HBCDD Hexabromocyclododecane in Polystyrene Foams Product Safety Assessment

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1. Introduction

Polystyrene foam is used in a wide range of insulation applications, in the residential, commercial, institutional and industrial building sectors as well as for civil engineering. From roof to floors to walls, from cavity fill to perimeter insulation and anti-frost layers, polystyrene foam provides versatile insulation solutions, adapted to every situation. The largest application is thermal insulation to prevent heat transfer. Buildings last longer and have less maintenance because of the durability and moisture resistance of PS foam. Due to its insulation performance, light weight, rigidity and flexible shape design, PS foam reduces space requirements for walls and roofs, and hence maximizes internal volume. This is especially important when existing buildings are being renovated to meet improved insulation standards. Polystyrene foams contain small amounts of hexabromocyclododecane – HBCDD.

HBCDD has been listed in Annex A of the Stockholm Convention and its use is forbidden with exemptions for Polystyrene (PS) foams in certain applications. National implementations follow suit such as for the EU where the POP Regulation sets the boundaries for any future use of HBCDD.

The aim of this document is to provide a general basis for the safety assessment of polystyrene foam products and to demonstrate it for the overall exposure scenario of insulation foam. The document provides background information demonstrating that polystyrene foams containing HBCDD, when properly handled in-use and disposed of, do not represent a risk neither to man nor to the environment. Worse case exposure scenarios have been investigated for the purpose of this report. Together with toxicity testing to aquatic organisms, proof could be delivered that in the exposure scenarios described neither adverse effect nor exposure and hence no risk to man and to the environment have to be expected. The investigations have further shown that the flame retardant HBCDD is retained in the polystyrene foam matrix, thus preventing migration and exposure via surface contact. The scenarios chosen reflect primarily the use-phase but can be read-across to the end of life situation

2. Exposure assessment

During service life, the foams might be exposed to **air, water and soil**. Therefore, the potential release of HBCDD during service life of Expanded PolyStyrene-EPS and Extruded PolyStyrene-XPS used in applications representing worst case scenarios has been assessed.

The following relevant applications have been considered:

- ***Exposure to air and light:*** External walls
- ***Exposure to (rain) water.*** Inverted roof, cellar, perimeter, railways and under roads
- ***Exposure to soil:*** Cellar, railways and under road

a) Exposure to light (degradation) - External walls

In typical applications like external walls and facades EPS or XPS foam is not exposed to light since the foam is covered with a facing or layer so that light is not able to access. In Europe the foam is used quickly meaning that it is normally not stored for long periods of time outside before construction, which limits access to light. Experience from long-term results (up to 32 years service life) indicates that the foam is durable during service life when the foam is covered according to the technical rules.

To further illustrate the case, measurements of bromine content have been made in uncovered XPS foam specimens for a period of approximately 19 years. The specimens were cubes of approximately 8 cm^3 volume with a HBCDD content in the range of 0.3% to 5.8 weight-%. The cubes were stored in natural light and under standard laboratory conditions with respect to temperature and humidity. Total bromine content was measured in 1987/8 using the neutron activation method and in 2007 using X-ray fluorescence. According to these measurements it could be concluded that levels of HBCDD remained stable in all the cubes for a period extending over approximately 19 years.
To be noted that solely in the case of agricultural building the foam being exposed on the walls there is however only limited access to light.

b) Exposure to water - Inverted roof.

The Inverted roof (upside-down roof) is considered to be the worst-case application scenario for potential emissions of HBCDD to water. This is because there is direct contact with water in the form of rain, and the water run-off may lead to exposure to the environment via drains and directly to the soil compartment.

An examination of an XPS foam board from an inverted roof (25 years of service life) has been made by measurements of the bromine level in samples taken in different points across the board. Total bromine content was measured and compared to the original levels detected immediately after the production of the foam. The original concentration of HBCDD in 1982 was 0.61%. In 2007, concentrations across the foam were between 0.59% and 0.62%, with an average of 0.61%. The standard deviation for the total 12 analyses was 0.01%. This study shows that the HBCDD was equally distributed in the foam and the levels remained at a similar level (within the experimental error of 0.01%) compared to the initial levels.

c) Emissions to air - Emission test chamber experiment

The emission test chamber experiment can, similarly to the inverted roof case, be considered to be the worst-case scenario for potential emissions of HBCDD to, in this case, the (indoor) air compartment. This is because of the relatively small volume of the test chamber and the high air exchange rate.

Polystyrene boards with an emitting surface of 0.931 m^2 were incubated in an emission test chamber with a volume of 200 L and an air exchange rate of 0.4 m^3 / h for 90 days at room temperature. The air was directed through a glass wool adsorber for 42 and 48 days, respectively (total duration 90 days) and the latter extracted with dichloromethane. For both collection periods no HBCDD could be found in the dichloromethane extract (limit of quantification 20 ng/m^3).

d) Emission modeling

In 2012 an emission modeling investigation on the simulation of specific air emissions of HBCDD from EPS/ XPS foams was undertaken. Applying a generally recognized diffusion model cumulative emissions to the air compartment during the long-term use of HBCDD containing PS insulation board could be made.
Based on an assumed diffusion behavior of HBCDD in polystyrene for an EPS/ XPS insulating panel with an estimated service time of 100 years a cumulated total emission of 175 µg /m^2 HBCDD after 100 years at 23^0C would result, if no boundary resistance at the surface exists i.e. HBCDD evaporates readily to air. In other words, due to the very low diffusion rate of HBCDD in polystyrene it would take approximately 100 years to deplete 0.1

µm of the polystyrene skin layer of the EPS/XPS insulating panel. Should a slower evaporation rate compared to the diffusion rate apply as boundary resistance at the foam/ air interface the HBCDD emission would be even lower. The investigation provides further proof that HBCDD releases by means of air emissions from PS foams are practically inexistent due to extremely slow evaporation rate with the foam/air interface acting very much as the rate determining step.

3. Hazard/ toxicity assessment

The assessment of possible releases of HBCDD during service life of EPS and XPS foams under worst case conditions could be validated in a series of biotests conducted for the evaluation of the environmental waste classification of EPS and XPS foam boards containing HBCDD as flame retardant.

a) The Water Accommodated Fractions (WAFs) of extruded and expanded polystyrene materials (XPS and EPS), containing up to ca. 2 weight-% HBCDD as flame retardant, were experimentally tested for possible acute aquatic toxicity. As test organisms the green alga *Desmodesmus subspicatus* (Method C.3 Commission Directive 92/69/EEC (SafePharm Laboratories, Project number: 2631/0002 and2631/0004, unpublished studies, 2008) and *Daphnia magna* (Method C.2 Commission Directive 92/69/EEC (SafePharm Laboratories, Project number: 2631/0001 and 2631/0003, unpublished studies, 2008) were used.
The test organisms, conditions and procedure were based on UK Environmental Agency Technical Guidance Document WM2 (Hazardous Waste; Interpretation of the Definition and Classification of Hazardous Waste – Appendix C: C14-H14 Ecotoxicity) amended 2006. This allows for testing to prove whether a hazardous property is present or not.

b) Corresponding to this procedure a Water Accommodated Fraction (WAF) was generated by stirring samples of the test materials (foam cubes of XPS and EPS) for 48 hours in the test medium at 20 °C corresponding to an initial loading rate of 100 mg/l. The test organisms were then exposed to the aqueous eluent of the test material without further dilution (limit test).
After 48 and 72 hours exposure, no adverse effects on Daphnia mobility/mortality and algae growth, respectively, were observed at a loading rate of 100 mg/l for both XPS and EPS foam tested. No corresponding chemical analysis was performed.

c) The results confirm the findings of previous studies. In one of these studies flame retarded EPS, in the form of beads, was tested at a loading rate of 100 mg/l for acute toxicity towards daphnids and freshwater algae, using an even longer period of elution. Also in those studies no lethality in daphnids or growth inhibition in algae was observed. In another series of tests with 20 hours WAFs of XPS and EPS foams with up to 2 weight-% HBCDD no adverse effects on the growth of the marine alga *Skeletonema costatum* was observed.

4. End-of-life

At the end-of-life stage it is equally critical that HBCDD will not become released to the environment, be it to air, water and soil. Since the exact composition of polystyrene foams obtained from building demolition is usually unknown and, as some of these foams (XPS) may contain (H)CFCs (used in past production processes as blowing agent), it is highly recommended that the foam should not be compacted, but transported to the nearest suitable municipal solid waste incinerator. By the same token, the HBCDD incorporated and retained in the PS Foam matrix remains unexposed to the environment, whilst being safely destroyed through incineration with energy recovery in state of art municipal solid waste

incinerators. It follows that during the deconstruction steps care should be taken to minimise foam breakage and to divert PS foams to outlets that limit the release of fine particles and of dust. Landfilling does not represent a viable option anymore, since POP and other EU waste legislation demand the destruction of HBCDD at the end of its service life in PS foams.
To be noted that the exposure assessments carried out on the service life scenarios do equally apply for end of life scenarios including (existing) landfilling. No specific investigations have been carried out to that effect.

Municipal solid waste co-incineration

In support of the end of life scenario industry has carried out a controlled one-week co-incineration investigation that was conducted by a broad consortium of stakeholders to evaluate the effects of polystyrene foams containing HBCDD on the performance of the large-scale energy recovery incinerator in Würzburg, Germany (MHKW) in 2013. Besides plant operations where the stable performance of the incinerator throughout the trial was noted, with no impact on energy balance and boiler efficiency, the results of the co-incineration investigation at the MHKW facility in Würzburg:

- Have demonstrated that HBCDD is very efficiently destroyed in normal state of art MSWI operations with a confirmed destruction efficiency of 99,999%, confirming, beyond earlier laboratory investigations, the excellent destruction performance in an advanced commercial scale incinerator[1].
- Have shown that the regulated dioxins/furans are well below the limit values set for these compounds.
- Have confirmed that HBCDD-containing PS foam waste can be treated alongside other municipal solid waste at standard state of art MSW incineration conditions; hence no special high temperature hazardous waste incineration is required.
- Have demonstrated the successful addition of up to 2 weight- % of PS foam with HBCDD concentrations typical for the insulation materials EPS and XPS, to the normal municipal waste stream.

The use of a modern large-scale incinerator for municipal solid waste, such as the plant in Würzburg, Germany, has been shown to be suitable for the safe and effective treatment of HBCDD containing PS foam obtained from the Building and Construction market (B&C). Advanced Solid waste Incineration (ASWI) represents one of the disposal methods of choice for the elimination of HBCDD, as acknowledged in the General Technical Guidelines adopted in May 2015[2].

5. Best practice considerations

When taking a building down it is advisable to identify the categories of foams beforehand, to remove the foams undestroyed, to prepare the foams for recovery and to organise the end-of-life options according to best practice. In this context foams should neither be destroyed i.e. broken nor reduced/crushed into small pieces or compacted. This to avoid the release of potential (H)CFCs in the case of XPS and any dispersion of foam particles/ dust containing HBCDD. Recovery and recycling of PS foams from building deconstruction is complicated by

[1] Mark, F.E. et al, 2015. "Destruction of the flame retardant hexabromocyclododecane in a full-scale municipal solid waste incinerator", *Waste Management & Research,* vol. 33 No. 2, pp. 165–174;
and Vehlow, Jurgen 'End-of-Life Treatment of HBCD-containing polystyrene insulation foams: Technical Summary Report' PlasticsEurope, 2015

[2] http://www.basel.int/Implementation/POPsWastes/TechnicalGuidelines/tabid/5052/Default.aspx

the fact that these may be contaminated with concrete and other materials, and that related processing will require (dust) emission control in state of art installations. Therefore, since during deconstruction it is often not possible to separate the different categories of foams, incineration with MSW offers today the only possibility to soundly manage on a large scale the waste streams that arise from building demolition. As far as incineration with MSW is concerned, the mixing of foams does not matter. Most insulants, whether foams or fibres, will eventually be excluded from landfill, principally because of organic content and/ or stability requirements of the landfill sites.

6. Conclusion

On the basis of the available data and the application of conservative assumptions, for the scenario of insulation of a polystyrene foam, no adverse health effects and environmental impacts are anticipated as a result of the use and disposal of HBCDD containing PS foams, since it could be demonstrated in a number of independent studies that HBCDD is immobilized within a stable PS matrix and as such is not released into the environment. Equally once the PS foam has reached its end of life stadium, the boards containing HBCDD do not need to be classified as hazardous waste (unless specific national rulings concerning POP substances per se are being applied) and can be safely destroyed in MSW incinerators without incremental emission burdens to the environment.