

Concept Note/ Blue Print on Management of Antimony Containing Glass from End-of-Life of the Solar PV Panels

1. Background

An application OA No. 473 of 2017, Niharika Vs Union of India and Others was filed before Hon'ble NGT regarding use of Antimony containing glasses used in solar Photo Voltaic panels and the possible environmental risks or consequences at the end of life of such solar panels.

Central Pollution Control Board (CPCB) has filed a report on 'Release of Antimony from Solar Panels and the options for disposal of Antimony containing solar panels' prepared by NGT constituted Expert Members comprising of Professor V. A. Juvekar, IIT Bombay, Dr. Rajesh Kumar, Senior Director, MNRE and Shri B. Vinod Babu, Scientist-E, CPCB. However, realizing the fact that there is no policy or Rules on management of Antimony containing glass used in solar panels, Hon'ble NGT in its order dated 04/01/2019 directed that MoEF &CC, MNRE and CPCB to specify minimum time that may be required for preparation of a policy or Rules for management of Antimony containing solar glass panels. In its order dated 27/03/2018 the Hon'ble NGT directed MNRE to complete the exercise of preparation of blue print within a period of three weeks from the date of issue of the order dated 27/02/2019. Whereas MOEF&CC was directed to complete the exercise of preparing and declaring a policy within three weeks after receipt of the blue print from MNRE and the original application No.473 of 2017 was disposed.

2. Antimony Containing Solar PV Panels

Antimony is used in solar panel glass to improve stability of the solar performance of the glass upon exposure to ultraviolet radiation and/or sunlight. The combination of low iron content, Antimony and/or patterning results in glass substrate with high visible transmission and excellent light refracting characteristics (Ref. US Patent US8802216B2 dated 12/8/2014). Antimony Containing Solar Panel Glass (ACSPG) is being used worldwide. Glass in solar panel constitutes about 70 % of the weight of solar panel.

The number of PV installations is predicted to increase continuously all over the world. Major installations of solar panels in India have taken place since last 5-6 years, and these currently installed solar panels will become waste over the next 15-20 years. The glass in

the PV panel after end of its life is reusable/ recyclable

Improper treatment or disposal of PV waste may result in the loss of this reusable resource/ recyclable material. The estimated waste production factor is about 75 MT of waste for every 1 MW of solar PV installed capacity. Solar panels with Antimony containing glass (SPACG) would leach Antimony from the glass when the waste panels after its end of life are exposed to wet conditions. Such conditions may occur, when waste glass from end-of-life solar panels is disposed on land through unsecured manner.

Recycling of PV modules is technologically and economically feasible; however, limitation in recycling may arise when there is limited quantity of PV waste for recycling. Countries like Germany have developed PV recycling technology and Antimony containing glass may be recycled without affecting its properties. The recycling process of 1 ton of PV panel is likely to produce 686 Kg. of clean glass and 14 Kg of contaminated glass. The recycled glass can be used to produce new SPACG

However, in case there are no facilities to recycle, the option of disposal in secured landfills or safe storage till development of such facility needs to be considered.

Two samples of Antimony containing glass from used solar panels were studied by CPCB for Antimony concentration. The analysis of which indicate that the concentration of Antimony in textured glass in the range of 0.13 and 0.29 %, respectively. The results are presented in Table below:

Table-1: Concentration of Antimony in textured glass

Sl No.	Source of Antimony containing solar panel	Concentration of Antimony	Estimated Concentration of Antimony Trioxide (ATO)
1.	Textured Glass of a solar panel procured from China	2967 mg/Kg (0.29 %)	4037 (0.4%)
2.	Textured Glass of a solar panel procured from M/s Borosil, India	1290 mg/Kg (0.13%)	1754 (0.17%)

CPCB also conducted Soluble Threshold Limit Concentration (STLC) test on Antimony containing glass following method as stipulated under HOWM Rules, 2016. The leached liquor was tested for concentration of Antimony so as to compare with standards stipulated under HOWM Rules, 2016 to categorize the waste as hazardous. The findings are given in Table below:

Table-2: CPCB findings on STLC test on Antimony containing glass

	Type of Textured Glass	Total Concentration of Antimony mg/Kg	STLC value for Antimony in mg/L	Limit for classification as Hazardous Waste
1.	Antimony containing Textured Glass of China origin collected from National Institute of Solar Energy. MNRE	2697	0.21	20
2.	Antimony containing Textured Glass procured from M/s Borosil, India	1290	0.12	20
3	Antimony free Textured Glass procured from M/s Borosil, India	163	BDL	Not Applicable

Results indicates that samples of waste solar panel glass containing Antimony does not fall in the category of hazardous waste as per the concentration limits stipulated for Antimony in Schedule II of Hazardous and Other Waste Management Rules, 2016.

However, waste Antimony glass has potential to leach Antimony in wet conditions including wet landfill conditions. Therefore, the waste Antimony containing glass may be considered as a 'low effect' waste needs to be regulated for environmentally safe handling, recycling or disposal.

3. Antimony free Solar Panels

There are manufacturers which produces Antimony free glass that can be used in production of PV modules. However, the use of the same is not yet significant. As there is no regulation on use of solar panel glass, manufacturers can produce and market both Antimony free as well as Antimony containing solar panel glass.

Even at the end of life the PV panel using Antimony free glass, cannot be disposed on land as it may contain chemical compounds of PV material and the glass is a valuable resource, hence required to be recycled.

4. Impacts of Antimony on Human Health and the Environment

Antimony is a silvery-white metal that is found in the earth's crust. The chemical symbol for Antimony is Sb (atomic weight of 121.75 g/mol) and it is a type of heavy metal. Commercially, most used compound of Antimony is Antimony trioxide Sb_2O_3 (ATO). It is a white powder and slightly soluble in water. The other compound is potassium Antimony tartrate (APT, $K_2Sb_2(C_4H_2O_6)_2$), which was used as an emetic (a medicine that induces nausea and vomiting) during middle ages. Antimony in the form of potassium Antimony tartrate is a toxic compound.

The textured solar glasses used in solar PV modules contain Antimony in the form of Antimony trioxide (ATO). ATO is considered by World Health Organization [WHO 2003] to have very low toxicity due to its low solubility in water and poor bioavailability. After long contact with water, ATO from solar panel glass leaches and undergoes hydrolysis to form Antimony oxo- anion $[Sb(OH)_6^-]$. Antimony is penta-valent in the oxo-anion form, and toxicity is much less compared to trivalent form of Antimony (ATO).

Drinking water standards for Antimony are not yet notified in India. However, WHO has set a permissible limit of Antimony as 5 $\mu\text{g/L}$, expressed as total Antimony in drinking water. WHO limit was derived based on toxicology studies on potassium Antimony tartrate and not based on toxicity of Antimony trioxide (ATO). Therefore, Antimony that may release from solar panel glass even if it exceeds WHO limit of 5 $\mu\text{g/L}$, the corresponding toxicological effects will be less. The limits on the concentration of Antimony in drinking water / groundwater are given in Table below:

Table-3: Limits on the concentration of Antimony in drinking water / groundwater

S. No	Agency	Permissible concentration of Sb, $\mu\text{g/L}$
1	World Health Organization(WHO) (2003)	5
2	US Environmental Protection Agency (1986) and	6

3	Office of Environmental Health Hazard Assessment - California Environmental Protection Agency (2016)	20
4	Groundwater quality standard of Canada, Government of Alberta	6

5. Management of Antimony Containing Solar Panel Glass

India has a target of deployment of 100 GW solar power generation facilities by 2022 which will require massive use of solar panels. It is estimated that 75 MT of PV modules would be needed for 1 MW of solar power, glass constitutes about 70% of the PV panels by weight.

Management of PV module need to follow the cradle-to-grave life cycle assessment in four stages: (1) component production; (2) module manufacturing; (3) module use; (4) end-of – life- use stage. Every stage of life cycle would be important in life cycle of Solar panel glass, the present case addresses management of end of life solar panel modules.

Since, there is no restriction on use of Antimony free glass, it is required to ensure safe handling and disposal of the end of life of SPACG panel. Furthermore, the disposal should be done in environmentally safe manner and glass needs to be recycled following the principles of resource recovery, resource efficiency and circular economy.

The option of disposing waste solar panel glass in common hazardous Treatment Storage and Disposal Facilities (TSDFs) to be considered as least preferred action when recycling facility is not available in the country.

Recycling facilities for SPACG at the end of life of solar panel is not yet available in the country. Such facilities may be created by industry once adequate quantity of PV waste is available for recycling and also a policy framework that stipulates the responsibility to the generator or producer for sending the waste for recycling. The following regulatory interventions may be considered;

- Recycling of end of life solar panel glass containing Antimony may be made mandatory on the generators as part of environmental liability.

- Producers may be made responsible for ensuring recycling of end-of-life glass panels as part of their extended producer’s responsibility (EPR) as in case of E-Waste, used lead acid batteries, packaging material, etc.
- Generators shall ensure environmentally sound handling of used solar panel waste

The recommended options are given below;

(a) Reuse/ Recycling

- It is technically feasible to reuse/ recycle the glass from the PV panels; however, the same is not practiced at present because of high operating costs and low profitability. However, the generator or the manufacturers may be given responsibility of recycling of used solar glass panel for re-producing new glass for solar panels.
- Every generator may set up facilities for safe dismantling of used solar panels or tie-up with an authorized dismantling facility.
- It shall be ensured that Antimony containing glass should never get mixed with normal glasses for recycling, as it may contaminate entire glass being produced.
- The possibility of utilizing used solar panels by co-processing in cement kilns should also be explored.

(b) Handling & Storage

- The end-of life solar panels are required to be collected and stored safely under a covered shed till the time the material is sent for recycling or the option for recycling is available.
- Transportation of waste solar panels should be done in covered trucks, preferably in trucks authorized for transportation of hazardous wastes as per Motor Vehicles Act.

(c) Ultimate Disposal in Secured Landfill

- It should be ensured that end-of-life solar panels shall never be disposed or dumped in open landfills as it may release Antimony into the environment.
- Disposal of used solar panel glass in secured landfill is not the preferred option. The option of disposal in secured landfill may arise only in case the waste Antimony glass

cannot be recycled even in long run.

- Only the non-recyclable material in solar panel after removal of glass, aluminum and junction box, may be allowed for disposal through secured landfills.
- Considering the leaching potential of Antimony, the end-of-life solar panels may be treated as 'low effect waste' and handled as per the provisions under Hazardous and Other Wastes Management Rules, 2016 with valid authorization from concerned State Pollution Control Boards.