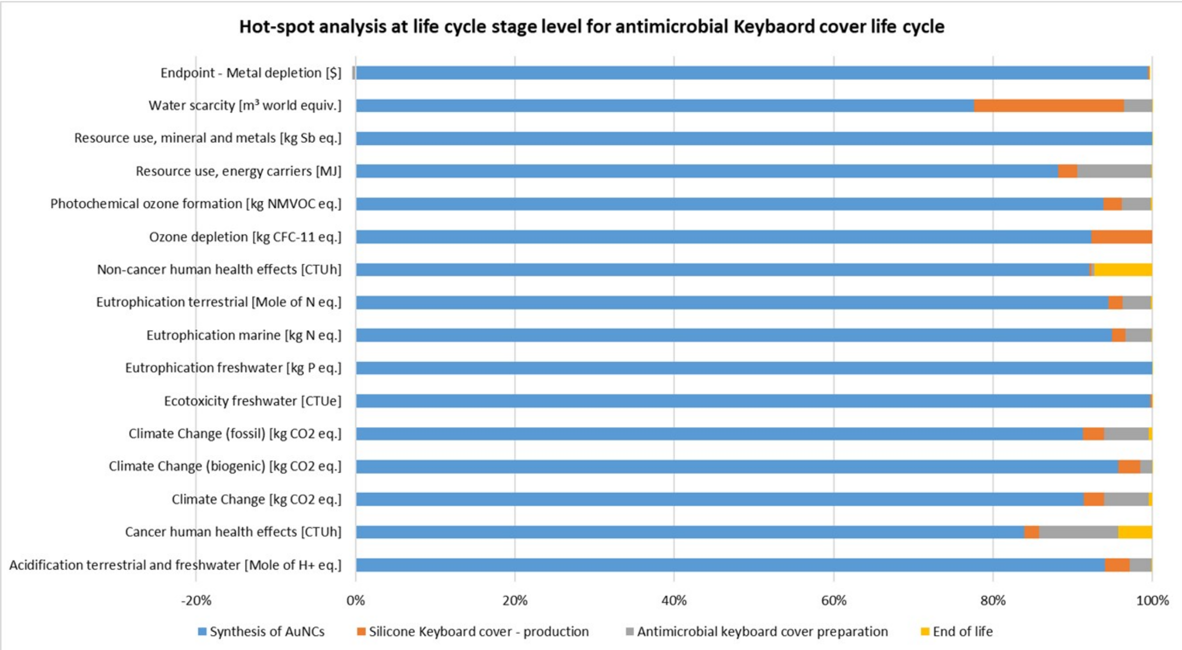


Figure SI 1 *Hot-spot analysis at for the synthesis of gold nanoclusters [$Au_{25}(Cys)_{18}$]. Specifically, for a.k.c. produced to satisfy the demand at European level, with a production faulty of 5%.*

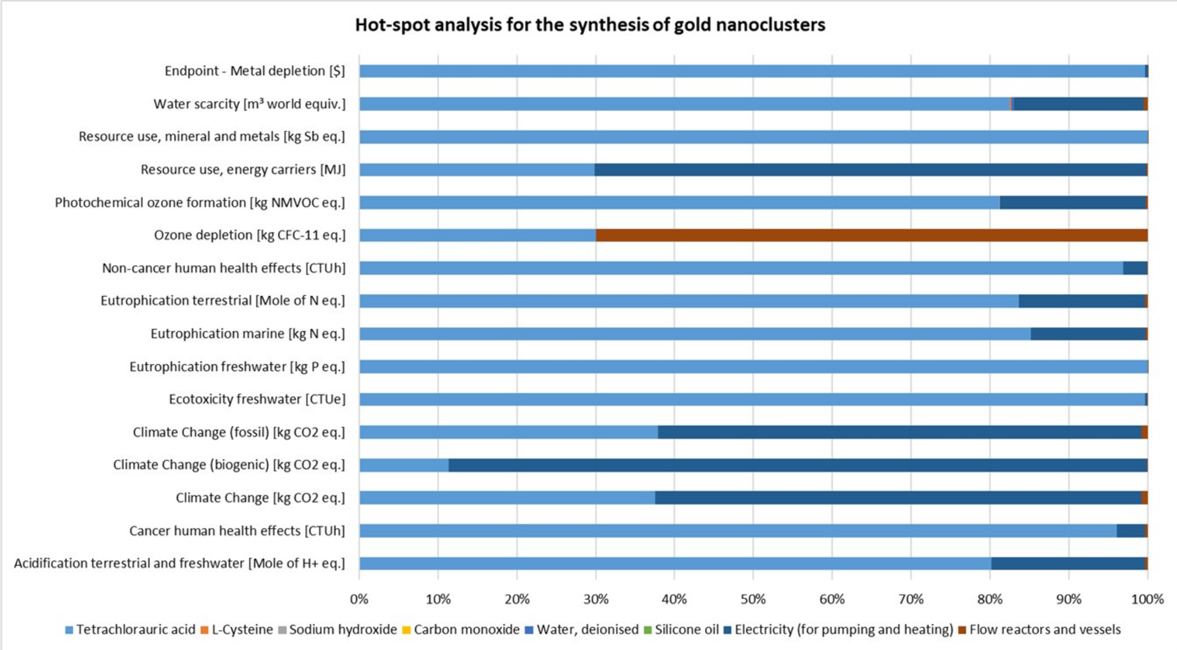


Figure SI 2 Hot-spot analysis at life cycle stage level for antimicrobial keyboard covers. Specifically, for a.k.c. produced to satisfy the demand at European level, with a production faulty of 5% (baseline).

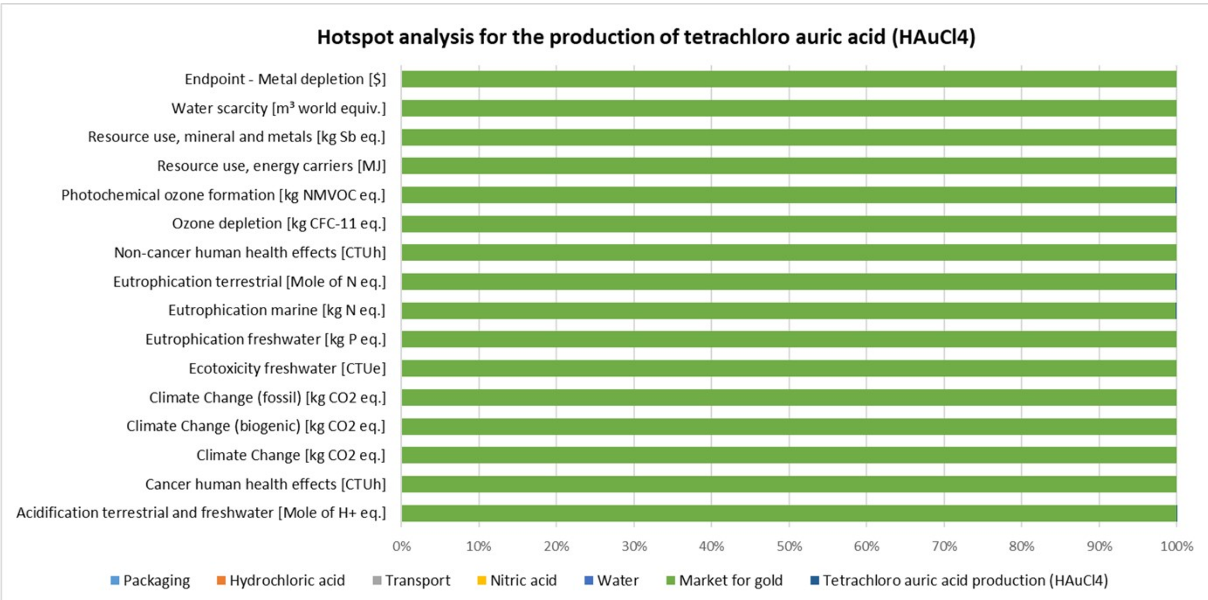


Figure SI 3 Hot-spot analysis at for the production of tetrachloroauric acid used for synthetizing gold nanoclusters, [Au25(Cys)18]. Specifically, for a.k.c. produced to satisfy the demand at European level, with a production faulty of 5% (baseline).

ANNEX VII: sensitivity analysis on the parameter "life-time" of antimicrobial keyboard covers in the UK and in the European scenarios. The life-time has been varied between 6 months and 2 years. Calculation are based on the baseline scenario with a faulty rate of 5%.

Table SI 13 Results of the sensitivity analysis on the variance of the life-time of the antimicrobial keyboard covers in the UK. The baseline model assumes a life-time of 1 year. The length has been varied between 6 months and 2 years.

Environmental Footprint method (EF 2.0)	Unit	UK scenario 6 months life-time	UK scenario 1 year life-time [baseline]	UK scenario 2 years life-time
Acidification terrestrial and freshwater	Mole of H+ eq.	8.96E+03	4.48E+03	2.24E+03
Cancer human health effects	CTUh	2.48E-02	1.24E-02	6.20E-03
Climate Change	kg CO2 eq.	9.08E+05	4.54E+05	2.27E+05
Climate Change (fossil)	kg CO2 eq.	9.00E+05	4.50E+05	2.25E+05
Climate Change (biogenic)	kg CO2 eq.	6.36E+03	3.18E+03	1.59E+03
Ecotoxicity freshwater	CTUe	1.11E+07	5.55E+06	2.78E+06
Eutrophication freshwater	kg P eq.	1.88E+04	9.40E+03	4.70E+03
Eutrophication marine	kg N eq.	3.54E+03	1.77E+03	8.85E+02
Eutrophication terrestrial	Mole of N eq.	3.44E+04	1.72E+04	8.60E+03
Non-cancer human health effects	CTUh	1.70E+00	8.51E-01	4.26E-01
Ozone depletion	kg CFC-11 eq.	2.54E-01	1.27E-01	6.35E-02
Photochemical ozone formation - human health	kg NMVOC eq.	7.70E+03	3.85E+03	1.93E+03
Resource use, energy carriers	MJ	1.53E+07	7.65E+06	3.83E+06
Resource use, mineral and metals	kg Sb eq.	2.06E+03	1.03E+03	5.15E+02
Water scarcity	m³ world equiv.	3.18E+05	1.59E+05	7.95E+04

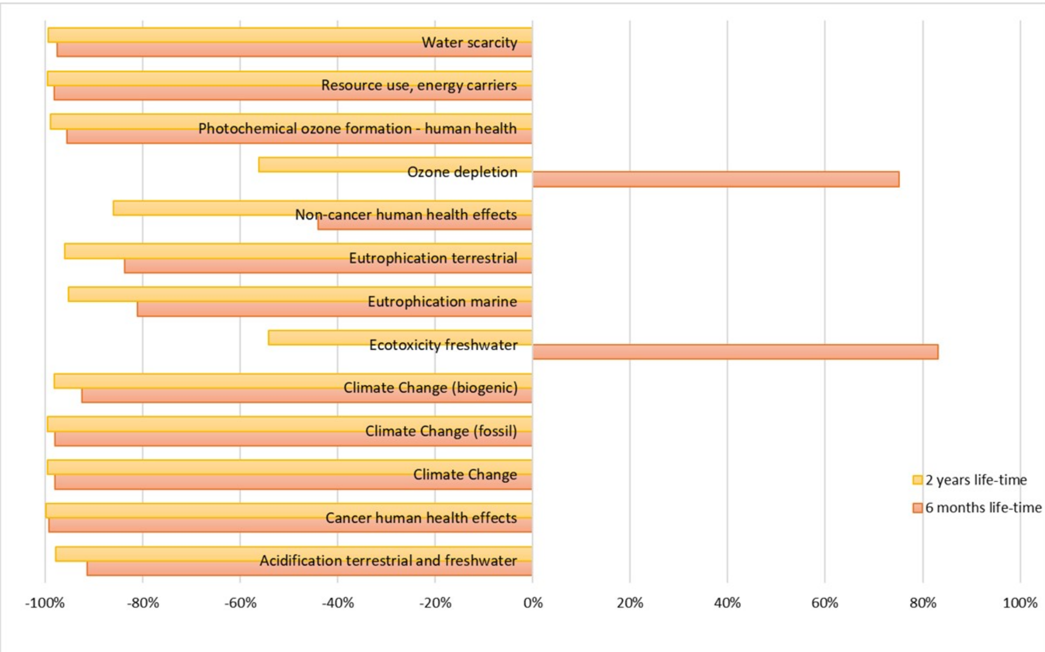


Figure SI 4 Relative changes between the alcohol wipes and gloves system and the akcs when the life-time varies. Production in the United Kingdom. The relative changes of eutrophication freshwater and resource use, mineral and metals impact categories have not been displayed due to their very high value, that would have made difficult reading the graph.

Table SI 14 Results of the sensitivity analysis on the variance of the life-time of the antimicrobial keyboard covers in Europe. The baseline model assumes a life-time of 1 year. The length has been varied between 6 months and 2 years.

Environmental Footprint method (EF 2.0)	**Unit**	**EU cont. 6 months life-time scenario**	**EU cont. 1 year life-time scenario [baseline]**	**EU cont. 2 years life-time scenario**
Acidification terrestrial and freshwater	Mole of H+ eq.	8.16E+04	4.08E+04	2.04E+04
Cancer human health effects	CTUh	1.95E-01	9.74E-02	4.87E-02
Climate Change	kg CO2 eq.	1.36E+07	6.80E+06	3.40E+06
Climate Change (fossil)	kg CO2 eq.	1.34E+07	6.71E+06	3.36E+06
Climate Change (biogenic)	kg CO2 eq.	1.84E+05	9.22E+04	4.61E+04
Ecotoxicity freshwater	CTUe	8.52E+07	4.26E+07	2.13E+07
Eutrophication freshwater	kg P eq.	1.44E+05	7.20E+04	3.60E+04
Eutrophication marine	kg N eq.	3.08E+04	1.54E+04	7.70E+03
Eutrophication terrestrial	Mole of N eq.	3.04E+05	1.52E+05	7.60E+04
Non-cancer human health effects	CTUh	1.33E+01	6.67E+00	3.34E+00
Ozone depletion	kg CFC-11 eq.	1.95E+00	9.74E-01	4.87E-01
Photochemical ozone formation - human health	kg NMVOC eq.	6.94E+04	3.47E+04	1.74E+04
Resource use, energy carriers	MJ	2.52E+08	1.26E+08	6.30E+07
Resource use, mineral and metals	kg Sb eq.	1.58E+04	7.92E+03	3.96E+03
Water scarcity	m³ world equiv.	2.74E+06	1.37E+06	6.85E+05

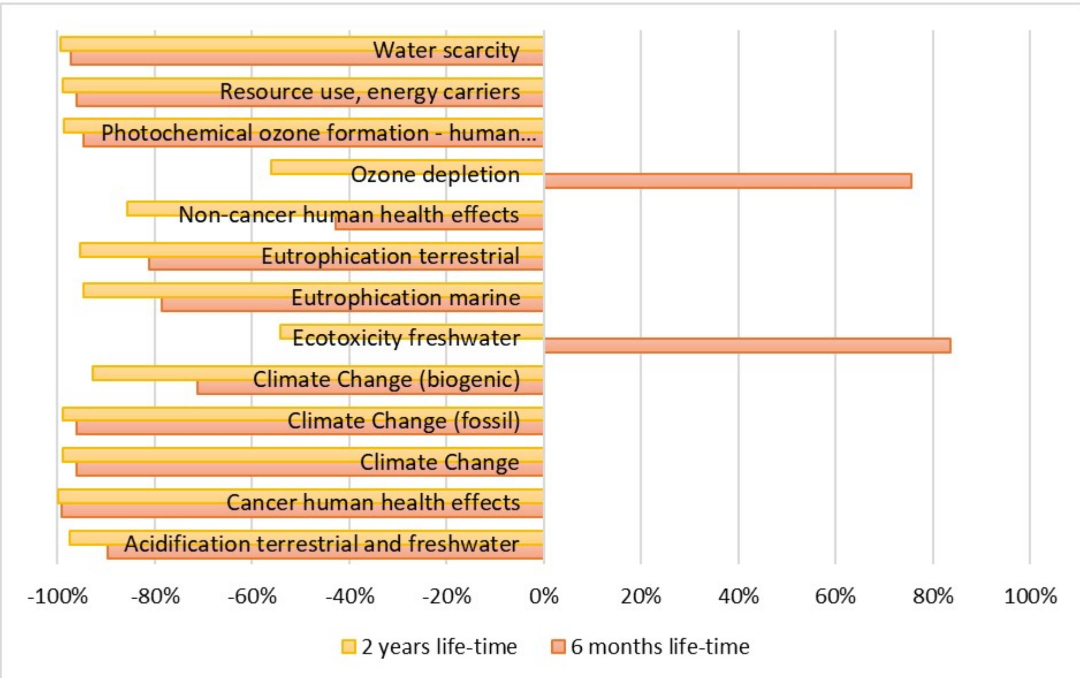
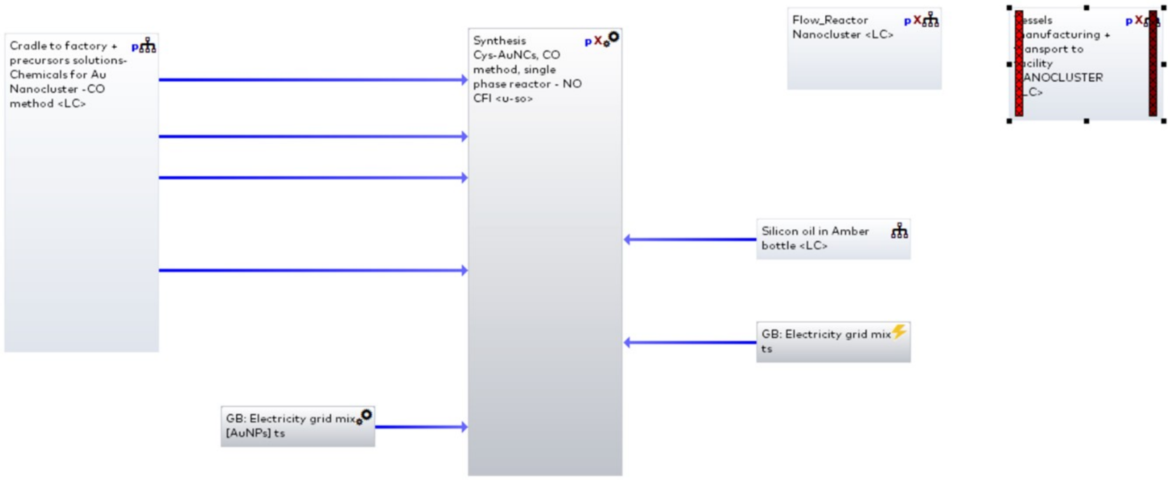


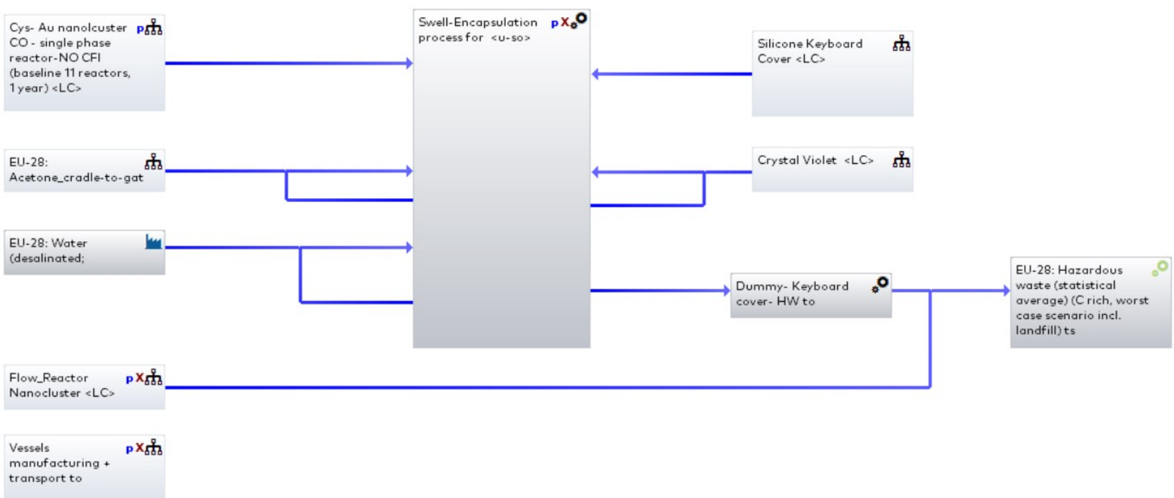
Figure SI 5 Relative changes between the alcohol wipes and gloves system and the akcs when the life-time varies. Production in the European continent. The relative changes of eutrophication freshwater and resource use, mineral and metals impact categories have not been included in the graphs, due to their very high value, that would have made difficult reading the graph.

ANNEX VIII: LCA models on antimicrobial keyboard cover system and alcohol wipes and nitrile gloves.

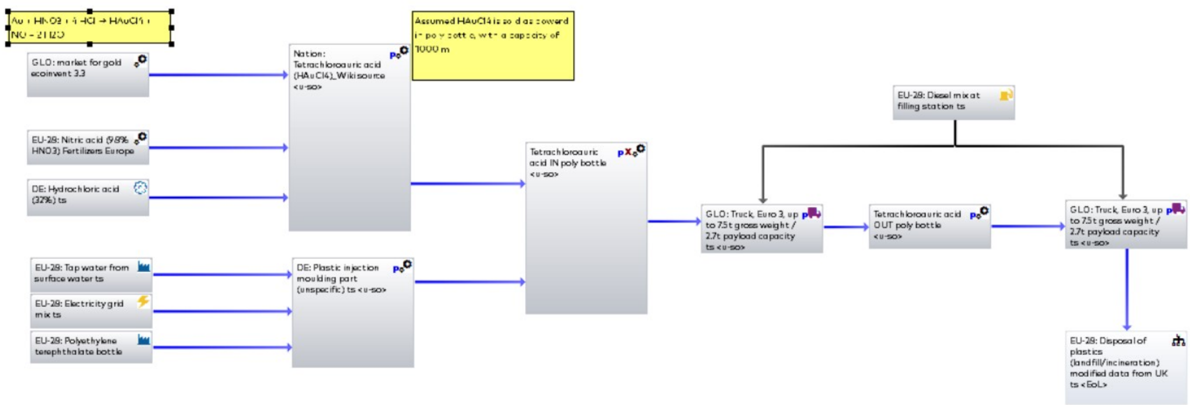
ANTIMICROBIAL KEYBOARD COVERS SYSTEM.
Main plan: antimicrobial keyboard covers



Gold nanoclusters

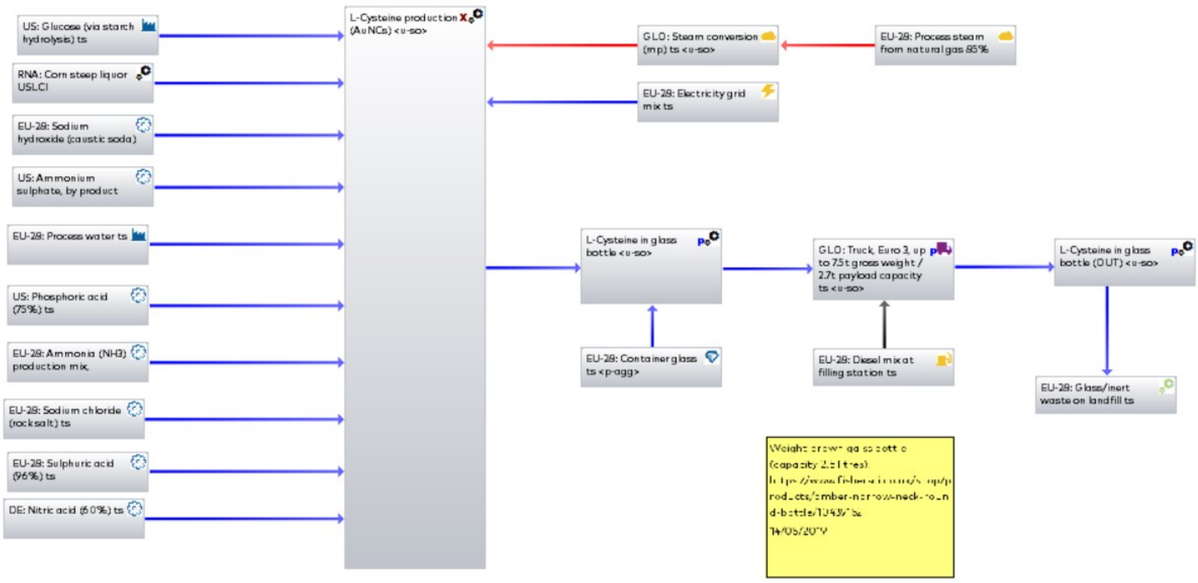


Cradle to factory: gold precursor

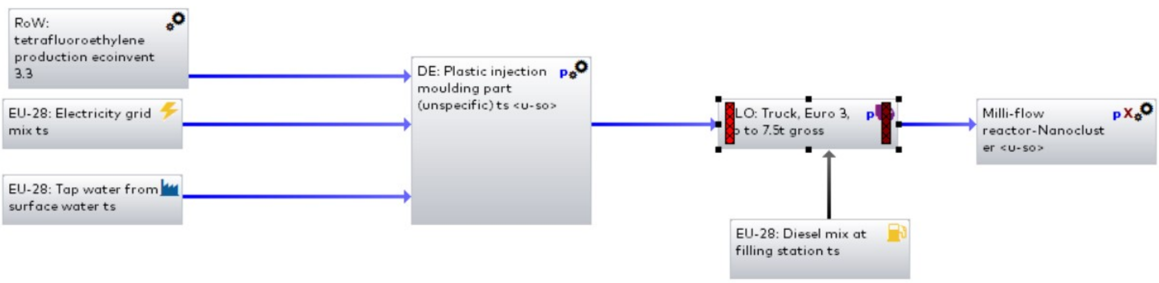


Sodium hydroxide

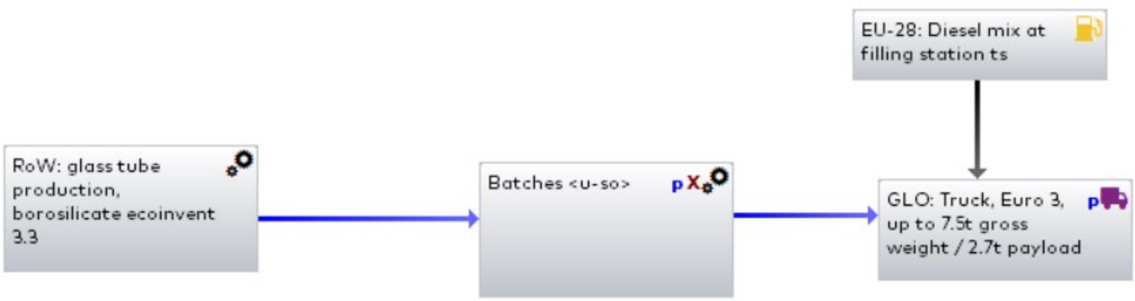
Cysteine production – proxy



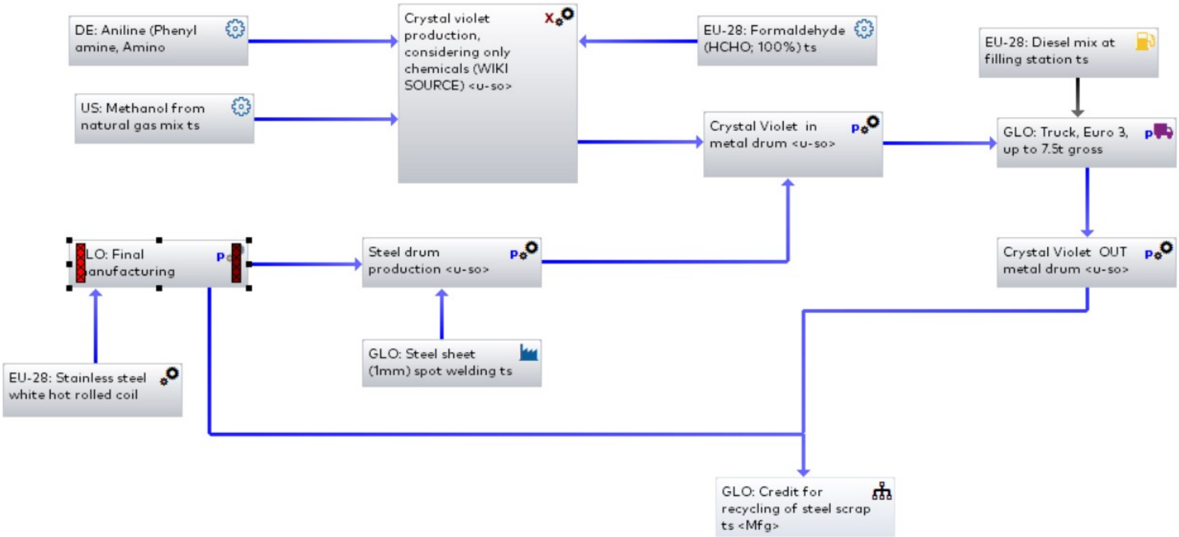
Flow reactors- tubing



Glass vessels

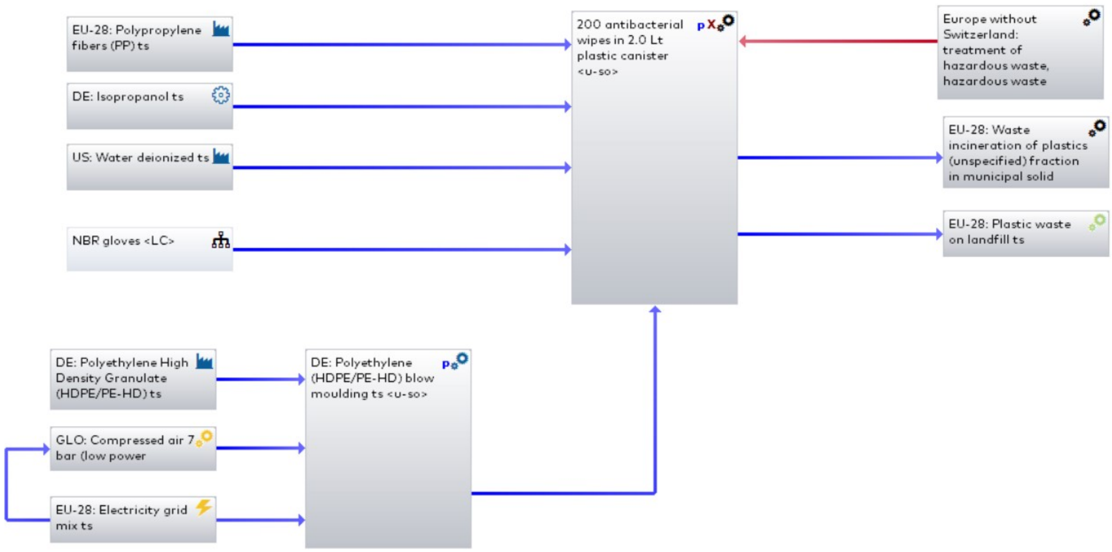


Crystal violet production



ALCOHOL WIPES AND NITRILE GLOVES.

Alcohol wipes (70%) in a 2 litres canister.



Nitrile gloves.

BIBLIOGRAPHY:

(1) Hwang, G. B.; Huang, H.; Wu, G.; Shin, J.; Kafizas, A.; Karu, K.; Toit, H. Du; Alotaibi, A. M.; Mohammad-Hadi, L.; Allan, E.; MacRobert, A. J.; Gavriilidis, A.; Parkin, I. P. Photobactericidal Activity Activated by Thiolated Gold Nanoclusters at Low Flux Levels of White Light. *Nat. Commun.* **2020**, *11* (1), 4–13. https://doi.org/10.1038/s41467-020-15004-6.

(2) Fazio, S.; Castellani, V.; Sala, S.; Schau, E.; Secchi, M.; Zampori, L.; Diaconu E. *JRC Technical Reports. Supporting Information to the Characterisation Factors of Recommended EF Life Cycle Impact Assessment Method. New Models and Differences with ILCD Contents*; 2018. https://doi.org/10.2760/671368.

(3) Seppälä, J.; Posch, M.; Johansson, M.; Hettelingh, J. P. Country-Dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator. *Int. J. Life Cycle Assess.* **2006**, *11* (6), 403–416. https://doi.org/10.1065/lca2005.06.215.

(4) Posch, M.; Seppälä, J.; Hettelingh, J. P.; Johansson, M.; Margni, M.; Jolliet, O. The Role of Atmospheric Dispersion Models and Ecosystem Sensitivity in the Determination of Characterisation Factors for Acidifying and Eutrophying Emissions in LCIA. *Int. J. Life Cycle Assess.* **2008**, *13* (6), 477–486. https://doi.org/10.1007/s11367-008-0025-9.

(5) Rosenbaum, R. K.; Bachmann, T. M.; Gold, L. S.; Huijbregts, M. A. J.; Jolliet, O.; Juraske, R.; Koehler, A.; Larsen, H. F.; MacLeod, M.; Margni, M.; McKone, T. E.; Payet, J.; Schuhmacher, M.; Van De Meent, D.; Hauschild, M. Z. USEtox - The UNEP-SETAC Toxicity Model: Recommended Characterisation Factors for Human Toxicity and Freshwater Ecotoxicity in Life Cycle Impact Assessment. *Int. J. Life Cycle Assess.* **2008**, *13* (7), 532–546. https://doi.org/10.1007/s11367-008-0038-4.

(6) IPCC. *Climate Change 2007 - The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the IPCC.*; 2007. https://doi.org/10.1260/095830507781076194.

(7) Struijs, J.; van Wijnen, H. J.; van Dijk, A.; Huijbregts, M. A. J. Ozone Layer Depletion. In *ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoing and the endpoint level*; Goedkoop, M., Heijungs, R., Huijbregts, M. A. J., De Schryver, A., Struijs, J., Van Zelm, R., Eds.; 2009.

(8) WMO. *Scientific Assessment of Ozone Depletion: 1998. Global Ozone Research and Monitoring Project*; Geneva, 1999.

(9) van Zelm, R.; Huijbregts, M. A. J.; den Hollander, H. A.; van Jaarsveld, H. A.; Sauter, F. J.; Struijs, J.; van Wijnen, H. J.; van de Meent, D. European Characterization Factors for Human Health Damage of PM10 and Ozone in Life Cycle Impact Assessment. *Atmos. Environ.* **2008**, *42* (3), 441–453. https://doi.org/10.1016/j.atmosenv.2007.09.072.

(10) Guinée, J. B.; Gorrée, M.; Heijungs, R.; Huppes, G.; Kleijn, R.; de Koning, A.; van Oers, L. F. C. M.; Sleeswijk, A. W.; Suh, S.; Udo de Haes, H. A.; de Brujin, H.; van Duin, R.; Huijbregts, M. A. J. *Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards.*; Kluwer Academic Publishers: Dordrecht, 2002.

(11) Poh, G. K. X.; Chew, I. M. L.; Tan, J. Life Cycle Optimization for Synthetic Rubber Glove Manufacturing. *Chem. Eng. Technol.* **2019**, *42* (9), 1771–1779. https://doi.org/10.1002/ceat.201800476.