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Modelling approach for a PCB inventory in our environment

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Abstract: The data of more than 100 monitoring programs in Germany for the substance group of persistent organic pollutants (POPs), including the polychlorinated biphenyls (PCBs) are to be used for a modelling approach for a PCB inventory. The application landscape of the Federation/Laender POP-DioxinDatabase, which is operated in the German Environment Agency, pursues an interdisciplinary approach and includes all these data. A cross-media evaluation and assessment of environmental data are necessary and relevant to the target system, compiling an inventory of PCBs in our environment. The question arises how the integrated modelling concept can control the knowledge-based methods, with the aim to assess the state of PCB contamination in context to PCB-footprints in the environment.

Keywords*: Polychlorinated Biphenyls; environmental monitoring; environmental fate; persistent organic pollutants, emission, Database*

1 PCB INVENTORY – MODELLING APPROACH

1.1 Introduction

PCBs are the term generally given to a substance group of very toxic chemicals, the Polychlorinated Biphenyls. PCBs are one of the substance group of persistent organic pollutants (POPs), regulated in the Stockholm Convention. The total bans on PCB use was enacted in Germany in 1989 by the PCB-, Polychlorinated Terphenyls (PCT) -, Vinyl Chloride (VC)-Prohibition Ordinance. Initially produced on an industrial scale in 1929, due to its physical and chemical properties PCBs soon came into wide use as a coolant and insulation material in the electronics industry, as a hydraulic fluid in the machinery industry, and as a heat transfer fluid in many different industries (so called contained use). It was also used as a plasticizer and flame retardant in paints, varnishes, adhesives, sealants and packaging materials (so called open use).
Thus, PCBs became an extraordinarily successful technical application that has resulted in widespread application all over the world. The fact that PCBsare toxic, persistent, bio accumulated connected with the potential for long-range transport they were widely disseminated in the environmental compartments. They are very soluble in fat so the transfer into the food chain is evident. The fate of the human exposure of PCBs occurs via food ingestion, primarily meats, fish and dairy products.
Although PCBs has been banned for more than 25 yearsthere are still entries on the various paths in the environment, the food chain and ultimately in humans. To quantify pollutions in the past and the present timein Germany there are a lot monitoring programs to investigate the exposition and the fate for PCBs. The study will be used these data for compiling an inventory of PCBs in several compartments. The target is to design an integrated modelling concept used knowledge-based methods, with the aim to assess the state of PCB contamination in context to PCB-footprints in the environment.
This study also explores the limits of the modelling concept linked to environmental monitoring data of heterogeneous programs, managed in the POP-Dioxin Database. For further investigations in context of compiling an inventory, the opportunities and risks for future data storage methods and data models are examined.

1.2 Materials and methods

For more than 15 years data of approximately 100 sectoral monitoring programs of Federal and Laender Agencies and Research Institutes has been stored for the substance group of POPs in a large database system in Germany. The so-called POP-DioxinDatabase has a cross-media approach. That means, data of polychlorinated biphenyls (PCBs) and other POP data in several environmental and human compartments are structured in a database system, accessible via a web-based service interface.
Data on emissions and on environmental monitoring programmes of polychlorinated biphenyls (PCBs) often exist in various forms, qualities, files and databases. If the documentation does not include all relevant parameters, e.g. the scale of time and space and quality assurance, the datasets are impractical for further use. The metadata - data about data - is an essential issue for an integrated approach for evaluation and assessment. Therefore, the harmonisation of this metadata has been done and the data model reflected this approach. The complete analytical datasets are stored as congeners in the database. This allows a single congener specific approach for a cross-media evaluation procedure. The compilation of PCB-footprints and patterns in different compartments, the modelling of environmental transport and fate of PCBs, needs ultimately quality assurance measures for all available data in the data base.
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. Additional information was extracted from other research studies or national or international reports.
Information on the situation of PCBs in open applications from other countries has been screened and was 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 and is looking for sources and sinks. In addition, findings from this project were considered where appropriate.

1.3 Results and discussion

In Germany, from 1930 to 1983, the Bayer AG produced about 159,062 tons of PCBs as Clophen in different chlorination grades. After Hillejan & v. Schaaffhausen (1990) a total of approximately 83,000 tons PCB were used by West German companies in different applications and products, of which 72,500 tons 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. The East-German production volume was 60 tons in 1955, until 1964 the total production included about 1,000 tons. 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 tons. The total amount of PCB in technical applications remained in East Germany is estimated to about 12,300 tons from 1955 until 1985 (Figure 1).

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

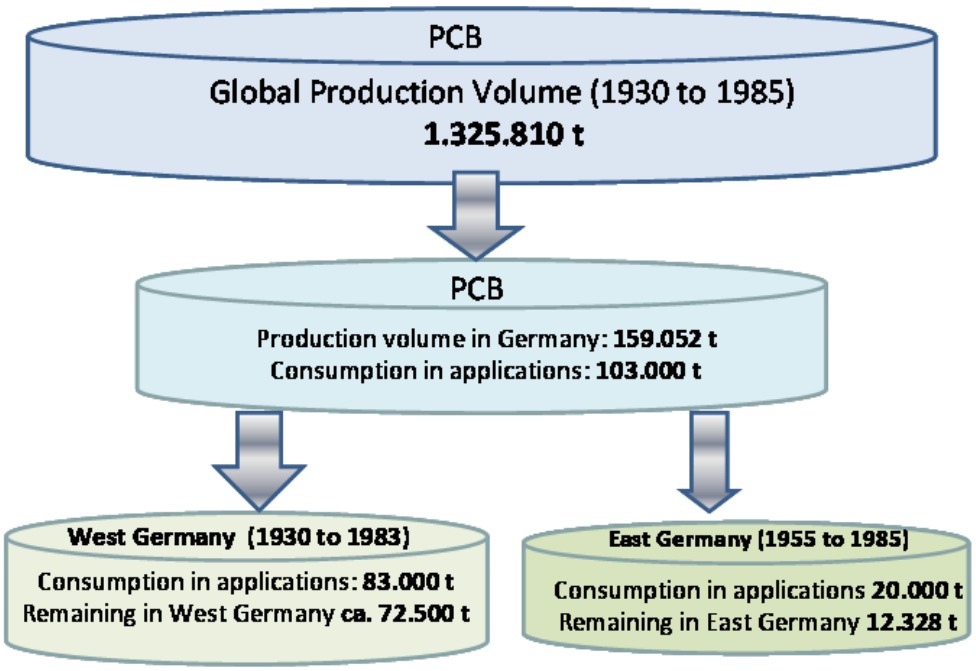

Figure 1.

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

In West Germany, approximately 83,000 tons of the approx. 150,000 tons 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:

- 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.

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.
- 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) 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.
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 2005. Figure 2 shows the time trend of PCB emission from 1990 until 2013, based on the national trend tables of the German reporting of atmospheric emissions (1990 – 2013).

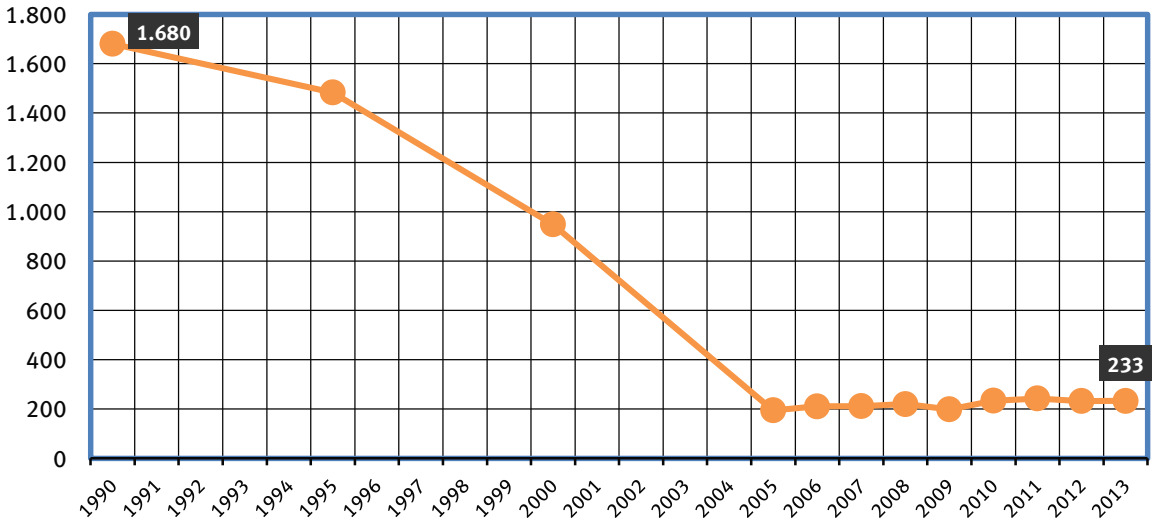

Figure 2.

Time trend of PCB emission from 1990 until 2013 in Germany, Source: German reporting of atmospheric emissions (1990 – 2013)

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 is available from 2007 to 2013 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.

Figure 3 gives an overview of the time trend of the PCB-concentration in ambient air from 2000 to 2011. This evaluation was possible using relevant information in the Meta Database of the POP-Dioxin-Database and the cross-media approach of the data model.

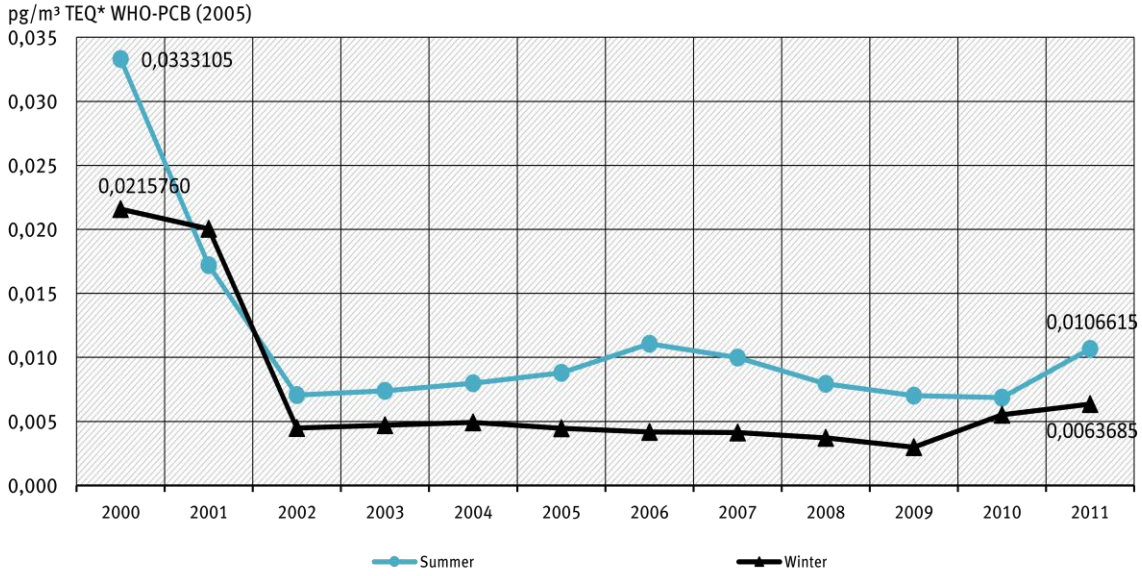

Figure 3.
Time trend of PCB concentration in ambient air from 200 until 2011 in Germany, Source: The German POP-Dioxin Database (www.uba.de)

1.5 Conclusions and Recommendations

The data model of the application of the Federation/Laender POP-Dioxin Database realized an interdisciplinary approach with a detailed structure for metadata and analytical data of the substance group of persistent organic pollutants (POPs). A cross-media evaluation and assessment of environmental data are necessary and relevant to the target system, compiling an inventory of PCBs in our environment. The releases of PCB into the environment via different pathway are not known in details. Emission data are necessary to identify the sources and to find sinks and reservoirs of PCB in the environment. The pathway via the ambient air is obviously (Figure 3). Particular attention is paid to look to the food chain, the transfer into food and feeding stuff. For PCBs the most important sources are the open applications such paints and sealants, which are responsible for the majority of the current emissions and atmospheric deposition.
A challenge for the future is get more data for this database for these technical products to recognise which pattern of PCB contamination in food is relevant. The integrated modelling concept of the POP Dioxin-Database could be adopted for other chemicals in our environment.

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