

Tracking the fate of contaminants from solar panels using stable isotopes



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INTRODUCTION

Crystalline silicon (c-Si) solar panels (SPs) are the most widely used type of photovoltaic technology, accounting for ~90% of the total market share. Regarding the potential toxicity of SPs, researchers emphasize the significant role of damage and/or aging of this e-waste in the overall rate of contaminant release. Increased mobilization of Pb, Cd, Ag, Cu, Ni, Zn etc. from different types of SPs has been documented under simulated water-based/environmental conditions. To date, there is no systematic study that would provide data on stable metal(loid) isotopes, Ag, Sb and Cu (Table 1), in any e-waste from SPs and their subsequent behavior in the environment, soil (Fig. 1).

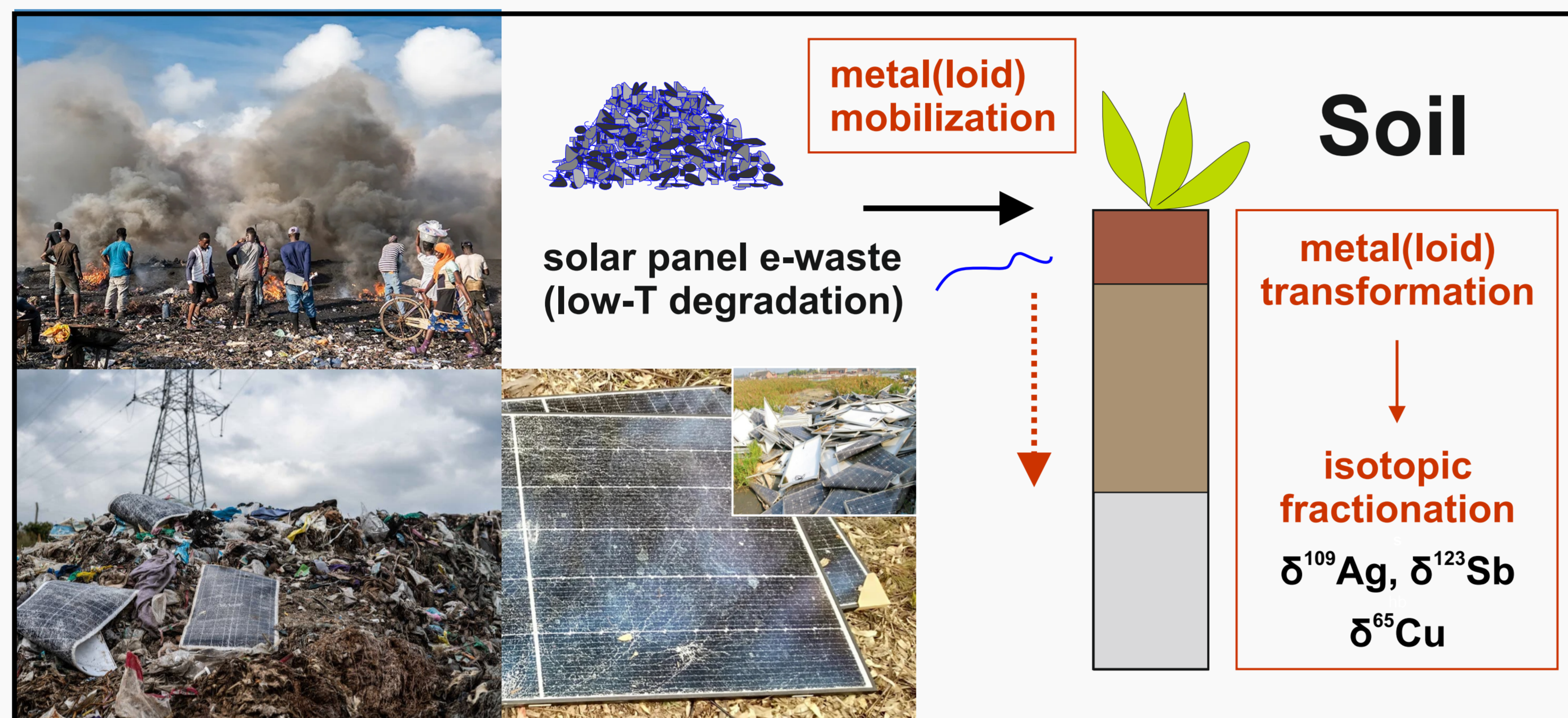


Fig. 1. A simplified scheme of solar panel e-waste degradation during low-T alteration processes in soils, resulting in the release, migration, accumulation and transformation of trace metal(loid)s (Ag, Sb and Cu) and associated isotopic fractionation, i.e., at e-waste disposal sites, or natural sites - soils.

Table 1. List of isotope systems emphasized in this research.

Element		Priority pollutant	CRM	Isotopes (abundance, %)	Typical notation
Silver	Ag	+++	+++ (U.S.)	¹⁰⁷ Ag (51.84) ¹⁰⁹ Ag (48.16)	$\epsilon^{109}\text{Ag}$ or $\delta^{109}\text{Ag}$
Antimony	Sb	+++	+++ (EU)	¹²¹ Sb (57.21) ¹²³ Sb (42.79)	$\epsilon^{123}\text{Sb}$ or $\delta^{123}\text{Sb}$
Copper	Cu	+++	+++ (EU)	⁶³ Cu (69.17) ⁶⁵ Cu (30.83)	$\delta^{65}\text{Cu}$

Priority pollutant list (USEPA, 2014).
Report on Critical Raw Materials (CRM) and the Circular Economy (EU, 2018, 2023), EC's Raw Material Information System <http://rmis.jrc.ec.europa.eu>

PRELIMINARY DATA

First data from different (operationally-defined) samples of SPs, including pc/mc-Si cells, show an apparent variability in both Ag concentrations and Ag isotopic composition (Fig. 2).

The identified $\delta^{109}\text{Ag}$ values, which are in the range of +0.03 and +0.11 (± 0.02 , 2SD) (Fig. 2), suggest both the isotopically lighter Ag fraction present in the SPs (protective) glass as well as different source origins of Ag in the mc- and pc-Si cell samples.

As for the environmental systems, redox reactions are generally considered the key factor influencing metal(loid) isotopic fractionation.

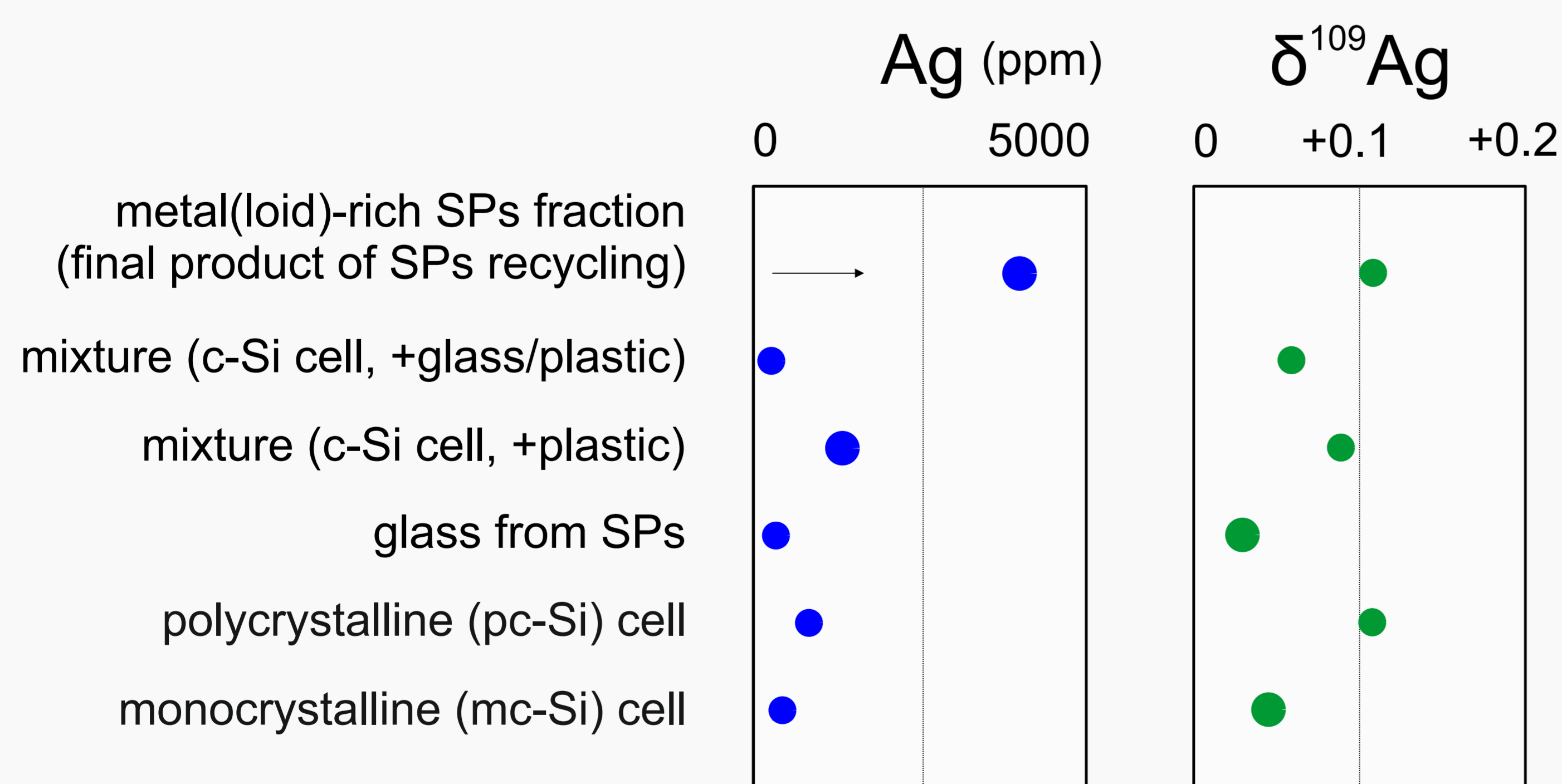


Fig. 2. Distribution of Ag and Ag isotopic ratios (with $\delta^{109}\text{Ag}$ notation; ‰) in different (operationally defined) samples of SPs and pc/mc-Si cells. The individual materials were obtained from the Solar Panel Recycling Division of DEKONTA Inc. (CZ); <https://www.dekonta.cz/en/>.

FUTURE?

The first stage of this research involves determining the isotopic composition of Ag, Sb, and Cu in various SPs types and their subcomponents. Then, model (bag/field) incubation experiments with SPs in contrasting soil types are planned.

The following three hypotheses are to be tested ---

- (A) Changes in the isotopic signatures of Ag, Sb, and Cu reflect redox-driven leaching.
- (B) Silver and Cu isotopes serve as indicators of specific sorption to soil constituents, e.g. oxides.
- (C) Linking Ag, Sb, and Cu concentration and isotope data in a model soil system identifies soil sub-processes following SPs degradation and the origin of contaminant sources (anthropogenic vs. geogenic).



References:
USEPA, 2014. Toxicity and Priority Pollutants under the Clean Water Act. Available from: <https://www.epa.gov/eg/toxic-and-priority-pollutants-under-clean-water-act#toxic>
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