Comparative study between life-cycle HBCD and CO_2 emissions for the risk trade-off analysis

Managaki S[1], Hondo H[1], Yokoyama Y[1], Miyake Y[2], Kobayashi T[3], Miyake A[1], Masunaga S[1]
[1] Graduate School of Environment and Information Sciences, Yokohama National University, Japan
[2] Institute for Environmental Sciences, University of Shizuoka, Japan
[3] Center for Risk Management and Safety Sciences, Yokohama National University, Japan

Introduction

For the sustainable chemical management decision-making, an integrated methodology which includes the approach, not for only single risk (e.g., chemical risk) but for multi risk (e.g., climate change and accident) has been growing importance. In this multi-risk assessment, however, the reduction policy in a target risk often cause the increase or appearance of the other risks, and thus result in no risk reduction in total (risk trade-offs). Currently, limited research work has focused on the multi risks including chemical risk. The present study aims to contribute to developing a risk reduction policy for chemicals, considering risk trade-offs over a product life-cycle.

HBCD are important synthetic additives which are used to reduce the flammability of articles. Despite their benefits, however, the occurrence of HBCD in the environment as contaminants have recently an increasing attention because of the widespread use, high chemical stability and bioaccumulation potential. HBCD has been detected in various environmental compartments such as house dust, riverine sediment near the HBCD production plant and sewage sludge from municipal sewage treamtment plant. Also, stock in use increased continuously due to the longer life time of product in HBCD. In Japan, The stock of HBCD in comsumer products was estimated as approximately 16000 tone[1]. The consideration for management of wastes and stockpiles of HBCD would be also required for risk assessments.

In this study, taking brominated flame retardants (i.e., HBCD) as an example, Environmental emissions from end-products containing brominated flame retardants (i.e., HBCD), has been estimated under five disposal scenario and compared them with other environmental factor such as CO_2 emissions though their life cycle.

Materials and Methods

Target chemical and product

In Japan, polystyrene insulating boards make up by far the most important component of HBCD consumption (approximately 80% in 2009). In this study, polystyrene insulation board including HBCD was selected and we estimated life-cycle HBCD and CO_2 emissions associated with the use of insulating board containing HBCD, focusing on the difference of treatment of insulating board at the end of their useful life time (i.e., landfill, incineration and recycling).

Scenario

88,000 tone of insulation board with a residence time of 30 years was set as functional unit. This residence time was consistent with average life time of residential house in Japan. Also, we assumed that the amount of insulation board (i.e., 88,000 tons) was a maximum in 30 years[2]. In this study, the content of HBCD in insulation board was 3%. During the life time of the products, we did not consider the degradation loss of HBCD.

Figure 1 shows the life cycle flow of HBCD products in Japan. The boundary was defined as the spatial system from the process of the formulation of HBCD and formulation of Polystyrene (PS) to the process of waste (landfill or incineration) / recycling. In this study, we considered five types of waste management options based on Japanese waste management systems.

Reference scenario (Landfill)

In Japan, 72% of HBCD in insulation board waste is distributed to landfill and 13% is incinerated (2005)[3]. Therefore, the landfill option was considered to be the most realistic case. This scenario was set as reference in this study.

Scenario 1 (material recycle and landfill)

5% (scenario 1-1) and 30% (scenario 1-2) of the insulation board waste was recycling and the reminder was distributed to landfill in this option. So far, the amount of recycling plastic was limited in Japan, due to the problem of the cost or the quality such as plastic dirt. Thus, we applied 5% recycling, which is a feasible amount by a current technology and 30%, which is the maximum feasible amount in the future[4]. We assumed that recycled polystyrene contained same amount of HBCD and thus this polystyrene has a same function (i.e., reduce the flammability) as a new insulation board including HBCD. This means that recycled polystyrene can substitute new insulation board, which is produced from a new polystyrene and new HBCD.

Scenario 2 (material recycle and incineration)

30% of the insulation board waste was recycling and the reminder was incinerated in this option. Also, we assumed that the power generation (10% efficiency) was partly compensated by thermal recycling during incineration of waste.

Scenario 3 (incineration)

In this scenario, all of the insulation board waste was incinerated and 1 % of remaining transported to landfill after incineration. We assumed that the power generation (10% efficiency) was partly compensated by thermal recycling during incineration of waste.

Life cycle inventory analysis

For all the processes in each scenarios (Fig.1), we calculated HBCD and CO_2 emissions based on the quantitative data concerning to emissions and flow. For HBCD, details of the procedure have been described elsewhere[1]. Briefly, the environmental emissions were calculated by multiplying the input into each process by an emission factor. Emission factors during all processes were evaluated or estimated according to the European Chemicals Bureau (2006) [5]. For CO_2 emissions, it was calculated by multiplying the input into each process by CO_2 emission factor. The data were gathered from JEMAI-LCA online data base and JEMAI-LCA pro, which is a software package that can be used for Life cycle assessment in Japan. In incineration process, we assumed that

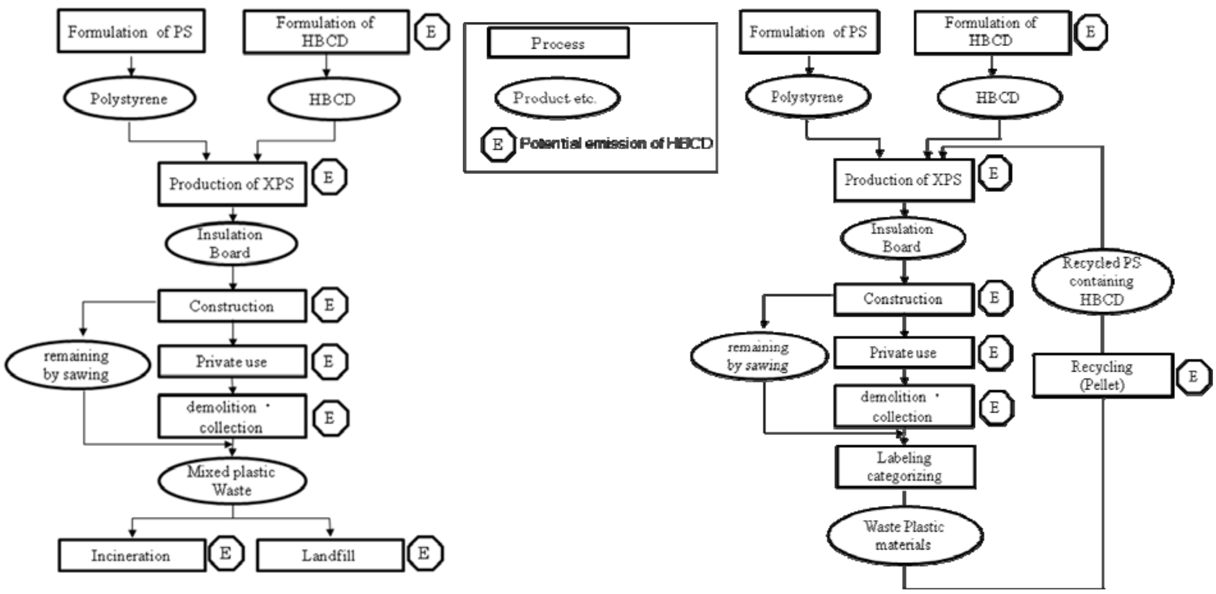

Figure 1 Life cycle of HBCD products in Japan

the power generation (10% efficiency) was partly compensated by thermal recycling during incineration of waste and thus CO_2 emissions by the system power generation were decreased (412g-CO_2/kWh).

Results and Discussion

Life-cycle HBCD emission

Life-cycle HBCD emissions in each scenario are shown in Figure 2. The production of insulation board process was the largest contributor (53-80% of total emissions) to the environment, followed by landfill process. Thus, the reference scenario, which is landfill option with no recycling, made the largest emission scenario.

In the scenario 1-1 and 1-2, which includes the recycling process, HBCD emissions was decreased relative to the reference scenario as the amount of insulation board waste distributed to landfill was decreased. In addition, we assumed that some extent of recycled insulation board contained HBCD compensated the production of a new insulation board in this study. In a result, small but a significant amount of HBCD emissions in the production of insulation board process were decreased. Therefore, the decreasing trend of HBCD emissions was estimated with the increasing of the amount of recycled polystyrene. 24% decrease of HBCD emission in the scenario 1-2 was estimated relative to the reference scenario. In the scenario 2 and 3, we assumed that the less amount of HBCD in the incineration process was released relative to landfill process. Scenario 2, which is 30% recycling with

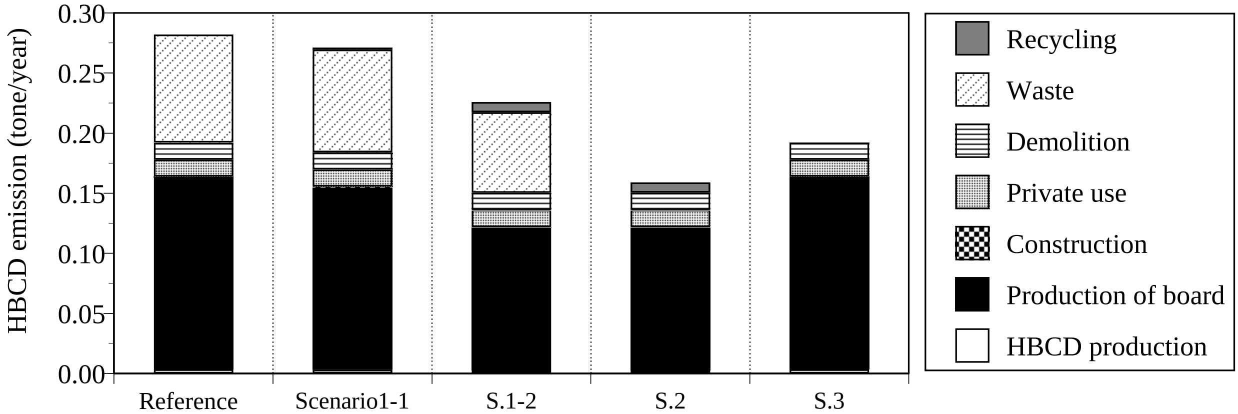

Figure 2 Life cycle HBCD emission

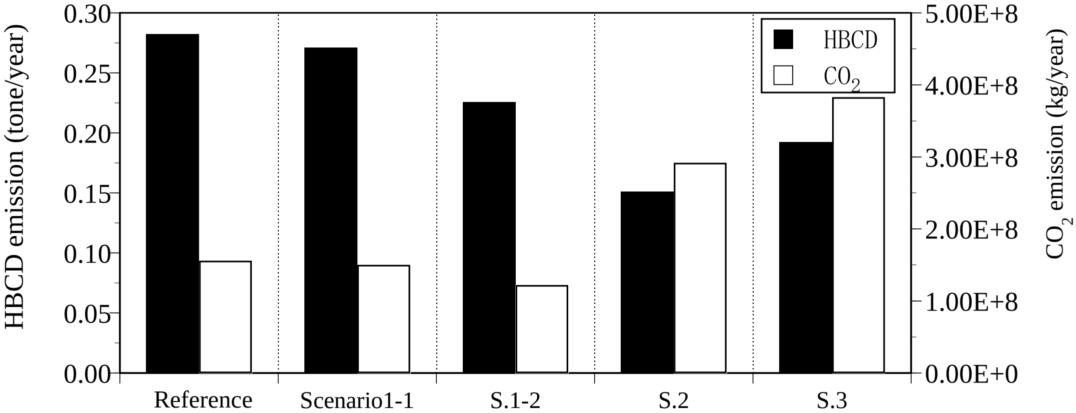

Figure 3 Life cycle CO_2 emission

incineration process, showed a minimum HBCD emission amoung five disposal scenario. 56 % decrease of HBCD emission in the scenario 2 was estimated relative to the reference scenario.

Comparison between HBCD and CO_2 emissions

Life-cycle CO_2 emissions at the same scenario of HBCD emissions were shown in Figure 3. To highlight the difference of HBCD emissions, life-cycle HBCD emissions were also shown for comparison. In CO_2 emissions, the larger emissions were estimated from scenario 2 and 3. This result contrasts with HBCD emissions. This can be explained by incineration process, which was the largest contributor in the life-cycle of insulation board. In this study, we consider the CO_2 emission decrease in the system power generation as the power generation (10% efficiency) was partly compensated by thermal recycling during incineration of waste. However, it only accounted for 15% of life-cycle CO_2 emissions. This result indicates that the selection of incineration or landfill processes influences life-cycle CO_2 emissions rather than the introduction of recycling process.

For a comparison between HBCD and CO_2 emissions, a disposal option that minimizes life-cycle HBCD emission always doesn't minimize life-cycle CO_2 emission. Therefore, when we evaluate the five disposal scenario from the viewpoint of the reduction of HBCD emission, the scenario 2 (recycling with incineration) was estimated to be the best scenario. However, for CO_2 emission reduction, this scenario would not be the best. Our study implies that the risk reduction strategy, which only focus on the chemical risk may interfere the other risks. It is important to consider trade-offs of different risks over a life-cycle of a product containing chemicals.

Acknowledgments

This work was financially supported by Environment Research and Technology Development Fund (C-1003; "Environmental Risk Minimization Method Based on Lifecycle Risk Assessment and Alternative Assessment for Persistent Organic Pollutant, such as HBCD, in Products"), headed by Prof. Masunaga of the Ministry of the Environment, Japan. We thank the members of the Risk Information Platform for Self-management of Chemicals research project (http://www.anshin.ynu.ac.jp/renkei/).

a

References

1. S. Managaki et al., (2009) Emission load of hexabromocyclododecane in Japan based on the dynamic substance flow analysis. Organohalogen Compound, Vol71, pp.2471-2476.
2. The Ministry of the Environment, Japan, 2003. Thermal insulation board for control of fluorinated gases emission report (in Japanese).
3. The Ministry of Economy, Trade and Industry (METI), Japan, Announcement (No. 241) through official gazettes on Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, etc (in Japanese).
4. Clean Japan Center (2003) A report on construction of free-recovery system of thermal insulators (extruded foamed polystyrene panels) for construction. pp.53 (in Japanese).
5. European Chemicals Bureau, 2006. European Commission. Joint Research Centre. European Union Risk Assessment Report. Hexabromocyclododecane, CAS No: 25637-99-4, EINECS No: 247-148-4.