Could CdTe PV Modules Pollute the Environment?

Vasilis M. Fthenakis

National Photovoltaic Environmental Health and Safety Assistance Center

Brookhaven National Laboratory

Upton, NY 11973

SUMMARY

As CdTe PV modules reached commercialization, vocal opposition emerged based on concerns about potential emissions of cadmium from them. In this short article I discuss the pertinent technical issues and conclude that CdTe PV modules do not present any risks to health and the environment during their use, and recycling the modules at the end of their useful life completely resolves any environmental issues.

1.INTRODUCTION

The PV community well understands that the future of solar cells rests upon preserving an environmentally friendly industry, in addition to lowering the cost of manufacturing these cells. The US DOE is supporting research at Brookhaven National Laboratory to identify the potential EH&S hazards of new technologies, processes, and materials before their large-scale commercialization. In deference to these concerns, EH&S issues related to CdTe module life-of cycle have been extensively studied[1-4]. Lately, questions have been raised about the potential of CdTe modules to pollute the environment during their use and during decommissioning. Alsema (1996) estimated the potential for accidental damage of CdTe and CIS modules, corresponding to specific accident and release scenarios[5]. His estimates apparently were taken out of context and the CdTe technology is being attacked as inevitably polluting the environment, as illustrated by Greenpeace's comment to the California Power Authority. *"Greenpeace is deeply concerned with the possibility of the CPA choosing to purchase solar modules that contain toxic metals…Current CdTe panels contain approximately 6 g/m^2, resulting in cadmium emissions of 0.5g/GWh, equivalent to that of a coal fired power plant[5]. The majority of these emissions (77%) result from mining and utilization of the modules, therefore a comprehensive collection and recycling program would not reduce the environmental impacts of these panels. Greenpeace believes that the CPA's commitment to sustainability would be compromised if you were to purchase CdTe panels. The state should not spend taxpayer money on technologies that will ultimately end up polluting the environment. There are many solar PV technologies that have fewer adverse effects on the environment that will satisfy the needs of the California Power Authority's request for bids."*

Three technical issues are raised in this comment: (a) The physical and toxicological properties of CdTe; (b) the possibility of CdTe releases from PV modules; and, (c) comparisons with other technologies and products.

2. PROPERTIES OF CdTe

Although elemental cadmium, the parent compound of CdTe, is a lung carcinogen and has long-term detrimental effects on kidney and bone, CdTe is more stable and less soluble. The limited toxicological data on CdTe suggest that CdTe is more toxic than the PV compounds CIS and CGS, but comparisons have not been made to the parent compound[6]. OSHA considers all cadmium compounds to be toxic, and, as a general guidance, all facilities working with any such compounds should control the indoors concentrations of CdTe dust or fumes to below the Permissible Exposure Level-Time Weighted Average (PEL-TWA) concentration of 0.005 mg/m^3. The Immediately Dangerous to Life or Health (IDLH) concentration for all cadmium compounds is 9 mg/m^3. The IDLH is defined by NIOSH as "…the maximum concentration from which one could escape within 30 minutes without any escape-impairing symptoms or any irreversible health effects."

Manufacturing CdTe solar cells can cause occupational health risks because cadmium compounds are used in powder and liquid forms that can be accidentally dispersed.[1-4] However, the US industry is vigilant in preventing health risks, and has established proactive programs in industrial hygiene and environmental control.[7] Workers' exposure to cadmium in PV manufacturing facilities is controlled by rigorous industrial hygiene practices, and is continuously monitored by medical tests, thus preventing health risks.

3. THE POSSIBILITY OF CdTe RELEASES FROM PV MODULES

Toxic compounds cannot cause any adverse health effects unless they enter the human body in harmful doses. The only pathways by which people might be exposed to PV compounds from a finished module are by accidentally ingesting flakes or dust particles, or inhaling dust and fumes. The thin CdTe/CdS layers are stable and solid, and are encapsulated between thick layers of glass or plastic. Unless the module is ground to a fine dust, dust particles cannot be generated. The vapor pressure of CdTe at ambient conditions is zero. Therefore, it is impossible for any vapors or dust to be generated when using PV modules.

Alsema (1996) referred to potential exposure to Cd vapors via inhalation if the modules are consumed in residential fires and people breath the smoke from the fire.[5] However, common US residential fires are not hot enough to vaporize CdTe; flame temperatures in roof fires are in the 800-900 ^oC range, and, in basement rooms, in the 900-1000 ^oC range[8]. The melting point of CdTe is 1041 ^oC, and evaporation starts at 1050 ^oC. The melting point of CdS is 1750 ^oC. Studies at Brookhaven[9] and at the GSF Institute of Chemical Ecology in Germany[10], showed that CdTe releases are unlikely to occur during residential fires or during accidental breakage[11]. The potential for CdTe emissions may

exist only in large externally fed industrial fires. In any case, the fire itself probably would pose a much greater hazard than any potential Cd emissions.[12]

Mining cadmium could endanger the health of workers, but only if appropriate safeguards are not in place. However, since cadmium is a byproduct of zinc mining, the levels of zinc production set the levels of Cd production. One could argue that CdTe helps in fixing Cd that is generated anyway as a byproduct of zinc mining.

4. COMPARISONS WITH OTHER TECHNOLOGIES AND PRODUCTS

Alsema (1996)[5] lists potential Cd emissions from fires and from incinerating PV modules. As discussed , the first are improbable in residential systems. The second can occur only if CdTe modules end in waste-incineration streams. Such emissions from accidental operations should not be compared with routine emissions from other technologies. The operation of CdTe PV does not generate any Cd emissions. Every PV generation, regardless of technology, is a zero-emissions process. Thin-film α-Si, CdTe and CIGS solar cells are durable and do not produce any emissions during extreme conditions of accelerated aging with low earth-orbit radiation and thermal cycles from +80 ^{o}C to -80 ^{o}C.[13]

In contrast, coal burning, steel production, fertilizer production/ use, and zinc coatings all routinely generate Cd during operation. Under the best/optimized operational and maintenance conditions, burning coal for electricity releases into the air a minimum of 2 g of Cd/GWh (assuming well-maintained electrostatic precipitators or bag-houses operating at 98.6% efficiency, and median concentration of Cd in US coal of 0.5 ppm).[14] In addition, 140 g/GWh of Cd inevitably collects as fine dust in boilers, bag-houses, and ESPs, thereby posing occupational health- and environmental- hazards. Furthermore, a typical US coal-power plant emits per GWh about 1000 tons of CO_2, 8 tons of SO_2, 3 tons of NOx, and 0.4 tons particulates.

The only issue of some real concern is the disposal of the well-encapsulated, relatively immobile CdTe at the end of the modules' useful life. Today's CdTe PV end-of-life or broken modules pass Federal (TCLP-RCRA) leaching criteria for non-hazardous waste. Therefore, according to current laws, such modules could be disposed of in landfills. However, recycling PV modules offers an important advantage and I believe that the industry should consider it carefully as they move towards large and cost-effective production. This issue of recycling is not unique to CdTe. The disposal of current x-Si modules, most of which incorporate Pb-based solder, presents similar concerns.[15]

The amount of Cd in CdTe solar cells is very small, and could be reduced even further as the cells become thinner; a NiCd flashlight battery has more Cd (7g) than a square meter of today's CdTe PV module. About 20,000 tons of Cd are used worldwide each year, about half for Ni/Cd batteries. About 2,000 tons of Cd is thrown away each year in the form of used toy batteries. Using this quantity of Cd in CdTe photovoltaics would produce 35 GW of PV per year.

CdTe is less soluble and possibly less toxic than its parent compound. CdTe modules are very well sealed and Cd cannot be released during normal operation, or even during fires in residential roofs. Using Cd in CdTe PV modules effectively isolates and sequesters this compound, instead of throwing it away as is currently the case.

If a collection and recycling program were established, all health concerns about CdTe and other end-of-life photovoltaic modules would be resolved fully. The technical feasibility of recycling CdTe modules has been proven by Solar Cells Inc.[16] (currently First Solar Inc.), Drinkard Metalox Inc. and others, in research funded by DOE. Recycling can be done at an estimated cost of 0.10 to 0.12 $/W for dispersed installations, and 0.04-0.05 $/W for large installations.[17]

5. CONCLUSION

It was shown that Cd compounds can not be emitted from CdTe PV modules during normal operation or during foreseeable accidents in residential installations. Emissions to the environment could occur only after decommissioning, if such modules inadvertently ended up in municipal waste-incinerators. Comparisons of potential Cd emissions from CdTe modules with those from coal-fired power plants are erroneous; the former are impossible during normal use, whereas the latter happen routinely during normal operation. Large-scale implementation of CdTe PV modules do not present any risks to health and the environment, and recycling the modules at the end of their useful life completely resolves any environmental concerns. During a useful life of 20-30 years, these modules do not produce any pollutants or noise, and, furthermore, by displacing fossil fuels, they offer great environmental benefits.

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