INVENTORY OF POP-PBDEs IN THE TRANSPORT SECTOR IN NIGERIA

Acknowledgement:

This case study has been developed and prepared by the Basel Convention Coordination Center - Africa. The valuable contributions of Oladele Osibanjo (Executive Director BCCC - Africa and Professor of Analytical & Environmental Chemistry, University of Ibadan, Nigeria), Joshua Babayemi (Analytical & Environmental Chemistry Unit, Department of Chemistry, University of Ibadan, Nigeria) Omotayo Sindiku (Analytical & Environmental Chemistry Unit, Department of Chemistry, University of Ibadan, Nigeria) and Dr. Roland Weber (POPs Environmental Consulting, Germany) who developed, compiled and edited the case study are acknowledged.

1 Introduction

In 1902, Lagos witnessed the arrival of the first two motor vehicles in Nigeria. About 35 years later, the number was said to have increased to 7,507 all over the country, with the first public transport system commencing in Lagos in 1915 (Agbo, 2011a)[1]. Today the transportation by car and minibus is the most common commuting system in Nigeria while train, subway and public bus systems have not yet been extensively developed. The imported vehicles, buses, trucks, and other transportation fleets such as planes and ships contain large metal resources (e.g. ferrous metals, copper and aluminium) but on the other hand also a wide range of pollutants which need to be managed at the end-of-life (see *PBDE BAT/BEP Guidelines*[2]; Vermeulen et al., 2011[3]). While the pollution from the end-of-life treatment of electronic equipment is well documented (Nnorom and Osibanjo, 2008[4]; Ogungbuyi et al 2012[5]) this is less documented for the transport sector/vehicles possibly with the exemption of ship dismantling[6]. A considerable share of used vehicles often with low environmental performance are exported from industrial countries to developing countries and countries with economies in transition where the vehicles are often used for a long time before they finally break down (*POP-PBDE Inventory Guidance*[7], UNEP 2010[8]). Therefore, today a large share of the transport fleets from 1970s to 2004[9] partly containing c-PentaBDE or c-OctaBDE are still in operation in developing countries.

While for EEE/WEEE a detailed national inventory has been established for Nigeria (Ogungbuyi et al., 2012)[5], no national inventory has been established for the transport sector which could have been used as base for this POP-PBDE inventory. Therefore a preliminary inventory of the transport sector of Nigeria was established in this study.

[1] Agbo, C.O.A. (2011) A critical evaluation of motor vehicle manufacturing in Nigeria. Nigerian Journal of Technology 30 (1), 8-16.

[2] Secretariat of the Stockholm Convention (2014) Guidelines on best available techniques and best environmental practices for the recycling and disposal of articles containing polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants. Draft December 2014.

[3] Vermeulen I, Van Caneghem J, Block C, Baeyens J, Vandecasteele C (2011) Automotive shredder residue (ASR): reviewing its production from end-of-life vehicles (ELVs) and its recycling, energy or chemicals' valorisation. J Hazard Mater. 190, 8-27.

[4] Nnorom IC, Osibanjo O. (2008) Electronic waste (e-waste): Material flows and management practices in Nigeria. Waste Management 28 1472–1479.

[5] Ogungbuyi O, Nnorom IC, Osibanjo O, Schluep M (2012) Nigeria e-Waste Country Assessment. Basel Convention Coordinating Centre for Africa (BCCC-Nigeria) and Swiss EMPA, Ibadan,Nigeria and St.Gallen,Switzerland May 2012. http://www.ewasteguide.info/Ogungbuyi_2012_BCCC-Empa

[6] http://archive.basel.int/ships/index.html; http://archive.basel.int/ships/index.html

[7] Stockholm Convention (2015) Guidance for the inventory of polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants. Draft March 2015.

[8] UNEP (2010) Technical review of the implications of recycling commercial penta and octabromodiphenyl ethers. Stockholm Convention document for 6th POP Reviewing Committee meeting (UNEP/POPS/POPRC.6/2) and Annex (UNEP/POPS/POPRC.6/INF/6) Geneva 11-15. October 2010.

[9] The production of POP-PBDEs is considered to have ended in 2004.

2 STEP 1: Planning of the inventory and identification of stakeholders

In this first step the objectives and scope of the inventory need to be defined and a work plan developed (see section 3.1. of the *PBDE Inventory Guidance*[7]). The POP-PBDEs inventory of the transport sector is expected to address the following life cycle stages:

- Vehicles imported/exported in the inventory year. Possibly import data of previous years as a basis for estimating/evaluating stocks;
- Stocks of vehicles (vehicles in use/possession of consumer/corporates)[10];
- End-of-life vehicles entering the waste stream;
- Polymers from end-of-life vehicles recycled;
- Polymers of end-of-life vehicles disposed in the past.

At an inception workshop on new POPs (with an emphasize on POP-PBDEs) held in early March 2012 in Nigeria a working group comprised of a lead transport sector expert and members from ministries, waste management authorities, customs offices, industrial sectors, the Basel Convention Regional Centre, academic institutes initiated the work to develop a POP-PBDE inventory. It became clear during the workshop that no national inventory on the transport sector was available. Furthermore no national policy or strategy on end-of-life management has been established. It was also not known if and to which extent polymers from the end-of-life management of vehicles were recycled. At the workshop a core inventory team to establish the preliminary inventory was formed including the Basel Convention Regional Centre in Nigeria, a transport sector expert in Nigeria (Professor Agbo) and a research institution (University of Ibadan). The team was also supported by an international consultant. These stakeholders compiled the information in cooperation with the Ministry of Environment and approaching other stakeholders having information on the transport sector. Furthermore a contact to Vienna University was established for support of using the free software STAN[11] for the calculation/visualisation of the material/substance flows (see below).
For the establishment of the POP-PBDE inventory a work plan was developed early March 2012 with a planned time frame of 8 weeks to compile the information.

3 STEP 2: Choosing the inventory methodology

The POP-PBDE inventory was developed following the 5 step inventory approach provided by the *POP-PBDE Inventory Guidance*[7] (Chapters 3 and 5).
In the short time available (the mentioned workshop was early March and an inventory was to be established in May) only tier 1 (preliminary survey of data and selection of main sectors for the preliminary inventory) and tier 2 (establishing an inventory by gathering, screening and evaluating available data and compiling these data) out of three tiers were carried out for this study.
For the preliminary inventory it was concluded not to use a questionnaire approach out of following reasons.

[10] Consumers here include households, public and private sector institutions and organizations.
[11] http://iwr.tuwien.ac.at/resources/downloads/stan.html

- In a brain storming on gathering the inventory data no useful approach on distributing questionnaires could be developed. The approach of using the network of the transport sector expert and the network of the Basel Convention Coordination Center via personal contacts was considered more efficient.
- The time frame to develop this preliminary inventory was 2-3 months. Former experience of using questionnaires for inventory purpose has shown that the time for returning questionnaires were often several months even with follow-up by phone calls
- Former experiences have further shown that the direct contact with stakeholders resulted in more useful information compare to the replays on questionnaires. Therefore when using questionnaires[12] in Nigeria e.g. for the EEE/WEEE inventory they were normally filled by face to face interviews (Ogungbuyi et al 2012)[5].

For the preliminary inventory it was decided that considering the limited time only cars and other road vehicles (busses and trucks) were to be inventoried. Since these are the major portion of the transport sector in Nigeria this sector contains also the largest volume of POP-PBDEs of the transport sector. The focus and methodology of the preliminary inventory therefore focused on these vehicles. Other sectors (planes, trains and ships) were not considered for the preliminary inventory but it was concluded that during the literature search also accessible information on these sectors should be gathered.

Since POP-PBDEs were produced and used (mainly) in the period from approximately 1975 to 2004[7,8,13], vehicles produced within this period were considered for this POP-PBDE inventory following the *POP-PBDE Inventory Guidance*[7] approach. Also it was decided that the impact factors of the *POP-PBDE Inventory Guidance*[7] are used.

In the planning of the inventory it was also concluded that the data should finally be subjected to a material flow and substance flow analysis to visualize the material/substance flows as a (discussion) base for policy making 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 Centre in cooperation with University of Ibadan where two PhD students were working on PBDE/BFR assessment in polymers of electrical und electronic equipment and related waste also supporting the inventory development in this sector (see case study on inventory of POP-PBDE in electrical and electronic equipment and related waste in Nigeria).

[12] A questionnaire has been developed and is included as Annex in the *POP-PBDE inventory guidance*

[13] It is important to note, however, that dust samples from automobiles made in or after 2004 showed measurable levels of BDE-47 and BDE-99 with highest levels from cars manufactured in the United States (Lagalante et al., 2009). This might be a consequence of the use of rebond from recycled PUR foam containing c-PentaBDE in new cars. It may also be partly due to the debromination of c-DecaBDE (Lagalante et al., 2011). Other flame retardants are now used in the transport sector including e.g. HBCDD in textile back-coating. HBCDD is proposed for listing as a POP at COP6 in 2013.

4 STEP 3: collecting and compiling the data

4.1 Tier 1 inventory approach

Within two weeks, information from a literature search have been compiled by the team of the University of Ibadan. This included

- Number of registered cars, busses and trucks (research articles) between 1980-2004;
- National statistics on number of imported vehicles in the past 19 years (1988-2006);
- data from Lagos state motor vehicle statistics 2010
- International trade statistics (http://unstats.un.org/unsd/comtrade/)
- Available literature and peer reviewed paper on Nigerians transport (see in the respective sections below)

The information gathered was assessed by the transport expert and the director of the Basel Convention Regional Centre and approved for use in the preliminary inventory compilation (tier 2). Furthermore the expert on Nigerian transport supplied data from his research results on Nigerian road safety.
Within the information gathering phase also preliminary information of the Nigerian air fleet was gathered. They were however not used for calculation due to missing information on POP-PBDE content and might be included in the future when an in-depth inventory is conducted with impact factors established.

4.2 Tier 2 inventory approach – inventory based on available and estimated data

4.2.1 Methodology for Data Collection

The evaluation of available and relevant national data on the transport sector was conducted by using the approach of the *PBDE Inventory Guidance*[7] with the available data identified and by extrapolating the data to fill data gaps.

4.2.2 Formula used for calculating POP-PBDEs in vehicles

The following basic formula from the *POP-PBDE Inventory Guidance*[7] is used to calculate the POP-PBDEs content of vehicles for the different categories (cars/trucks or busses) in different life cycle stages:

Amount of POP-PBDEs$_{\text{Vehicle category}}$ =

Number of vehicles$_{\text{category}}$ (manufactured 1975 to 2004) **x** amount POP-PBDEs$_{\text{category}}$ **x** F_{regional}

Where:

- *Number of vehicles$_{category}$* is the number of vehicles (manufactured 1975-2004) present in a category (car, bus or truck) calculated for the different life cycle stages.
- *Amount POP-PBDEs$_{category}$* is the amount of POP-PBDEs in an individual car, truck or bus treated with POP-PBDEs
- $F_{regional}$ The regional factor of percentage of POP-PBDE impacted vehicles produced in a region

Factors needed for POP-PBDE calculation for vehicles were:

- the amount of vehicles for the different sectors (cars, busses and trucks)
- the amount of vehicles in the different life cycle stages (import, use, end-of-life)
- the origins of manufacturers of vehicles
- impact factors for the different vehicle types. The estimated contents of POP-PBDE in respective vehicle type are given by the *POP-PBDE Inventory Guidance*. However one different approach was taken by the Nigerian inventory team: The Inventory Guidance suggests an amount of 1,000 g PentaBDE for a bus (with average 33 seats). For Nigeria however the largest share of busses are minibuses. As country specific impact factor 320 g c-PentaBDE (corresponding to PUR foam of two passenger cars or 32 kg PUR foam) was selected based on expert judgement.

Distribution of the different vehicle types

The distribution of the different vehicle types was established as follows: Of motor vehicles registered between 1999 and 2004 in Nigeria, 70% were cars and 30% buses and trucks[14]. Of 7,600,000 vehicles said to be registered up to the year 2007[15], about 1% were said to be trucks. Hence, this distribution (70% cars, 29% (mini)buses and 1% trucks) was used for calculations in this inventory.

Import distribution for the different region for distribution

Only a part of the cars produced between 1975 to 2005 worldwide have been treated with c-PentaBDE. The use of c-PentaBDE depends on the national/regional legislations and production/use patterns. Approximately 90% of c-PentaBDE has been used in the US/North America (*POP-PBDE Inventory Guidance* Chapter 5)[7]. According to the use pattern of c-PentaBDE, approximately 200 million cars produced in the US/North America from 1975 to 2004 could have been contaminated with c-PentaBDE. It is most likely that some cars produced in US/North America during this period (1975 to 2004) contain other flame retardants (e.g. phosphorous flame retardants and later brominated alternative Firemaster 550/600). Therefore an impact factor of 0.5 (50% of cars impacted) is suggested for vehicles imported from US/North America (*POP-PBDE Inventory Guidance*[7] Chapter 5). An impact factor of 0.05 is suggested as regional adjustment factor for other regions (*POP-PBDE Inventory Guidance)*[7].

The distribution originating from Europe, Asia, North America and other regions were estimated to 12%, 69%, 7% and 12% respectively. These estimates were derived from the relatively detailed data from Lagos State Motor Vehicle Statistics (2010) which also mentions the origin of the vehicle. For this preliminary inventory it was assumed that the vehicles distribution for the entire country of Nigeria is similar as that in Lagos. This is a reasonable approach since most vehicles are imported via Lagos and therefore should have a similar distribution. This

[14] Abam, F.I., Unachukwu, G.O. (2009). Vehicular emission and air quality standards in Nigeria. European Journal of Scientific Research, 34 (4): 550-560.

[15] WHO data and statistics (http://www.who.int/violence_injury_prevention/road_safety_status/country_profiles/nigeria.pdf)

information and assumption allowed the choice of the regional factor given in the *POP-PBDE Inventory Guidance*[7] for calculating the c-PentaBDE impact factor for the vehicles.

Ratio of old and new vehicles in imports

From the available statistical data of imported cars to Lagos, the ratio of new cars to old/used cars was 1:5. This ratio was used to also estimate the distribution of other categories. This information is needed, for example, for estimating the share of imported vehicles produced before 2005 which could possibly be impacted with POP-PBDEs.

Recycling of polymers from end-of-life vehicles

One of the data gaps which could not be adequately filled within the short time of inventory development was the estimation of the amount of recycling of polymers. For this assessment an estimate using average waste management data was used.

4.2.3 POP-PBDEs in vehicles in use and stockpiled

The inventory was based on the national and federal state/city registrations, peer reviewed literature and additional interviews with national experts and vehicle users.

Due to the link between imported vehicles and vehicles in use, the two life cycle stages are discussed together (see calculation of imported vehicles in the next section). In addition to the collection of available statistical data, face to face interviews with the association of importers and exporters of vehicles were conducted. With this approach it was possible to collect data on imported cars between 1988 and 2006 but without production year data. The number of the imported cars and that of the actually registered were compared for plausibility.

Data on registered cars, busses and trucks between 1980 and 2004 were available at the national level (see table B-1). Further, in particular the state of Lagos with approximately 11% of the total population had a very detailed registration of vehicles including also the originating country/region until 2009.

However in this preliminary inventory several gaps and inconsistencies exist. For such cases an expert judgement as well as development of approximation was used to estimate some of the data. The gathered data comprehensively fill out Table 5-1 to 5-4 of the *PBDE Inventory Guidance*[7].

Expert survey for specific estimation has been used:

- For the estimation on national registered vehicles the detailed data from 2005 to 2009 were missing. These data were extrapolated from registration data for Lagos state up to 2009 (see calculation below).
- For cars, busses, and trucks import data were available only between 1988 and 2006;
- Distribution of the originating regions of the imported vehicles were available for Lagos state and extrapolated from the detailed registration in Lagos state;

Based on the available data 7 million passenger cars, 3 million (mini)busses and 0.1 million trucks were officially registered in Nigeria (154.7 million inhabitants) between 1980 and 2006.

Table B-1: New registration of vehicles in Nigeria (1980-2004) continued below

Vehicle	1980	1981	1982	1983	1984	1985	1986	1987	1988
***Cars**	206,830	263,066	251,552	208,066	113,579	89,909	41,017	28,116	14,749
***Buses**	85,687	108,984	104,214	86,199	47,054	37,248	16,993	11,648	6,110
***Trucks**	2,955	3,758	3,594	2,972	1,623	1,284	586	402	211
****Total**	295,472	375,808	359,360	297,237	162,256	128,441	58,595	40,165	21,070

**Source: Aderamo, 2010[16]

*Estimated using 70% (cars), 29% (buses; mainly minibusses) and 1% trucks (Abam & Unachukwu, 2009)

Table B-1 (continued)**:** New registration of vehicles in Nigeria (1980-2004)

Vehicle	1989	1990	1991	1992	1993	1994	1995	1996
***Cars**	18,024	20,770	29,522	45,077	69,763	61,543	287,000	336,000
***Buses**	7,467	8,605	12,230	18,675	28,902	25,497	118,900	139,200
***Trucks**	257	297	422	644	997	879	4,100	4,800
****Total**	25,748	29,671	42,200	64,400	99,700	87,919	[a]410,000	[a]480,000

**Source: Aderamo, 2010[17]

*Estimated using 70% (cars), 29% (buses) and 1% trucks (Abam & Unachukwu, 2009)

Table B-1 (continued): New registration of vehicles in Nigeria (1980-2004)

Vehicle	1997	1998	1999	2000	2001	2002	2003	2004
***Cars**	385,000	434,000	1,960,000	280,000	490,000	770,000	420,000	210,000
***Buses**	159,500	179,800	812,000	116,000	203,000	319,000	174,000	87,000
***Trucks**	5,500	6,200	28,000	4,000	7,000	11,000	6,000	3,000
****Total**	[a]550,000	[a]620,000	2,800,000	400,000	700,000	1,100,000	600,000	300,000

**Abam and Unachukwu (extracted from a figure, hence there could be a slight difference)

*Calculated using 70% (cars), 29% (buses) and 1% trucks (Abam and Unachukwu, 2009)

[a] Values for these years were estimated by extrapolation

Extrapolation of numbers of motor vehicles registered in Nigeria in 2005-2009 and estimation for 2010:

The total number of new registration of motor vehicles in Lagos State (**2009**) was 210,798. For this preliminary inventory, it is assumed that the number of motor vehicles registered is proportional to the population to estimate the number for the entire country. Since the penetration rate in rural areas is lower compared to Lagos this is rather a conservative estimate and will possibly need a refinement in the establishment of an in-depth inventory.

[16] Aderamo, A.J. (2010). Transport in Nigeria: the case of Kwara State. African Economic and Business Review, 8 (1): 19-40.

[17] Aderamo, A.J. (2010). Transport in Nigeria: the case of Kwara State. African Economic and Business Review, 8 (1): 19-40.

The data for some other years (2005-2008) were extrapolated using statistical data of the previous years; the estimates are given in Table B-2 below.

Table B-2: Estimate of motor vehicles registered in Nigeria (2005-2009)

Vehicle	2005	2006	2007	2008	2009	2010
***Cars**	490,000	700,035	980,000	1,260,000	1,526,889	1,573,502
***Buses**	203,000	290,015	406,000	522,000	632,568	651,879
***Trucks**	7,000	10,001	14,000	18,000	21,813	22,479
****Total**	700,000	1,000,050	1,400,000	1,800,000	[a]2,181,270	[a]2,247,860

*Calculated using 70% (cars), 29% (buses) and 1% trucks (Abam and Unachukwu, 2009)
**Extrapolated, including statistical data for previous years (see Figure B-1)
[a]Calculated using Lagos state statistics and Nigeria population

Table B-3: Registration of vehicles in Nigeria (1980-2010) (Total)

Vehicles	Number
Cars	13,564,009
Buses	5,619,375
Trucks	193,774
Total	19,377,158

In Figure B-1 below, the data from 1995 to 2004 are plotted including the calculated numbers for 2009. The data for 2005 to 2008 were extrapolated then. Overall the import data were not very consistent and will need a detailed assessment when establishing a detailed inventory.

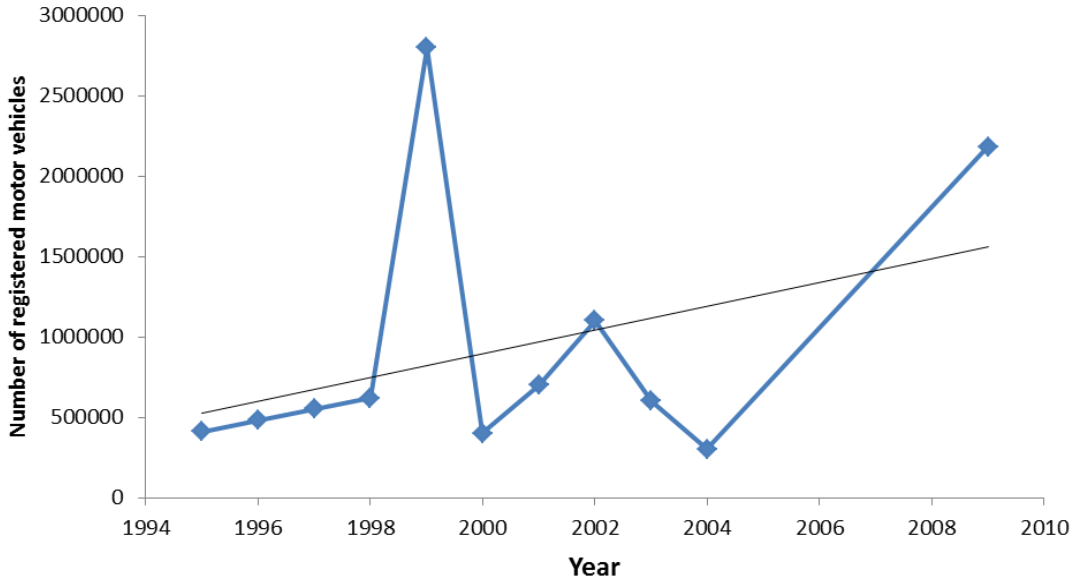

Figure B-1: Number of registered cars 1995-2004 and estimation of number of registered motor vehicles in 2005-2009

Information on current transport fleet

For this preliminary inventory relatively good data were available for registration of vehicles until 2005. All vehicles registered from 2005 on were considered still in use[18]. The results are shown in Table B-4.

This considered that

- cars imported before 2005 were considered
- from the vehicles imported from 2005 to 2010 approximately 80% are considered used cars and 20% new cars with estimated 60% of the cars produced before 2005
- For busses and trucks imported between 2005 and 2010 75% were assumed to be produced before 2005.

Table B-4: New registration of vehicles in Nigeria (2005-2010) (summations from Table B-2) and those from (1980-2004) which are still in use (calculated from Table B-1)

Registered Vehicles	1980-2004	2005-2010 (those produced before 2005)	Total produced before 2005
Cars	4,637,672	6,530,426 (3,918,256)	8,555,928
Buses	1,918,700	2,705,462 (2,029,097)	3,947,797
Trucks	66,253	93,293 (69,970)	136,223
Total	4,637,672	9,329,181 (6,017,323)	12,639,948

*Cars (60%), buses/trucks (75%) of those registered (2005-2010)

**Those registered (1980-2004) and of (2005-2010) produced before 2005

Based on the data from Lagos state motor vehicles statistics where the origin of imported vehicles are registered, the distribution for Nigeria were extrapolated: Based on this data vehicles have mainly been imported from Asia (69%), and Europe (12%) and to some extent from North America (7%) and remaining from other regions. With these data the current stock (in use, re-use and stockpiled) have been calculated (Table B-5).

Based on the compiled data and assumptions the POP-PBDE inventory of current stocks were calculated according the *POP-PBDE Inventory Guidance*[7] (Table B-5).

[18] From the expert judgement, certain percentages of vehicles registered 1980-2004 were assumed to have entered end-of-life by the year 2010 (considering about 30 years life expectancy); the remaining percentages were considered to still be in use or stored by private and business owners, and hence accounted within current transport fleet.

Table B-5 (corresponding to Table 5-1 of *the POP-PBDE Inventory Guidance*[7]) Amount of POP-PBDEs in vehicle in current use of the inventory year 2010 (please note that only the vehicles produced between 1985 and 2004 are considered for the POP-PBDE inventory)

Number of cars/trucks (originating from **Europe** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in cars in use and formerly originating from **Europe** in 2010
Cars: **8,555,928** x 0.12 = 1,026,711 Trucks: **136,223** x 0.12 = 16,347	160 g/car	**1,043,058 x 0.16 kg x 0.05= 8,344 kg**
Number of cars/trucks in use (originating from **Asia** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in cars in use (formerly originating from **Asia** in 2010
Cars: **8,555,928** x 0.69 = 5,903,590 Trucks: **136,223** x 0.69 = 93,994	160 g/car	**5,997,584 x 0.16 kg x 0.05= 47,981 kg**
Number of cars/trucks in use (originating from **US/North America** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in cars in use (formerly originating from US/North America in 2010
Cars: **8,555,928** x 0.07 = 598,915 Trucks: **136,223** x 0.07= 9,536	160 g/car	**608,451 x 0.16 kg x 0.5= 48,676 kg**
Number of cars/trucks in use (originating from other regions before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in cars in use (formerly originating from other regions in 2010
Cars: **8,555,928** x 0.12 = 1,026,711 Trucks: **136 223** x 0.12 = 16,347	160 g/car	**1,044,058 x 0.16 kg x 0.05= 8,352 kg**
Number of busses in use (originating from **Europe** in before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in busses in use (originating from **Europe**) in 2010
3,947,797 x 0.12 = 473,736	320 g/bus	473,736 **x 0.32 kg x 0.05= 7,580 kg**
Number of busses in use (originating from **Asia** in before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in busses in use (originating from **Asia**) in 2010
3,947,797 x 0.69 = 2 723 980	320 g/bus	2,723,980 **x 0.32 kg x 0.05= 43,584 kg**
Number of busses in use (originating from **US/North America** in before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in busses in use (originating from **US/North America**) in 2010
3,947,797 x 0.07 = 276,346	320 g/bus	276,346 **x 0.32 kg x 0.5= 44,215 kg**
Number of busses in use (produced in other regions before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in cars in use (formerly produced in regions other than US) in 2010
3,947,797 x 0.12 = 473736	320 g per bus	**513,214 x 0.32 kg x 0.05= 7,580 kg**
Total POP-PBDEs 21)		**Sum of POP-PBDEs: 216,312 Kg**

4.2.4 Data compilation for imported/exported[19] vehicles and related POP-PBDEs content

Please note for vehicle imports to Nigeria from 2012 on: The Nigerian legislation only allows the import of used cars which are less than 8 years old. Therefore from 2012 on the cars produced in and before 2004 are not allowed to be imported. This means at the same time that cars possibly impacted by POP-PBDE use (assumed to be produced before 2005) will not be

[19] No export activities of used vehicles have been discovered in the development of the current inventory.

allowed to be imported. Therefore the current legislation indirectly restricts the import of vehicles possibly containing POP-PBDEs.[20]

4.2.5 Information on imports of the inventory year (2010)

Following information and assumption were used for

- In 2010, 126,000 cars, 52,200 busses and 1,800 trucks were imported;
- 60% of imported cars in 2010 were estimated to be produced before 2005;
- 75% of imported busses and trucks in 2010 were estimated to be older than 2005;
- Based on Lagos state motor vehicles statistics vehicles have mainly been imported from Asia (69%), Europe (12%), North America (7%) and other regions (12%).

Based on the inventory of vehicles imported in 2010 have been compiled (Table B-6)

Table B-6: Vehicles import statistics of the inventory year (2010)

Vehicles		Number
[a]**Cars**	**New**	21,000
	Used	105,000
[a]**Buses**	**New**	8,700
	Used	43,500
[a]**Trucks**	**New**	300
	Used	1,500
Total	[b]**New**	30,000
	Used	150,000

[a]Estimated using distribution of 70% cars, 29% buses and 1% trucks
[b]Obtained from Financial Nigeria (2010)[21]

The POP-PBDEs in imported vehicles in 2010 were calculated according to the *POP-PBDE Inventory Guidance*[7] (Table B-7).
No export activities of used vehicles have been identified in the development of the current inventory.

[20] However some vehicles are illegally imported in particular via neighbouring countries. These illegal imports might also contain POP-PBDEs. The share of these illegal imports needs further assessment.
[21] http://www.financialnigeria.com/NEWS/news_item_detail.aspx?item=3933

Table B-7 (corresponding to Table 5-2 of *PBDE Inventory Guidance*[7]): Amount of POP-PBDEs in imported vehicles for the inventory year 2010 (please note that only the vehicles produced between 1975 and 2004 are considered for the PBDE inventory)

Number of imported cars/trucks (originating from **Europe** before 2005)	Amount of c-PentaBDE per car/truck	Total amount PBDE in cars imported from **Europe** in 2010
Cars: 126,000 x 0.6* x 0.12 = 9,072 Trucks: 1,800 x 0.75* x 0.12 = 162	160 g per car/truck	**9,234 x 0.16 kg x 0.05= 74 kg POP-PBDEs**
Number of imported cars/trucks (originating from **Asia** before 2005)	Amount of PentaBDE per car/truck	Total amount PBDE in cars imported in 2010 from **Asia**
Cars: 126,000 x 0.6* x 0.69 = 62,164 Trucks: 1,800 x 0.75* x 0.69 = 932	160 g per car/truck	**63,096 x 0.16 kg x 0.05= 505 kg POP-PBDEs**
Number of imported cars/trucks (originating from **US/North America** before 2005)	Amount of PentaBDE per car/truck	Total amount PBDE in cars imported in 2010 from US/North America
Cars: 126,000 x 0.6* x 0.07 = 5,292 Trucks: 1,800 x 0.75* x 0.07 = 95	160 g per car/truck	**5,387 x 0.16 kg x 0.5= 431 kg POP-PBDEs**
Number of imported cars/trucks (originating from **other regions** before 2005)	Amount of PentaBDE per car/truck	Total amount PBDE in cars imported in 2010 from other regions
Cars: 126,000 x 0.6* x 0.12 = 9,072 Trucks: 1,800 x 0.75* x 0.12 = 162	160 g per car/truck	**9,234 x 0.16 kg x 0.05= 74 kg POP-PBDEs**
Number of imported busses (originating from **Europe** before 2005)	Amount of PentaBDE per bus	Total amount PBDE in imported busses in use (originating from **Europe** before 2005) in 2010
52,200 x 0.75* x 0.12 = 4,698	320 g per bus	**4,698 x 0.32 kg x 0.05= 75 kg POP-PBDEs**
Number of imported busses (originating from **Asia** before 2005)	Amount of PentaBDE per bus	Total amount PBDE in imported busses in use (originating from **Asia** before 2005) in 2010
52,200 x 0.75* x 0.69 = 27,014	320 g per bus	**27,014 x 0.32 kg x 0.05= 432 kg POP-PBDEs**
Number of imported busses (originating from **US/North America** before 2005)	Amount of PentaBDE per bus	Total amount PBDE in imported busses in use (originating from **US/North America** before 2005) in 2010
52,200 x 0.75* x 0.07 = 2,741	320 g per bus	**2,741 x 0.32 kg x 0.5= 439 kg POP-PBDEs**
Number of busses (originating from other regions before 2005)	Amount of PentaBDE per bus	Total amount PBDE in imported busses in use in 2010 (originating from other regions before 2005)
52,200 x 0.75* x 0.12 = 4,698	320 g per bus	**4,698 x 0.32 kg x 0.05= 75 kg POP-PBDEs**
Total POP-PBDEs 22)		**Sum of POP-PBDEs: 2,105 kg**

*fractions of vehicles produced before 2005

4.2.6 Data compilation of end-of-life vehicles (ELV)

In a developing country like Nigeria economy does not allow most car/vehicle owners to change their vehicles frequently but to keep and (let) repair the vehicles until it becomes non-functional. The estimation of the average life expectancy of vehicles in Nigeria was difficult since in particular cars are often not deregistered, are stored in backyards for years or just near the roads and are reused again. For the purpose of this inventory, after consulting with experts the average time of vehicles in use and stockpiled with reuse was estimated to 30 years.

4.2.6.1 Estimate of PBDEs in end-of-life vehicles in 2010

The estimation of vehicles reaching end-of-life for the respective year is relevant for planning of waste/resource management of this material flow.

A) Vehicles reaching end-of-life based on average life span

Based on the estimated average life span of 30 years, roughly 3.3 % of cars could reach end-of-life for a particular year for a homogenous age distribution. Since the vehicle import has increased within the last 15 years, the share of ELVs can be considered lower than the 3.3 % since a larger share have been imported more recently and are not operated that long. Therefore for this preliminary inventory it is estimated that approximately 2% of the vehicle fleet (vehicles in use) have entered end-of-life in 2010. These are 132,453 vehicles from which approximately 95% have been produced before 2005 and therefore 125,830 vehicles are potentially impacted by POP-PBDEs (Table B8-a).

Table B-8a: Estimated amount of end-of-life vehicles in Nigeria in 2010

Vehicle	Number
***Cars**	**88,081**
***Buses**	**36,491**
***Trucks**	**1,258**
Total	**125,830**

*Distribution between vehicle types were calculated with the distribution in Abam and Unachukwu (2009) with 70% (cars), 29% (buses) and 1% trucks

B) End-of-life vehicles due to accidents

Additionally vehicles reach end-of-life due to accidents. About 2,673 vehicles were involved in accidents from January – June 2010[22] and hence approximately 5,300 for the whole inventory year 2010. Considering that these vehicles have also reached end-of-life the total amount of end-of-life vehicles is slightly higher (Table B8-b) and this total amount is used for the inventory.

Table B-8b: Total estimate of end-of life vehicles in 2010

Vehicle	Numbers
***Cars**	**91,636**
***Buses**	**37,964**
***Trucks**	**1,309**
Total	**130,909**

*Distribution between vehicle types were calculated with the distribution in Abam and Unachukwu (2009) with 70% (cars), 29% (buses) and 1% trucks

The POP-PBDEs in end-of-life in 2010 were calculated according to the *POP-PBDE Inventory Guidance*[7] (Table B-9).

[22] Resourcedat: (http://resourcedat.com/2011/08/nigerian-road-traffic-stats-jan-june-2011/)

Table B-9 (corresponding to Table 5- 2 of *POP-PBDE Inventory Guidance*): Amount of POP-PBDEs in end-of-life vehicles in the inventory year 2010 in the country (please note that only the vehicles produced between 1975 to 2004 are considered for POP-PBDEs inventory)

Number of ELV cars/trucks (originating from **Europe** before 2005)	Amount of c-PentaBDE per ELV car/truck	Total amount POP-PBDEs in ELV cars/trucks in 1980-2010 (originating from **Europe** before 2005)
Cars: **91,636** x 0.12* = 10,996 Trucks: **1,309** x 0.12* = 157	160 g per car/truck	**11,153 x 0.16 kg x 0.05 = 89 kg POP-PBDEs**
Number of ELV cars/trucks (originating from **Asia** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in ELV cars/trucks in 1980-2010 (originating from **Asia** before 2005)
Cars: **91,636** x 0.69* = 63,229 Trucks: **1,309** x 0.69* = 903	160 g per car/truck	**64,132 x 0.16 kg x 0.05 = 513 kg POP-PBDEs**
Number of ELV cars/trucks (originating from **US/North America** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in ELV cars/trucks in 1980-2010 (originating from **US/North America** before 2005)
Cars: **91,636** x 0.07* = 6,415 Trucks: **1,309** x 0.07* = 92	160 g per car/truck	**6,507 x 0.16 kg x 0.5 = 521 kg POP-PBDEs**
Number of ELV cars/trucks (originating from **other regions** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in ELV cars/trucks in 1980-2010 (originating from **other regions** before 2005)
Cars: **91,636** x 0.12* = 10,996 Trucks: **1,309** x 0.12* = 157	160 g per car/truck	**11,153 x 0.16 kg x 0.05 = 89 kg POP-PBDEs**
Number of ELV busses (originating from **Europe** before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV busses in 1980-2010 (originating from **Europe** before 2005)
37,964x 0.12* = 4,556	320 g per bus	**4,556 x 0.32 kg x 0.05 = 73 kg POP-PBDEs**
Number of ELV busses (originating from **Asia** before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV busses in 1980-2010 (originating from **Asia** before 2005)
37,964x 0.69* = 26,195	320 g per bus	**26,195 x 0.32 kg x 0.05 = 419 kg POP-PBDEs**
Number of ELV busses (originating from **US/North America** before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV busses in 1980-2010 (originating from **US/North America** before 2005)
37,964x 0.07* = 2,657	320 g per bus	**2,657 x 0.32 kg x 0.5 = 425 kg POP-PBDEs**
Number of ELV busses (originating from **other regions** before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV busses in 1980-2010 (originating from **other regions** before 2005)
37,964 x 0.12* = 4,556	320 g per bus	**4,556 x 0.32 kg x 0.05 = 73 kg POP-PBDEs**
Total POP-PBDEs		**Sum of POP-PBDEs: 2,202kg**

*factor estimating the share of vehicles from the region of production (12% from Europe, 69% from Asia, 7% from US/North America and 13% from other regions)

4.2.6.2 End-of-life vehicles in the years 1980-2010

For estimating the total deposited materials from the transport sector and the POP-PBDEs therein the amount of vehicles having reached end-of-life over the last 30 years were estimated. Due to the lack of de-registration data, estimates were made for the share of vehicles having entered end-of-life from those registered in 1980-1985 (90%), 1986-1990 (75%), 1991-1995 50%, 1996-2000 (25%) and 2001-2004 (10%) respectively (see Table B-11). For those registered 2005-2010 were considered to be still in use.

Total End-of-life vehicles between 1980 - 2010:

- Based on the preliminary inventory approx. 2 million passenger cars, 0.98 million busses (largely minibuses) and 34,000 trucks have entered end-of-life the last three decades;
- It is estimated that 95% of these vehicles have been produced before 2005;
- Regional distribution of these vehicles were assumed to be similar to the current car and bus fleet and trucks (Asia (69%), Europe (12%) North America (7%);

Table B-10: Estimate of vehicles in end-of-life (of vehicles registered 1980-2004)

Year	Category	Estimate of vehicles registered	Percentage in end-of-life	Estimate of vehicles in end-of-life	Estimate of vehicles entering current transport fleet
1980-1985	**Cars**	1,133,002	90	1,019,702	113,300
	Trucks	16,186		14,567	1,619
	Buses	469,386		422,447	46,939
1986-1990	**Cars**	122,676	75	92,007	30,669
	Trucks	1,753		1,315	438
	Buses	40,335		30,251	10,084
1991-1995	**Cars**	492,905	50	246,453	246,453
	Trucks	7,042		3,521	3,521
	Buses	204,204		102,102	102,102
1996-2000	**Cars**	3,395,000	25	848,750	2,546,250
	Trucks	48,500		12,125	36,375
	Buses	1,406,500		351,625	1,054,875
2001-2004	**Cars**	1,890,000	10	189,000	1,701,000
	Trucks	27,000		2,700	24,300
	Buses	783,000		78,300	704,700
Total	**Cars**			**2,395,912**	**4,637,672**
	Trucks			**34,228**	**66,253**
	Buses			**984,725**	**1,918,700**

The POP-PBDEs in end-of-life in 2010 were calculated according to the *POP-PBDE Inventory Guidance*[7] (Table B-11).

Table B-11 (corresponding to Table 5- 3 in the PBDE inventory guidance[7]) Amount of POP-PBDEs in wastes from end-of-life vehicles disposed to landfills/dumps from 1980 until inventory year 2010[23] in the country (please note that only the vehicles produced between 1975 to 2004 are considered for POP-PBDEs inventory)

Number of ELV cars/trucks (originating from **Europe** before 2005)	Amount of c-PentaBDE per ELV car/truck	Total amount POP-PBDEs in ELV cars/trucks in 1980-2010 (originating from **Europe** before 2005)
Cars: 2,395,912 x 0.12* = 287,509 Trucks: 34,228 x 0.12* = 4,107	160 g per car/truck	**291,616 x 0.16 kg x 0.05 = 2,333 kg POP-PBDEs**
Number of ELV cars/trucks (originating from **Asia** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in ELV cars/trucks in 1980-2010 (originating from **Asia** before 2005)
Cars: 2,395,912 x 0.69* = 1,653 179 Trucks: 34,228 x 0.69* =23,617	160 g per car/truck	**1,676,796 x 0.16 kg x 0.05 = 13,414 kg POP-PBDEs**
Number of ELV cars/trucks (originating from **US/North America** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in ELV cars/trucks in 1980-2010 (originating from **US/North America** before 2005)
Cars: 2,395,912 x 0.07* = 167,714 Trucks: 34,228 x 0.07* = 2,396	160 g per car/truck	**170,110 x 0.16 kg x 0.5 = 13,609 kg POP-PBDEs**
Number of ELV cars/trucks (originating from **other regions** before 2005)	Amount of c-PentaBDE per car/truck	Total amount POP-PBDEs in ELV cars/trucks in 1980-2010 (originating from **other regions** before 2005)
Cars: 2,395,912 x 0.12* = 311,469 Trucks: 34,228 x 0.12* = 4,450	160 g per car/truck	**315,919 x 0.16 kg x 0.05 = 2,527 kg POP-PBDEs**
Number of ELV busses (originating from **Europe** before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV busses in 1980-2010 (originating from **Europe** before 2005)
984,725 x 0.12* = 118,167	320 g per bus	**118,167 x 0.32 kg x 0.05 = 1,891 kg POP-PBDEs**
Number of ELV busses (originating from **Asia** before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV busses in 1980-2010 (originating from **Asia** before 2005)
984,725 x 0.69* = 679,460	320 g per bus	**679,460 x 0.32 kg x 0.05 = 10,871 kg POP-PBDEs**
Number of ELV busses (originating from **US/North America** before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV busses in 1980-2010 (originating from **US/North America** before 2005)
984,725 x 0.07* = 68,931	320 g per bus	**68,931 x 0.32 kg x 0.5 = 11,028 kg POP-PBDEs**
Number of ELV busses (originating from **other regions** before 2005)	Amount of c-PentaBDE per bus	Total amount POP-PBDEs in ELV busses in 1980-2010 (originating from **other regions** before 2005)
984,725 x 0.12* = 128,014	320 g per bus	**128,014 x 0.32 kg x 0.05 = 2,048 kg POP-PBDEs**
Total POP-PBDEs		**Sum of POP-PBDEs: 57,721 kg**

*factor estimating the share of vehicles from the region of production (12% from Europe, 69% from Asia, 7% from US/North America and 12% from other regions)

[23] The years actually considered in the calculation were 1988-2004, since vehicles newly registered between 2005 and 2010 were considered still in use in this preliminary inventory.

4.2.7 POP-PBDEs in polymers from end-of-life vehicles treatment (recycling, open burning, and disposal)

In total it was estimated that 2,700 tonnes of polyurethane foam from vehicles entered its end-of-life phase in 2010 (Table B-12) and 70,400 tonnes from 1980 to 2010. There are some polyurethane and plastic recycling activities in Nigeria. In Nigeria some of old seats that are not badly damaged are re-used. Polymers are also partly thermally recycled for heating and cooking (and open burned as waste management practice including cable burning for recycling of the copper). During the short study period no solid assessment could be conducted on recycling quota of these polymers which would allow an estimation for this inventory[24]. Therefore as a simple approach for this preliminary inventory it was assumed that the polymers from vehicles were recycled and thermally treated in the same proportions as the general municipal solid waste in Nigeria: this means a recycling rate of 13%, and a share of thermally treatment/open burning of 16% with the remaining 71% landfilled[25].

With this simple assumption for 2010 from the 2,700 tonnes of polyurethane (containing 2,200 kg POP-PBDEs) reaching end-of-life, 351 tonnes (containing 286 kg POP-PBDE) were recycled and 432 tonnes of polyurethane (containing 352 kg POP-PBDEs) was thermal treated (open burning and use for cooking/heating) (Table 12). The remaining 1,920 tonnes of polyurethane foam (estimated to contain 1,560 kg POP-PBDEs) were considered to be disposed/dumped.

For 1980 to 2010 from the 70,400 tonnes of polyurethane (containing 57,700 kg POP-PBDEs) reaching end-of-life, 9,150 tonnes (containing 7,500 kg POP-PBDEs) were recycled and 11,300 tonnes of polyurethane (containing 9,240 kg POP-PBDEs) was thermal treated (open burning and use for cooking/heating). The remaining 50,000 tonnes of polyurethane (containing 41,000 kg POP-PBDEs) were considered to be disposed/dumped.

For recycling (and the other end-of-life treatment) there is a considerable uncertainty about this estimate since the distribution of end of life treatment (recycling, thermal treatment and disposal) for this preliminary inventory is only based on the end-of-life treatment for average Nigerian waste[23]. Currently plastic/polymer recycling is established in Nigeria. Therefore a detailed assessment on the recycling and end-of-life situation of plastic/polymer will be established in future leading to more solid database for an in depth inventory then.

[24] Iron, copper, aluminium, catalyst converters and tyres are recycled. Most iron, copper and catalysts have subsequently been exported; however, there are some recycling of iron and aluminium in Nigeria; (Agbo, 2011)

[25] http://mr-gadget.hubpages.com/hub/Effect-of-waste-disposal-and-recycling-in-Nigeria

Table B-12: Vehicle polymers entering the waste stream (for the year 2010) and assumed treatment considering average end-of-life treatment of Nigerian waste.

WEEE Category	Total waste stream	Recycled	Thermally treated	Disposed
Total PUR foam in ELVs (2010) (tonnes)	2,700	351	432	1,920
Related POP-PBDEs (kg)	2,200	286	352	1,560
Total PUR foam in ELVs (1980 - 2010) (tonnes)	70,400	9150	11,300	50,000
Related POP-PBDEs (kg)	57,700	7,500	9,240	41,000

4.2.8 Calculation of individual POP-PBDEs homologues in the transport sector

For the Stockholm Convention the listed POP-PBDE homologues: tetraBDE, pentaBDE, hexaBDE and hepaBDE need to be finally considered and not the total amount of c-PentaBDE or c-OctaBDE. These homologues were calculated from the estimated amount of c-PentaBDE (or c-OctaBDE) by considering the percentages of homologues in the commercial mixtures given in Table B-13.

Table B-13 (Corresponding to table 5- 4 in the *PBDE inventory guidance*[7]) Recalculation of c-PentaBDE present in the transport sector to the listed POP-PBDEs for the relevant life cycle stages*.

(in kg)	Distribution homologues c-PentaBDE	POP-PBDEs in vehicles currently in use in inventory year (2010) (in kg)	POP-PBDEs imported* in vehicles in the inventory year (2010) (in kg)	POP-PBDEs in end-of-life vehicles in the year (2010) (in kg)	**POP-PBDEs recycled from transport sector (2010) (in kg)**	POP-PBDEs disposed off in the past from the transport sector (1980-2010) (in kg)
Inventoried c-PentaBDE		216,000	2,100	2,200	286	57,700
TetraBDE	32%	69,200	674	705	92	21,200
PentaBDE	56%	121,000	1,180	1,230	160	37,100
HexaBDE	9%	19,500	189	198	26	5,960
HeptaBDE	0.5%	1,080	11	11	1.4	289

* Please note that the imported vehicles are also included in the inventory of "current transport" and that these two categories are not summed up

4.3 Material and substance flow analysis of POP-PBDEs and POP-PBDE containing materials from transport sector

For compiling the data in a visualized form and to gain an overview on the life cycle of materials containing POP-PBDEs in the transport sector, a material flow analysis (MFA) of these materials and a substance flow analysis (SFA) of the c-PentaBDE and associated POP-PBDEs have been performed.

4.3.1 Material and substance flow analysis

MFA systematically shows the bulk material flows through society in a comprehensive way. The underlying principle of MFA is to account for all materials entering and leaving a system (e.g. country or company), based on a mass-balancing approach. The flow of materials/substance starts at a source (e.g. production or import) and ends at a sink[26] (e.g. export or landfill).

SFA is a specific type of MFA used for tracing the flow of a selected chemical (or group of substances) through a defined system (Baccini and Brunner 2012[27], Brunner and Rechberger 2003[28]).

A key aim of material flow analysis is to visualise the complex material/substance flow of a selected system (in this case the flow of POP-PBDEs in transport in Nigeria) in a simplified but correct manner to e.g. serve as a tool/support for decision making in waste management.

In the current study the system boundary is the country of Nigeria. The goods included in this study are main vehicle categories (cars, busses, and trucks). The substances considered in the substance flow are the POP-PBDEs. The system therefore comprises the materials in transport in Nigeria and focus on the listed POP-PBDEs used in transport (largely in polyurethane). The stocks and flows in the system include importation, use/reuse, end-of-life (recycling, thermal treatment, landfill/dump) and export.

4.3.2 Overview of flows and stocks of POP-PBDEs in transport sector Nigeria

The strength of the material/substance flow analysis is the visualization of complex material/substance flows. University Vienna provides here one of the best material flow software (STAN) as open source[29].
The above compiled POP-PBDE inventory data were included in the STAN software[29] for visualizing the stocks and flows of possibly impacted PUR foam in transport (Figure B-2) and of the estimated contained POP-PBDEs (Figure B-3). Figure B-2 shows the material flow of polyurethane in the transport sector and Figure B-3 the related substance flow of POP-PBDEs.

[26] A final sink is defined as a spot within the hydro-, pedo-, litho- or atmosphere, where the retention time of a substance is >10.000 years (Brunner and Rechberger 2003) or where it degrades.
[27] Baccini P, Brunner PH (2012) Metabolism of the anthroposphere: Analysis, evaluation, design. 2nd edition, MIT Press, Cambridge US.
[28] Brunner PH, Rechberger H (2003) Practical Handbook of Material Flow Analysis. Lewis Publishers.
[29] http://iwr.tuwien.ac.at/resources/downloads/stan.html

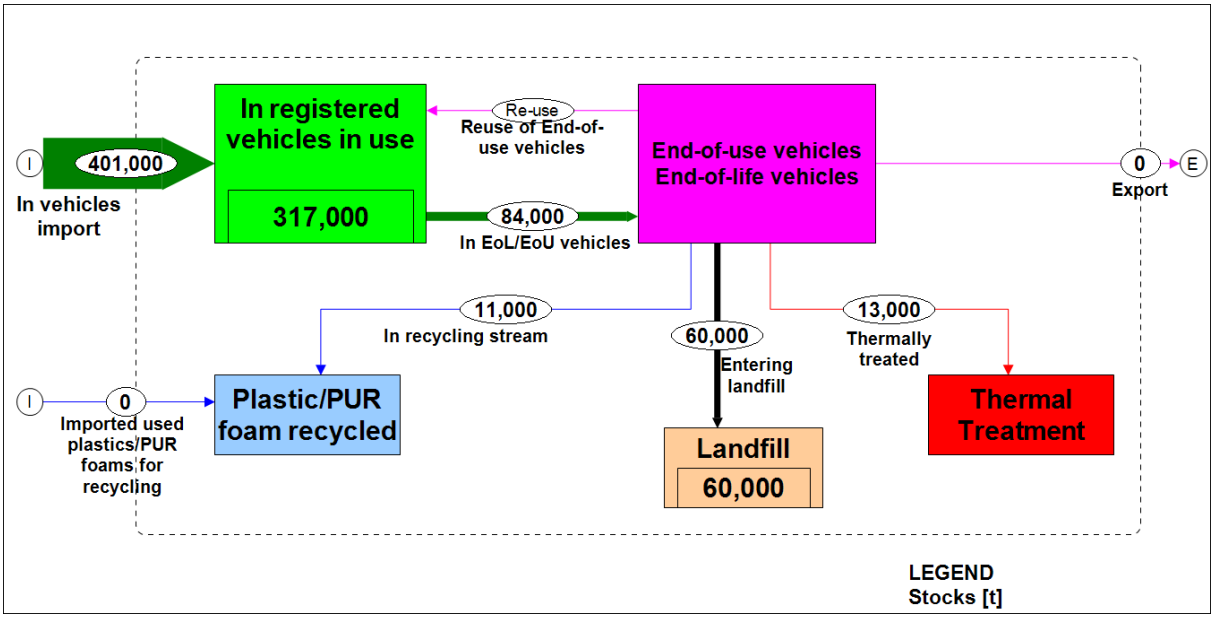

Figure B-2: Substance flow and stocks of polyurethane foam (in tonnes) in/from transport sector in Nigeria (1980-2010). The stocks are for the inventory year 2010. The flows are the total volume from 1980-2010.

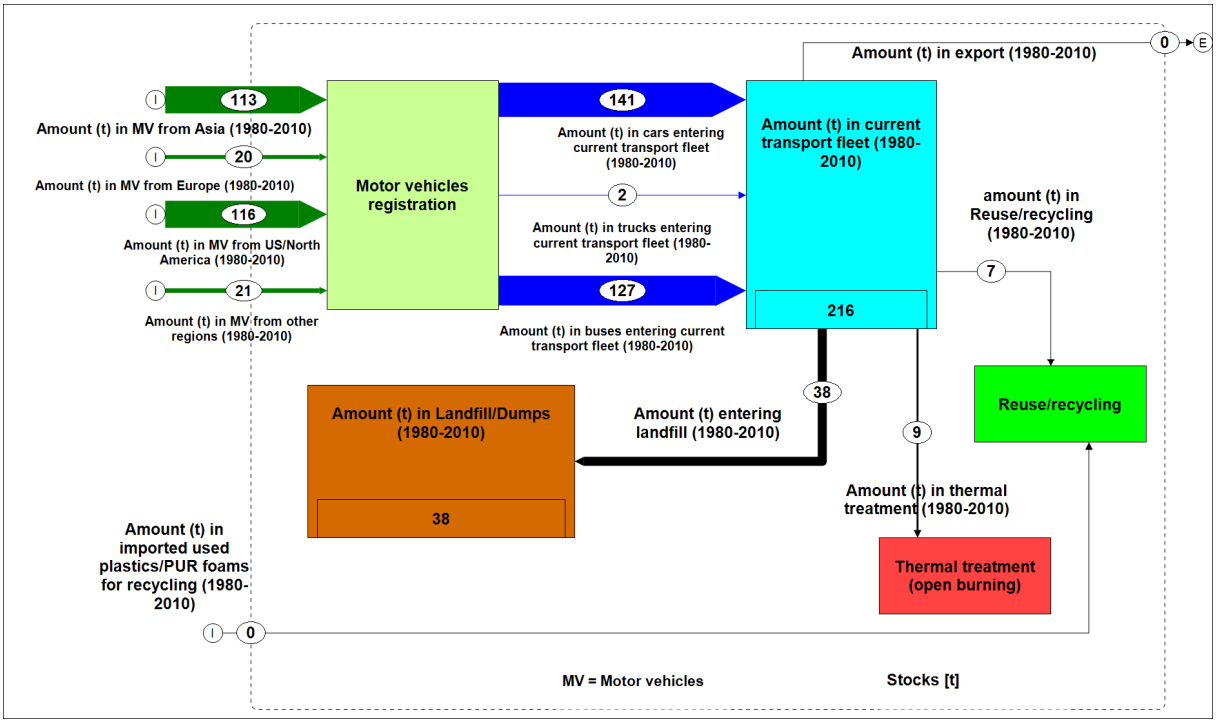

Figure B-3: Substance flow and stocks of POP-PBDEs in transport sector in Nigeria (1980-2010). The stocks are for the inventory year 2010. The flows are the total volume from 1980-2010.

5 STEP 4: Managing and evaluating data

The current inventory of POP-PBDEs in vehicles can be considered a preliminary inventory since it includes a range of uncertainties and assumptions (see below). It is the first inventory compilation of the Nigerian transport sector addressing also end-of-life vehicles.

5.1 Evaluation of data and further improvement of the data

In this inventory step the data are assessed for completeness and plausibility possibly including the comparison with data from other countries in the region. Within the short time available for the current inventory this step has only be done to some extent.

Data gaps in this study have (partly) been filled by extrapolation of data. This was done e.g. for the import data from different world regions and for the amount of vehicles in end-of-life (see above).

5.2 Uncertainties and improvements for developing a more robust inventory

The current preliminary inventory contains a range of uncertainties and assumptions:

- The distribution of originating regions of imported vehicles is currently based on data from Lagos vehicle statistics 2010 and was then extrapolated to the other regions of the country.
- There was no official statistics of end-of-life vehicles. The amount of end-of-life vehicles in the current inventory was therefore estimated from the total amount of vehicles in use and an estimated life span of vehicles. The improvement of this situation will need to wait for the overall development of vehicle de-registration system in Nigeria.
- The distribution of vehicles that were produced before 2005 and still in use in 2010 was estimated for those vehicles imported after 2005 by expert judgement for the different inventory sector.
- In the current inventory ships, airplanes and trains were not included.
- A large uncertainty exists for the percent distribution of end-of-life treatments including the recycling based for this preliminary inventory on data for general waste. This will need further assessment efforts for an in-depth inventory in particular considering that currently larger plans on polymer recycling exists in Nigeria. Therefore this is rather a task within the NIP implementation and not for short term improvement of the inventory.
- The POP-PBDE Inventory Guidance (chapter 5) mentions that the POP-PBDE impact factors for the different regions are based on a few measured data and on estimates. Therefore an in-depth inventory could be improved by screening and analysis of POP-PBDEs in vehicles.

5.3 Managing the data

The gathered general inventory data for Nigeria's transport sector have been compiled

- vehicles in the different life cycle stages

- materials in the transport sector potentially contaminated by POP-PBDE (volume of PUR foam[30]).
- POP-PBDE in the

and have been compiled in a material/substance flow.
Since the data are valuable for the (waste) management of end-of-life vehicles (and prediction of end-of-life vehicles) the data will also be made available to departments responsible for waste and resource management in Nigeria (Ministry of Environment and other responsible ministries). The data will then be fed into and further managed within a database of the governmental body responsible for waste and resource management.

5.4 Data gaps and need for improvements (preliminary action plan consideration)

This substance flow analysis of POP-PBDE in the transport sector describes the flow from import, use/stocks until the end-of-life including the recycling stage. There are currently considerable uncertainties in respect to the volumes of recycled polymers and to which products these polymers are recycled. Further due to the plan of the government to increase the recycling of polymers this issue needs to be better assessed and should become a priority within the action plan of NIP. Within this assessment the options and limitations of POP-PBDEs separation and management will be assessed.
Currently no assessment of the flows/releases of POP-PBDEs into the environment and towards human exposure in the different life cycle stages have been performed. This is a future task and might also be included in the action plan.
A detailed assessment in particular of the different end-of-life and recycling options need to be carried out focusing on best practice approaches which can be implemented in Nigeria in future.

6 STEP 5: Inventory reporting

In the final step 5 the compiled data are included with the methodology used and the detailed calculation in the POP-PBDE inventory report as an own chapter.
This task has been fulfilled with the report you are currently reading. At the same time the report was compiled in a way that it can be used as case study.

[30] In addition back-coated textile in the transport sector has been treated to some extent with POP-PBDE and other flame retardants. No monitoring study have been published on the extent.