A PCB INVENTORY AND MATERIAL FLOW CONSIDERING PRODUCTION, HISTORIC USES, WASTE MANAGEMENT, SINKS AND SOURCES

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Introduction

The production of polychlorinated biphenyls (PCBs) has stopped about 30 years ago. The global production and use has been compiled and is estimated at around 1.3 million tonnes[1,2]. PCBs have been used in a wide range of closed and open applications which are still present in many countries. The global inventory of PCBs of transformers and capacitors revealed approximately 3 million tonnes of waste PCBs oils and PCBs containing equipment[3]. In the frame of the Stockholm Convention, persistent organic pollutants (POPs) including PCBs are managed and phased out for the protection of human health and the environment. For this aim countries are developing inventories for the individual POPs for assessing their current relevance and managing the remaining stockpiles. PCBs were already included in the 12 initial POPs and were therefore targeted now globally for about a decade. PCB inventories normally only address the PCBs in closed applications in current use and stocks[3]. The PCBs in open applications are not addressed in these inventories and are not directly mentioned in the Stockholm Convention text or the EU POP inventory. Also an inventory of total historic PCBs use is not made and has not been published for any country to our knowledge.

However, it has been revealed that for industrial countries the open applications of PCBs have high relevance for contamination of the environment in particular the application of paints[4] and sealants[5a,b]. Additionally it has been revealed that the application of paint and sealants are a contemporary source for PCBs exposure of cattle[6,7] and chicken/eggs[8]. Furthermore open applications of PCBs in buildings are a contemporary exposure source for humans[9]: for people living in these buildings the PCB exposure via this pathway can considerably exceed their PCB exposure via food[9]. This demonstrates that a PCB inventory and management should also include the PCBs from open applications at least in industrial countries having used these applications in the past.

Furthermore it has been discovered over the last decade that disposed PCBs and PCB contaminated area can result in contamination of the food chain[10a,10b]. Therefore in addition to the PCBs in current use and stocks also these PCB legacies should be considered in a national PCB inventory. This has recently been taken up by the UNEP Dioxin toolkit[11] where PCB reservoirs and contaminated sites are highlighted as potentially PCDF contaminated sites which should be inventoried[11].

During the last 30 years a wide range of information has been compiled in Germany on total PCB use and the distribution in different PCB applications or remaining PCB sources at a certain time. In the current study these informations have been compiled.

Materials and methods

Information on PCB production and use were compiled from a range of studies. Several studies have been initiated by Research & Development project under the German Environmental Ministry[12-14]. Additional information were extracted from other research studies or national or international reports.

Information on the situation of PCBs in open applications from other countries have been screened and were considered in the compilation and for formulating assessment gaps.

Furthermore the German Environmental Agency is currently conducting a Research & Development project for assessing the impact of Dioxins and PCBs in the environment. Also findings from this project were considered where appropriate.

For air data two additional main information sources were used

a) The German PRTR register was screened for available data and assessed for data gaps.
b) The German POPs inventory having compiled information from PCB emission from thermal sources.

Results and discussion

Total PCB production and use volumes in former East and West Germany

In Germany, from 1930 to 1983, the Bayer AG produced about 159,062 tonnes of PCBs as Clophen in different chlorination grades[2]. After Hillejan & v. Schaaffhausen (1990)[13] a total of approximately 83,000 tonnes PCB were used by West German companies in different applications and products, of which 72,500 tonnes remained in West Germany (Figure 1).

The production and used quantities in East Germany (former German Democratic Republic (GDR)) were far lower. The production of PCBs started in East-Germany in 1955 with highly chlorinated biphenyls[14]. The East-German production volume was 60 t in 1955, until 1964 the total production included about 1,000 tonnes[15]. The PCB production was stopped by a devastating fire and the factory was closed down. The PCB consumption in East Germany was then covered by imports especially from Czechoslovakia. Total PCB imports from 1962 to 1985 for East Germany were 18,600 tonnes[14]. The total amount of PCB in technical applications remained in East Germany is estimated to about 12,300 tonnes for 1955 until 1985 (Figure 1).

Therefore in Germany, approximately 85,000 tonnes of PCB were used as pure products as well as in mixtures with other substances in open and closed systems[12].

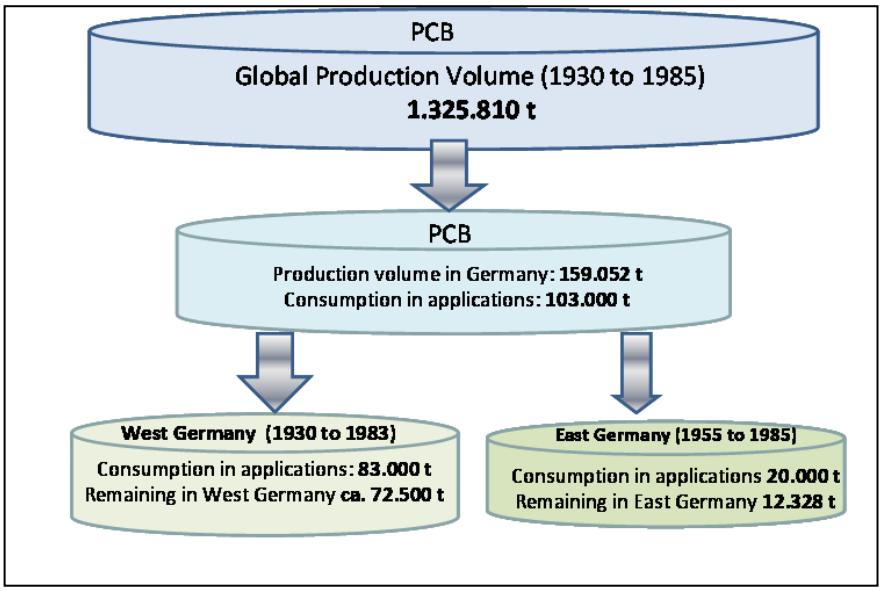

Figure 1: Production and consumption quantities of PCB in former West Germany and East Germany. Source: Balzer & Rauhut, 1987; de Voogt et al. 1989; Hillejan & Schaaffhausen,1990; Schaaffhausen & Gramenz, 1993; Knetsch, 2011[19]

Use of PCBs within Germany

In West Germany approximately 83,000 t of the approx. 150,000 t produced were brought in applications. The rest were exported as PCBs.

In closed systems, they served as coolants in transformers (fluids), as a dielectric in capacitors and as hydraulic oils. The used volumes in closed applications produced in Germany were[12]:

- Askarel-Transformers (ca. 23,000 t)
- Condensers (ca. 24,000 t)
- Hydraulic oils (ca. 12,500 t).

Approx. 24,000 t of PCB were used in open applications in Germany. In open systems, PCBs were used among other things as a plasticizer in sealants and paints, as a lubricant and as flame retardants in ceiling tiles or cable insulations or specific paper. From this the largest share was used for sealants in buildings and constructions (approx. 20,000 t). The distribution of the remaining 4,000 t for other open applications is not documented. Most probably a large share of this was used in paints. The relevance of PCBs in paints was revealed e.g. in Switzerland where a considerably share of electric posts and high pressure pipes at that time contain PCBs and at least 20% of public swimming pools are contaminated with PCBs.

Waste management of the PCBs

From the PCBs in closed application a considerable share has not been disposed/destroyed appropriately (in particular before legislation for PCB management had been introduced):

- From the approx. 12,500 t PCB of hydraulic oil used in mines it is assumed that most has been released during time of use[12,16].
- For condensers in East Germany approximately 50% (5,000 t) were not appropriately disposed. For West Germany the largest part of the approximately 3,200 t PCB in large condensers is considered to have been appropriately disposed. However from the approximately 10,000 t of PCB in small condensers a considerable share ended in landfills, shredder facilities and secondary metal industries.
- PCBs in transformers were appropriately managed after legislation came in place.

Overall Detzel et al. (1998)[12] estimated that approx. 30 to 50 % of PCBs in closed applications was not appropriately managed (including landfills). Therefore a large share of PCBs from closed applications was released into the environment.

For PCBs in open applications a large share (50 to 80%) is estimated to be still in use in sealants of buildings and other constructions and in paints. Other open uses with shorter life time (paper, cables) have already been disposed to landfills or were treated in incinerators.

Inventory of releases of PCBs

The atmosphere including airborne depositions plays an important role in respect to the influence of PCBs on terrestrial and aquatic ecosystems. It is an essential vector for the transfer of PCBs into the feed and food chain and ultimately into humans. PCBs can be released from primary sources (e.g. building seals, painted constructions or electrical capacitors) from point sources from disposal (e. g. landfills, contaminated sites, construction debris) as well as of secondary sources (e.g. metal industry, incinerators).

The emission of unintentionally produced PCBs from combustion plants and other thermal and diffuse sources is estimated at 200 kg/year in Germany since 2004[17]. Currently only a small share of this is covered by the pollution release transfer register (approximately 24 kg for air for three years) by the metal/steel and cement industry. Releases to further compartments like water and soil are documented by the German Pollutant Release and Transfer Register (ePRTR). It is an online information system for the quantification of the release of such pollutants in the environment. The on-line register of Germany (http://www.thru.de/thrude/) offers the possibility of operation-related emission data to more 90 pollutants. PCB is a category of substances in this list of pollutants. A notification for the register is only required if the thresholds for the release of 0.1 kg / year to air, water and soil are exceeded. Annual report information are available from 2007 to 2012 with detailed information of the branch of industry and their incorporation into the air, water bodies and (via the sewers) in external sewage treatment plants as well as disposed of hazardous and non-hazardous waste into the environment (Table 1).

Table 1: Notification for the German ePRTR of emission for PCB in the air, water and waste water
Source: http://www.thru.de/thrude/

PCB in kg /year	Air	Water	Transfer with waste water	Reporting PRTR
2010	9,7		1,78	Production of iron and steel, cement (air), sewage plant (Transfer with water)
2011	5,6	0,9		Production of iron and steel, urban drainage (water)
2012	9,02	0,8	2,73	Production of iron and steel, cement, incineration (air), sewage plant (Transfer with water), Urban drainage (water)

In environmental matrices inter alia air, soil and vegetation including feed (grass, silage, hay) the PCB congeners stem almost exclusively from commercial legacy PCBs with the exemption of PCB11[18]. This demonstrates the dominance of the industrially produced PCBs as emission and contamination source.

Further considerations

The current release of industrial PCBs and the first rough estimate of these releases highlight the need to further assess these sources and to appropriately manage PCBs in open applications. A more detailed inventory of open

applications sealants and paints seems also relevant for feed and food safety considering that several of recent PCB food contaminations (in particular chicken/egg, sheep and beef) in e.g. Germany, Netherlands and Switzerland stem from open PCB applications.

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