Electronic Supplementary Material (ESI) for Energy & Environmental Science.

Supplementary Information

Outdoor fate and environmental impact of polymer solar cells through leaching and emission to rainwater and soil

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Table S1. Characterisation of soil taken from DTU, Risø campus, Denmark.

Parameter	Unit	Value
Moisture content	[%]	14.0
pH	[-]	5.7
Organic carbon content	[%]	3.0
$CaCO_3$content	[%]	11
Electric conductivity	[$\mu S\ cm^{-1}$]	10.0
C/N-ratio	[-]	17
Total Li	[$mg\ kg^{-1}$]	2.4 ± 0.2
Total Na	[$mg\ kg^{-1}$]	55.2 ± 54.7
Total Mg	[$mg\ kg^{-1}$]	1083.3 ± 51.4
Total Al	[$mg\ kg^{-1}$]	2591.0 ± 116.1
Total K	[$mg\ kg^{-1}$]	546.3 ± 31.8
Total Ca	[$mg\ kg^{-1}$]	5718.2 ± 825.3
Total Ti	[$mg\ kg^{-1}$]	56.6 ± 7.7
Total Cr	[$mg\ kg^{-1}$]	4.9 ± 0.1
Total Mn	[$mg\ kg^{-1}$]	158.2 ± 2.1
Total Fe	[$mg\ kg^{-1}$]	4277.4 ± 186.9
Total Co	[$mg\ kg^{-1}$]	2.4 ± 0.1
Total Ni	[$mg\ kg^{-1}$]	5.4 ± 0.3
Total Cu	[$mg\ kg^{-1}$]	4.8 ± 0.3
Total Zn	[$mg\ kg^{-1}$]	18.6 ± 0.5
Total Ga	[$mg\ kg^{-1}$]	3.6 ± 0.1
Total As	[$mg\ kg^{-1}$]	2.3 ± 0.1
Total Se	[$mg\ kg^{-1}$]	0.2 ± 0.0
Total Mo	[$mg\ kg^{-1}$]	0.7 ± 0.0
Total Cd	[$mg\ kg^{-1}$]	0.6 ± 0.0
Total Ag	[$mg\ kg^{-1}$]	< LOD
Total In	[$mg\ kg^{-1}$]	< LOD
Total Sn	[$mg\ kg^{-1}$]	0.4 ± 0.0
Total Sb	[$mg\ kg^{-1}$]	< LOD
Total Pb	[$mg\ kg^{-1}$]	8.0 ± 0.2

Limit of detection (LOD) = 0.15 $mg\ kg^{-1}$.

Table S2. Characterisation results of 1 m^2 of 3 solar cell types leaching metals by rain runoff . ILCD 2011 Midpoint+ V1.05 / EU27 2010, equal weighting.

Impact category	Unit	Ag-damaged leaching	Ag-intact leaching	C-modules leaching	Ag OPV production	C OPV production
Climate change	kg CO_2 eq	0	0	0	0,79	2,32E-01
Ozone depletion	kg CFC-11 eq	0	0	0	5,57E-08	1,48E-08
Human toxicity, cancer effects	CTUh	0	0	0	2,48E-07	1,17E-08
Human toxicity, non-cancer eff.	CTUh	9,52E-07	6,97E-08	1,26E-07	6,39E-06	5,88E-08
Particulate matter	kg PM2.5 eq	0	0	0	8,27E-04	1,18E-04
Ionizing radiation HH	kBq U235 eq	0	0	0	0,11	4,50E-03
Ionizing radiation E (interim)	CTUe	0	0	0	2,85E-07	1,57E-08
Photochem. ozone formation	kg NMVOC eq	0	0	0	6,84 E-03	7,30E-04
Acidification	molc H^+ eq	0	0	0	9,12E-03	1,05E-03
Terrestrial eutrophication	molc N eq	0	0	0	2,95E-02	1,76E-03
Freshwater eutrophication	kg P eq	0	0	0	4,08E-03	7,98E-05
Marine eutrophication	kg N eq	0	0	0	2,49E-03	1,71E-04
Freshwater ecotoxicity	CTUe	47,20	2,24	3,85	155,65	3,30
Land use	kg C deficit	0	0	0	8,72	2,38E-01
Water resource depletion	m^3 water eq	0	0	0	2,57E-03	1,16E-03
Resource depletion	kg Sb eq	0	0	0	4,16E-03	7,35E-06

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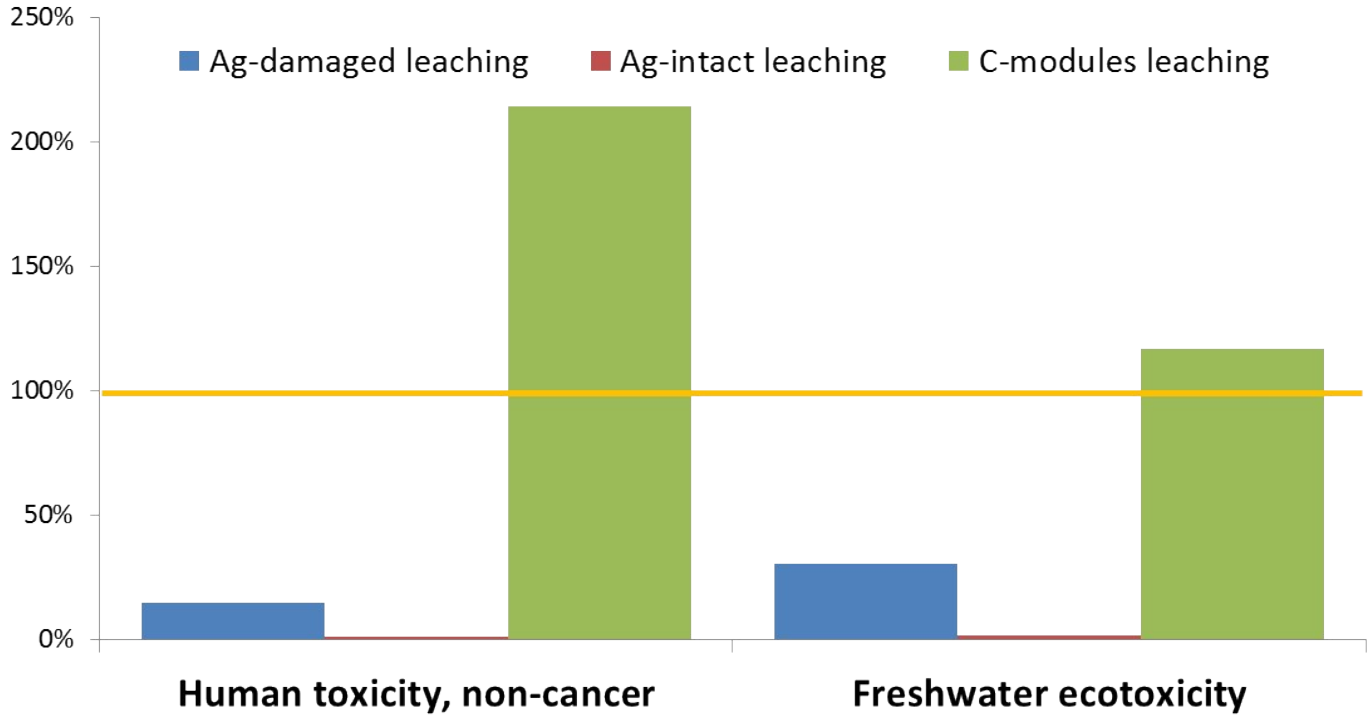

Fig. S1. Contribution to the leaching during the disposal phase and the manufacturing stage of the polymer solar cells. The baseline represents the manufacturing of the solar cells (both Ag- and C- based). For the Ag-OPV the impact that the disposal stage causes is relatively small in relation to the manufacturing impact For the C-OPV the opposite is observed. This is due to the fact that the overall manufacturing of the C-OPV has a comparatively lower impact than Ag-OPV, since it does not make use of scarce metals (it does not contain silver) and its energy demand is lower. The relative potential impact of the leached Zn versus disposal is therefore several times higher in comparison to the manufacturing.

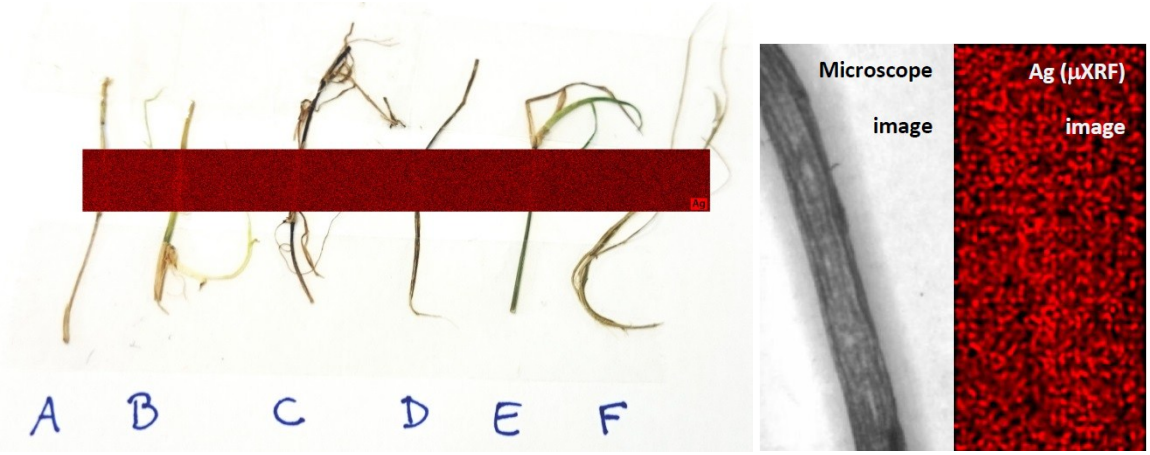

Figure S2. Left: Photographs of plant stems grown in the soil columns. Right: Microscope image of a root from the soil column A and the corresponding μXRF image with detection of Ag. There is marginal uptake of silver in the plant.