PBDE INVENTORY IN THE TRANSPORT SECTOR OF NIGERIA – A STEP FOR STOCKHOLM CONVENTION IMPLEMENTATION

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Introduction

Certain homologues included in commercial Pentabromodiphenylether (c-PentaBDE) or c-OctaBDE (namely tetraBDE, pentaBDE, hexaBDE and heptaBDE) have been listed in Annex A of the Stockholm Convention (SC) in August 2009 as persistent organic pollutants (POPs)[1,2]. These listed PBDEs (POP-PBDEs) are now officially recognised as POPs. The Stockholm Convention prohibits parties from production and use of POP-PBDEs. Also import and export of articles containing these listed PBDEs is prohibited however subject to certain defined exemptions. Furthermore Article 6 of the Convention requires that wastes containing POPs have to be managed in a manner protective of human health and the environment[3]. The new listing therefore requires parties of the Stockholm Convention to take appropriate measures to reduce or eliminate releases of POP-PBDEs[A] from stockpiles and wastes although exceptions can include, uniquely for POPs, certain recycling.

The transport sector (cars, busses, trucks, trains, planes, and ships) is one of the large material flows of goods in society and ultimately becomes a large waste and recycling stream. The end-of-life management of the transport sector is highly relevant for the recovery of materials and for managing pollutants[6,7]. A large proportion of c-PentaBDE use has been in the transport sector with the major use being for treatment of flexible PUR foams (used e.g. for automotive seating, head rests, car ceilings, acoustic management systems) with minor uses including back-coating of textiles used on car seat. Further c-OctaBDE has also been used to some extent in plastics parts (possibly steering wheels, dashboards, door panels)[4,5]. As a first step for addressing and managing POPs in a country a robust inventory of the respective POPs needs to be established. Based on POPs inventories then action plans for the management of material flows containing POPs are developed within the National Implementation Plan (NIP).

The study objective was to establish a preliminary POP-PBDE inventory for the transport sector of Nigeria. Guidance for developing inventories for PFOS and related substances and for POP-PBDEs (including also POP-PBDE inventory in the transport sector) have been developed within the Stockholm Convention process.[5,8] The current study was a pilot project to use the Stockholm Convention POP-PBDE Inventory Guidance draft and to comment and improve the draft guidance document by using the methodology. In addition a material and substance flow analysis was conducted.

Materials and methods

For the development of the POP-PBDE inventory the approach suggested by the Stockholm Convention POP-PBDE inventory guidance[5] has been followed. Vehicles considered in this inventory were those produced from the 1970s until 2004 when POP-PBDE production and use is considered to have stopped.

,The STAN (an acronym for subSTance flow ANalysis) software[A] from the University of Vienna has been used to establish the substance flow analysis and visualisation. STAN is freeware that helps to perform material flow analysis according to the Austrian standard ÖNorm S 2096 (Material flow analysis - Application in waste management). After building a graphical model with predefined components (processes, flows, system boundary, text fields) the software allows the input or importation of data (mass flows, stocks, concentrations, transfer coefficients) for different layers (good, substance, energy) and periods to calculate unknown quantities. All flows can be displayed in Sankey-style, i.e. the width of a flow is proportional to its value. The graphical image of the model can then be printed or exported.

[A] http://iwr.tuwien.ac.at/resources/downloads/stan.html

Results and discussion

Inventory of POP-PBDE in transport using Stockholm Convention POP-PBDE inventory guidance[5]

The inventory approach recommended by the Stockholm Convention guidance[5] was used to develop the POP-PBDE inventory. Cars and other road vehicles (busses and trucks) are the major part of the transport sector and contain the majority of POP-PBDEs in this sector. The focus and methodology of the preliminary inventory therefore focused on these vehicles. POP-PBDEs were produced and used in the period from approximately 1975 to 2004[4,5]. Therefore, following the SC guidance, vehicles produced within this period were considered for this POP-PBDEs inventory. The core team to establish the preliminary inventory included the Basel Convention Regional Center Nigeria together with experts on the transport sector and researchers from the University of Ibadan. At an inception workshop on POP-PBDE held in early March 2012 a working group lead by a transport sector expert and including ministries, waste management experts, customs, industrial sector, Basel Convention Center, academia and consultants set the objectives and scope of the inventory. Basically it was agreed to follow the 5-step approach of the PBDE inventory guidance developed by the Stockholm. Also it was concluded that the data should be included in a material flow analysis to visualise the material and substance flow as a base for developing regulatory measures and waste management strategies. Shortly after the workshop a work plan was developed to compile data. The main responsibility was given to the Basel Convention Center in cooperation with University Ibadan where two PhD students were working on PBDE/BFR assessment in electronic waste. The first assessment of available national data revealed that no comprehensive inventory of the transport sector existed in Nigeria. Within three weeks the available information from ministries, national statistics, regional/city statistics and scientific literature[9-12] were compiled. In particular Lagos state motor vehicles statistical reports included very useful information for establishing a preliminary inventory. From the relatively detailed data for 2010[9] in these reports estimates on the regional origin of vehicles was derived together with the country of origin of the individual vehicles. For the preliminary inventory it was assumed that the vehicle distribution for Nigeria was similar to those from Lagos since most vehicles are imported through Lagos port. The fractions originating from the European (12%), Asian (69%), American (7%) and other regions (13%) were estimated. The regional origin is important for the assessment since the SC POP-PBDE inventory guidance includes different impact factors for regions with high or low usage of POP-PBDEs in vehicles.[5]

The SC inventory guidance also provides impact factors of POP-PBDEs depending on the vehicle size (e.g. car or busses). One modification to the proposed SC guidance approach has been made for this assessment to meet the Nigerian country situation: The SC guidance suggests an average POP-PBDE content for busses of 1 kg POP-PBDEs (based on approx 33 seats) the busses used in Nigeria, however, are mainly minibuses with approximately 10 seats. Therefore a lower factor of 320 g POP-PBDE was used rather than the original levels in the guidance.

The POP-PBDE inventory data covering imports, use/stocks, end-of-life and historical deposits are shown in table 1 and figure 2. The total amount of POP-PBDEs in vehicles in Nigeria is estimated to be around 270 tonnes. The majority of which(213 tones) is in current used or stockpiled vehicles while approximately 41 tones of POP-PBDE has already been disposed to dumpsites between 1980 to 2010.

The recycling and reuse of polyurethane foam and plastic from vehicles could not be assessed within the limited time scale of this preliminary inventory. This assessment will be conducted in the forthcoming detailed inventory.

Table 1: POP-PBDE (in kg) in inventoried vehicles (cars, busses, trucks) in import, use/stocks, end-of-life and in landfills/dumps in Nigeria

	Distribution homologues c-PentaBDE	POP-PBDE in current transport	POP-PBDE in imports (2010)	POP-PBDE in end-of-life Vehicles (2010)	POP-PBDE already deposited (b)	POP-PBDE recycled in (2010)	Total POP PBDE in transport
Total c-PentaBDE		2.2×10^5	2.1×10^3	1.9×10^3	5.8×10^4	-	2.8×10^5
TetraBDE	32%	7.0×10^4	6.8×10^2	6.1×10^2	2.4×10^4	-	9.1×10^4
PentaBDE	56%	1.2×10^5	1.2×10^3	1.1×10^3	3.7×10^4	-	1.6×10^5
HexaBDE	9%	2.0×10^4	1.9×10^2	1.7×10^2	6.0×10^3	-	2.6×10^4
HeptaBDE	0.5%	1.1×10^3	1.1×10	9.5	2.9×10^2	-	1.4×10^3

2. Material flow approach

To visualize the inventory information and to improve the usability of the data e.g. for waste management and regulatory purposes, a substance flow analysis for PUR foam (Figure 1) and POP-PBDE (Figure 2) in transport have been performed using the free software tool STAN. The inventory established using the SC guidance and taking into account vehicles produced before 2005 and registered from 1980 to 2010 was used as input data.

This first inventory of the Nigerian transport shows that a total of about 19 million vehicles have been imported and registered between 1980 and 2010 and these contain approx. 270 tonnes of POP-PBDEs in 410,000 tonnes of PUR foam (Figure 1 & 2). Economic conditions in Nigeria mean that vehicles are not scrapped quickly but are stored or repaired and have an estimated "life span" of approximately 30 years. Therefore more than 75% of the imported vehicles from the last 30 years (15 million vehicles) are in current use or are stockpiled largely by private owners. This stock is estimated to containing 213 tones of c-PentaBDE in 317,000 tonnes of PUR foam. About 4 million vehicles containing 84,000 tonnes of PUR-foam with 57 tonnes of POP-PBDE have reached end-of-life in the last 3 decades (Figure 1 & 2). About 41 tonnes of POP-PBDEs in 60,000 tonnes of PUR-foam have been dumped or abandoned in backyards. Furthermore it is estimated that approximately 13,000 tonnes of PUR foam containing 9 tonnes of POP-PBDE have been "thermally treated" with most being open burned with the rest being used as fuel by the poor. While no detailed assessment of recycled material for the inventory year has yet been established (table 1) it is estimated by expert judgement that roughly 15% of the POP-PBDE containing polymers (11,000 tonnes of polymers containing 7 tonnes c-PentaBDE) have been recycled or reused (e.g. some PUR foam is reused for stuffing and some car seats are used in other cars or as seats for furniture). In this preliminary assessment no export of polymers from end-of-life vehicles has been discovered or has been reported.

Currently approximately 20 polymer recycling facilities are planned in Nigeria and one University group has recently compiled information on recycling of PUR foam and highlighted the importance of material recovery for more sustainable resource management in Nigeria (). Considering that the largest share of POP-PBDE is still in use and stockpiled in PUR foam in vehicles (with even more POP-PBDE present in EEE/WEEE plastic), these pollutants must be considered when reuse, recycling and recovery proposals are developed.

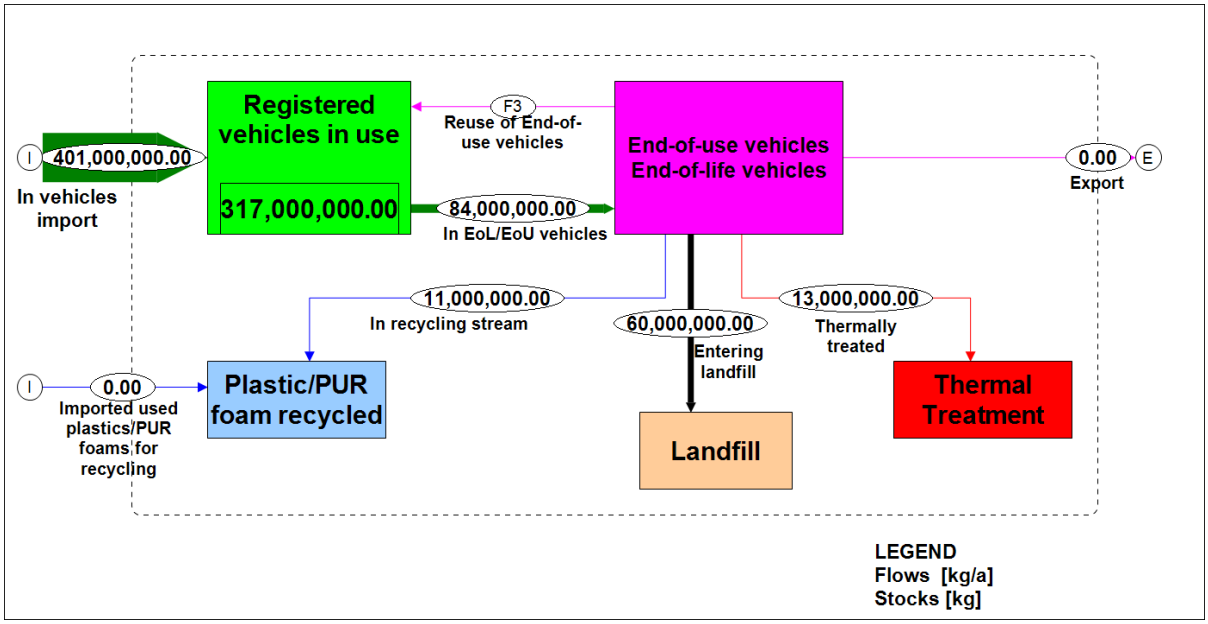

Figure 1: Material flow and stocks of polyurethane foam (kg) in vehicles in Nigeria (1980 to 2010).

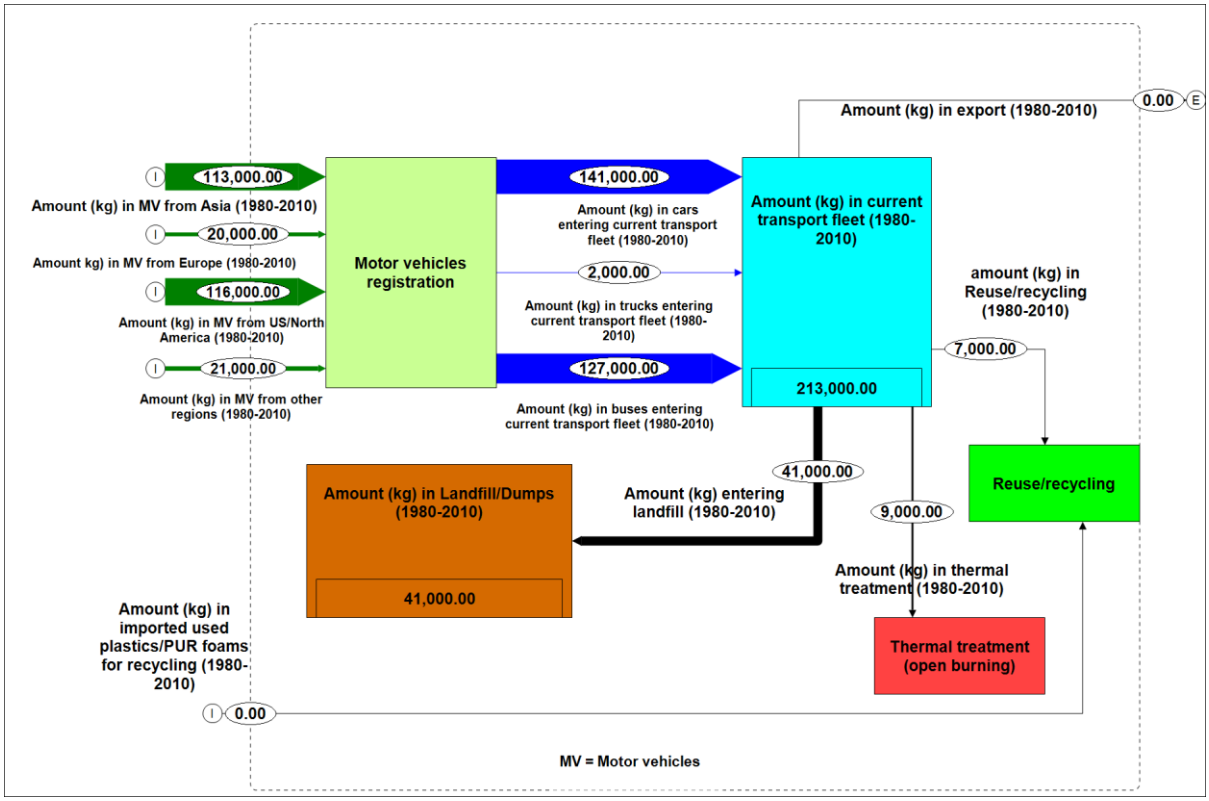

Figure 2: Substance flows of POP-PBDE (kg) in transport sector of Nigeria in the inventory 1980 to 2010

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