TEXTE
41/2014

Identification of relevant emission pathways to the environment and quantification of environmental exposure for Bisphenol A

Umwelt Bundesamt

| TEXTE | 41/2014

ENVIRONMENTAL RESEARCH OF THE
FEDERAL MINISTRY OF THE ENVIRONMENT,
NATURE CONSERVATION AND NUCLEAR SAFETY

Project No. (FKZ) 360 01 063
Report No. (UBA-FB) 001933/E

Identification of relevant emission pathways to the environment and quantification of environmental exposure for Bisphenol A

by

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UMWELTBUNDESAMT

ISSN 1862-4804

Study performed by:	BiPRO GmbH Grauertstr. 12 81545 München, Germany
Study completed in:	November 2012
Publisher:	Federal Environment Agency (Umweltbundesamt) Wörlitzer Platz 1 06844 Dessau-Roßlau Germany Phone: +49-340-2103-0 Fax: +49-340-2103 2285 Email: info@umweltbundesamt.de Internet: http://www.umweltbundesamt.de http://fuer-mensch-und-umwelt.de/
Edited by:	Section IV 2.3 Chemicals Enken Hassold

Dessau-Roßlau, June 2014

Explanation regarding confidential information:

Parts of the original version of this report are based on confidential data taken from REACH registration dossiers for bisphenol A submitted to the European Chemicals Agency (ECHA) by manufacturers or importers. Especially information on production or import volumes as well as detailed information on contents of Chemical Safety Reports is regarded as confidential business information, which must not be published or distributed to players on the market. The confidential parts of the original version of the report (including tables in the annex) concerning evaluation of registration dossiers for BPA have been deleted in this public version of the report. Some chapters are therefore only partly available.

Abstract

The aim of the project was to fill knowledge gaps as regards mass flow and uses of bisphenol A (BPA). Information about unknown emission sources had to be collected and evaluated. The first step of the project aimed at evaluation of registration dossiers for BPA submitted to the European Chemicals Agency (ECHA). Information about production and use of BPA in the EU was collected and the chemical safety assessment (CSA) performed by registrants was evaluated. In a second step, literature information and data from industry was collected to identify relevant life cycle steps not included in the CSR and to evaluate whether these uses result in relevant emissions of BPA to the environment. The third part of the project focused on collection and evaluation of up-to-date data on environmental concentrations of BPA in different environmental compartments.

Kurzbeschreibung

Das Ziel dieses Vorhabens war es, die aktuellen Wissenslücken über den Stofffluss und die Verwendungen von BPA zu schließen. Informationen zu bisher nicht bewerteten Quellen, Expositionspfaden und -mengen sollten identifiziert und bewertet werden um eine präzisere Stoffbewertung durchführen zu können. In einem ersten Schritt des Projektes wurden daher bei der Europäischen Chemikalienagentur (ECHA) eingereichte Registrierungsdossiers untersucht. Informationen über die Produktions- und die Verwendungsmengen von BPA wurden gesammelt und die von den Registranden erstellte Stoffsicherheitsbericht wurde ausgewertet. Im zweiten Projektabschnitt wurden Daten aus der Literatur und aus der Industrie gesammelt um Verwendungen zu identifizieren, welche in der Stoffsicherheitsbewertung nicht betrachtet sind um zu untersuchen inwieweit diese Verwendungen zu relevanten Emissionen von BPA in die Umwelt führen können. Der dritte Schritt des Projektes konzentrierte sich auf eine Literatursammlung und –auswertung zu Umweltkonzentrationen von BPA in verschiedenen Kompartimenten. Umweltmonitoringprogramme und die wissenschaftliche Literatur wurden nach veröffentlichten Daten zu gemessenen BPA Konzentrationen in Umweltmatrices durchsucht.

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List of Abbreviations

AC	Article category
BPA	Bisphenol A
Cons	Consumer
CoRAP	Community Rolling Action Plan
CSR	Chemical Safety Report
CSA	Chemical Safety Assessment
dw	Dry weight
DWPLL	Drinking water positive list limit
EA	Exposure assessment
ECHA	European Chemicals Agency
ERC	Environmental release categories
ES	Exposure Scenario
EU	European Union
EU RAR	European Risk Assessment Report
Ind	Industrial
IU	Identified uses
OC	Operational Conditions
PBT	Persistent Bioaccumulative Toxic
PC	Polycarbonate
PEC	Predicted Environmental Concentration
PROC	Process category
Prof	Professional
PVC	Polyvinylchloride
RCR	Risk Characterisation Ratio
REACH	Regulation (EG) Nr. 1907/2006 addressing Registration, Evaluation and Authorisation of Chemicals
RMM	Risk Management Measures
Tpa	Tonnes per year
vPvB	very Persistent very Bioaccumulative
WW	Waste Water
WWTP	Waste Water Treatment Plant

1 Background and objectives

1.1 Background

Bisphenol A (BPA) is an industrially important chemical that is used as a raw material in the manufacture of many products. Most of the manufactured BPA is converted into stable plastics (polycarbonate and epoxy resins) where it is present as polymer. It is known that under certain conditions BPA can be released from consumer products like can coatings or polycarbonate bottles and therefore enter the human body via food. Releases can occur due to leaching of residual monomers in the polymer matrix or due to break down of chemical bonds and thus destruction of the polymeric network, initiated for example by weathering effects in case of outdoor use. There are also some applications where BPA is directly used as monomer (e.g. as developing agent in thermal paper) and can therefore be easily released to the environment. Compared to the use in polymers, in these applications BPA is not chemically bound or held back in a network and therefore much more accessible for leaching for example by water.

Results of new scientific studies demonstrated that in certain animal species, BPA may disrupt reproduction even in very low concentrations. Some of the available scientific findings are the subject of controversial discussions among scientists [UBA 2010]. BPA enters the water cycle and the bodies of aquatic organisms. The presence of BPA in many water bodies all over the world has been confirmed by numerous measurements. Emissions to surface water like rivers in most cases originate from the wastewater treatment plants of companies which produce, process or use BPA. Various additional emission sources have to be considered due to the wide dispersive use of substances and articles produced from BPA.

In accordance with Council Regulation (EEC) 793/931 on the evaluation and control of the risks of “existing” substances a risk assessment of the priority substance BPA (EU RAR) has been carried out. A first risk assessment of BPA has already been published in 2003 [EU RAR 2003]. The conclusion of the authors was that further information was needed about toxic effects in fish and aquatic snails and environmental risks were identified for certain PVC applications and thermal paper recycling. Test requirements were published in two Commission Regulations and elaboration of a risk reduction strategy for the environment was indicated. In the meantime, industry was able to provide more detailed information on use pattern and releases for a number of the applications considered to pose a risk for the environment, including measured emissions data. Based on this evidence, the rapporteur (UK Environment Agency) considered that the emissions had been over-estimated in the published report. After the test programme to gather new information on toxic effects in fish and snails has been finished, an updated report combining the revised exposure information and an updated review of ecotoxicity data, has been published in 2008 as an addendum to the original risk assessment report [EU RAR 2008] and in 2010 these documents were combined to one risk assessment document.

Regarding risks resulting from use of BPA for human health, the majority of the Member States concluded that with proper use of products containing BPA there is no cause for concern about health risks. The European Food Safety Authority also came to the same conclusion. However, Denmark and France, for instance, have enacted further precautionary measures. Already in May 2009, the Danish parliament passed a resolution to ban the use of BPA in baby bottles and in March 2010, a temporary ban was declared by the Health Minister. French Senate approved a proposition of law to ban BPA from baby bottles in March 2010, which is applicable law since

July 2010. Furthermore, in October 2011, the French National Assembly voted a law forbidding the use of BPA in products aimed at less than 3-year-old children for 2013, and for all food containers in 2014. Finally, the EU banned the manufacturing by 1 March 2011 and the marketing and market placement of polycarbonate baby bottles containing BPA by 1 June 2011. Already in 2008 Health Canada concluded that BPA should be classified as toxic to human health and the environment and baby bottles containing BPA should be banned on precautionary grounds. In March 2010 the Canadian government enforced the ban on the importation, sale and advertising of polycarbonate baby bottles in Canada.

1.2 Background REACH

REACH[1], the new European legislation for Registration, Evaluation and Authorisation of Chemicals (Regulation (EG) Nr. 1907/2006) entered into force in 2007. Apart from few exceptions, REACH obliges manufacturers and importers of chemical substances, based in the European Union, to register at the European Chemicals Agency (ECHA) all chemicals which are imported or manufactured in the EU at more than 1 t/year per manufacturer or importer. A major aim of REACH is the save use of chemicals throughout the full life cycle and the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. REACH requests of the registrants the elaboration of a chemical safety assessment (CSA) including a hazard assessment in case a substance is manufactured or imported in quantities of 10 tonnes per year and above.

REACH foresees that Member States evaluate certain substances to clarify whether the substance poses a risk to human health or the environment. BPA has been included in the first CoRAP in February 2012 and Germany has been designated as evaluating member state for BPA. The substance evaluation process assesses all registration dossiers from all registrants specific to the same substance. Other sources of information that are available may also be considered. For example, registrants may need to provide studies on mode of action or monitoring of concentration levels in organisms or the environment[2].

1.3 Aim of the project

Germany proposed BPA for the substance evaluation process under the REACH regulation with the following grounds of concern:

1. Production volume as well as exposure estimates were based on production volumes considering past EU 15 member states only.
2. Environment monitoring data especially for sediment concentrations indicate that exposure might have been underestimated.
3. Degradation in sewage plant might have been overestimated. This might result in underestimation of exposure.

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[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:136:0003:0003:EN:PDF

[2] http://echa.europa.eu/web/guest/regulations/reach/evaluation/substance-evaluation

4. Information on toxicity towards snails indicates that effects on this organism group might have been underestimated.
5. Several studies indicate that Bisphenol A is an endocrine disruptor resulting in adverse effects at very low concentrations (at least low µg/L range) in aquatic organisms due to the endocrine mode of action. Risk calculated by PEC/PNEC ratios might underestimate the concern for the environment due to the endocrine disrupting mechanism of action.

The present project aims at supporting the substance evaluation process by identification of emission sources of BPA to the environment. The focus is on emissions of BPA to the environment from production and use of BPA in the European Union and on information on BPA concentrations found in the environment. Therefore, REACH registration dossiers have to be evaluated and assessed for their information content. Data gaps have to be identified. A key question is whether all relevant emission sources have been addressed by the EU RAR and the REACH CSA. Information from environmental monitoring programs has to be collected and evaluated to get an overview on BPA concentration in the environment. Emission pathways have to be identified and quantified and the relevance of the identified pathways in correlation to the total emission of BPA to the environment has to be assessed.

In the following chapter, information on production volumes, uses of BPA and related exposure scenarios available from REACH registration dossiers and CRSs submitted to ECHA by registrants is assessed and evaluated. Data gaps are identified and missing information which should be requested from registrants in the scope of the substance evaluation will be collected.

In chapter 3, information on production, use of BPA and release to the environment available from other sources like EU risk assessments and literature data is presented and compared to the data provided by registrants. Information on uses of BPA reported in literature is evaluated for uses not included in the chemical safety assessment of registrants. Potential sources for release of BPA to the environment not considered in risk assessments so far are identified and quantified to examine whether emissions to the environment have been underestimated in the REACH CSA.

Chapter 4 summarises information about BPA concentrations in the environment available from literature and monitoring programs. The evaluation concentrates on data published after 2008 as information available from older publications has been assessed in the EU RAR. The results provide an overview about the concentration of BPA found at different locations in different compartments in the EU. The aim is to compare results of the exposure estimations of the CSA, the EU RAR and chapter 3 with measured data and therefore evaluate whether these estimations are realistic or not.

Chapter 5 summarises the results. The most relevant emission sources are identified and uncertainties are discussed.

2 Assessment of REACH registration dossiers

2.1 Background REACH registration dossiers

Manufacturers or importers of chemical substances established in the European Union (EU) have to register their substances in accordance with the relevant provisions in the REACH regulation by submission of a registration dossier to the European Chemicals Agency (ECHA). For substances manufactured or imported in quantities of 10 tpa and classified as hazardous like BPA, dossier elaboration consists of the following steps:

- Documentation of all relevant and available information according to Article 10 and Annexes VI to XI in IUCLID format
- Performance of a Chemical Safety Assessment (CSA) which consists of:
    - hazard assessments (human health, environment, physico-chemical properties) and the PBT/vPvB assessment
    - definition and performance of exposure assessment(s) (including exposure scenario(s)
    - risk characterisation
- Record the results of the CSA in the CSR.

The CSA of a manufacturer shall address the manufacture of a substance and all the identified uses. According to Annex I of the REACH Regulation it shall consider the use of the substance on its own (including any major impurities and additives), in a mixture and in an article and shall consider all stages of the life-cycle of the substance including service life and waste stage.

However, at the moment when a substance is transferre into another substance like for example during production of polymers, the life cycle of the substance (monomer) as defined under REACH ends with the reaction (polymerization) as a new substance (polymer) is produced and therefore a new life cycle begins. This has to be seen different compared to the life cycle of a substance as defined from an environmental point of view, where the life cycle of a substance can be considered to end with degradation or transformation of a substance.

Against this background, registration dossiers for BPA which have been submitted to ECHA could serve as a first data source for identification and evaluation of relevant emissions to the environment from BPA production and use in Europe. Technical dossiers contain information about the amount of the BPA produced or imported by a registrant as well as information about the manufacturing process and the applications of BPA (uses). For every single use, the CSR covers an environmental exposure assessment and a risk characterization which provides information about estimated releases of BPA to the environment from the respective use taking into account the whole life cycle of BPA relevant for this use. This means that environmental emissions from the production process of BPA via intermediate uses like for example production of polymers until the last life-cycle step, for example thermal utilization or disposal should be addressed in the CSR.

2.2 Methodology of the assessment of REACH registration dossiers

Anonymized registration dossiers submitted to ECHA by industry until end of February 2012 have been evaluated and screened for information relevant for the assessment of emissions to the environment from production and use of BPA in Europe. The collected data was then used to elaborate a mass flow scheme showing the whole live cycle of BPA starting from production of BPA including emissions to the environment for each use and life cycle step. Data on production and import volumes from all registration dossiers have been collected to prepare an overview on the European market. Data gaps and uncertainties in dossiers and the CSRs related to exposure estimation and risk identification have been identified and listed. The criteria for analysis and assessment of the 49 REACH dossiers and CSRs have been defined with the aim to provide a set of information reflecting the life cycle and therefore the complete mass flow of BPA in Europe as proposed by industry.

In case dossier updates have been submitted by registrants, only the latest submissions (dossier updates) have been taken into account for the assessment. A template has been designed in a way that data from several registration dossiers can be analysed and aggregated data can be achieved. The template has been used as a working document when examining the dossiers. The complete assessment template covering the collected information is not attached to this report due to confidentiality reasons. The template includes besides others, information addressing production/import volumes, identified uses and estimated emissions from single uses. In addition, also information related to a number of endpoints that are not part of the standard information requirements according to REACH, but were considered of potential relevance for the assessment, have been included in the template.

2.3 Results of the assessment of REACH registration dossiers: Manufacture, import and form of the substance in the supply chain

All dossiers reported estimated manufactured and/or imported quantities in IUCLID section 3.2. Information provided in the dossiers was reported either as average tonnage of the last three years for 2010 or 2012 or as total tonnage without indication of the year. The estimated total volume of BPA manufactured in the EU in 2011 was calculated summarizing all the reported tonnages irrespective of the assigned years. This was considered to be the most suitable method to get an estimation of the European production volume of BPA in 2011. The estimated total amount of BPA produced in 2011 has been calculated to be 1 000 000 – 10 000 000 tonnes. This figure fits with the production volume of 1,150,000 tonnes reported in the EU RAR [EU RAR 2008].

Against the background that production of BPA in Europe is concentrated to a view companies during the last decade it seems to be reasonable that production volumes remained on the same level within the last years. Increase of production volumes would require installation of new production sites in Europe.

The total tonnages indicated in the importer dossiers and dossiers of Only Representatives together with the indicated tonnages for import from manufacturers dossiers have been used to calculate the estimated total amount of BPA imported in 2011 although some of the data has been submitted for different years. The estimated total amount of BPA imported to the EU in 2011 has been calculated to be 100 000 – 1 000 000 tonnes.

However, there are some aspects which have to be taken into account with respect to this figure:

Registrants shall indicate in the IUCLID file the form (substance, mixture or article) and/or physical state under which the substance is made available to downstream users, concentration or concentration range of the substance in mixtures made available to downstream users and quantities of the substance in articles made available to downstream users. This means that BPA produced and imported by different companies enters several different mass flows and it is therefore difficult to calculate amounts used for single applications.

In case a registrant reports in his dossier that the substance is available in the supply chain in a mixture, he is not required to report the tonnage of BPA used for the production of that mixture but the concentration of BPA in the mixture. Therefore, it is not possible to calculate from data in registration dossiers the volume of BPA used for the production of mixtures like epoxy resin hardeners.

BPA is used in the production of polymers (e. g. polycarbonate, epoxy resins). Under REACH, the monomers have to be registered and not the polymer itself. This means that in case a certain amount of polymer material (not articles from polymers, which are generally not covered by REACH) is imported to the EU, the importer registers the tonnage of the monomer used to produce the imported amount of polymer. In case a registrant indicates that BPA is available in the supply chain as such, it is unclear to which extent BPA is imported as a substance and which proportion of the estimated tonnage imported per year belongs to polymeric materials like for example PC granule.

BPA is also used to produce articles. Articles are not covered by REACH. Substances in articles, intended to be released have to be registered but this is not the case for BPA in articles.

Therefore, it is likely that BPA included in imported articles like thermal paper or PC/PVC articles have not been taken into account by registrants when they reported volumes in their REACH dossiers. The import of BPA incorporated in articles like thermal paper or PC/PVC articles which contribute to emissions to the environment during their live cycle are therefore not covered by the volumes reported in registration dossiers and therefore not covered by the volumes calculated during this assessment.

Conclusion:

According to the Information provided by registrants in their REACH dossiers, BPA is manufactured in the EU in a total annual amount of 1 000 000 – 10 000 000tonnes (data for 2011). This figure fits with the production volume of 1,150,000 tonnes reported in the EU risk assessment report [EU RAR 2008] for BPA. The total amount of BPA imported is 100 000 – 1 000 000 tonnes per year (data for 2011). This amount includes import of BPA as substance and import of BPA in form of polymers (epoxy resins/PC granules). Not included are imports of articles made from polymerised BPA and BPA in articles as this amount of BPA is not relevant for registration.

Registrants have reported different forms in the supply chain. As registrants are not required to report which proportion of the total BPA tonnage registered enters which kind of mixture, it is not possible to calculate precise figures for the imports of BPA as such or the imports of BPA in form of epoxy resin materials or BPA in form of other polymers like PC granules. Information about how much BPA produced/imported by a company enters which use/life cycle is not available from registration dossiers.

The import of BPA incorporated in articles like thermal paper or PVC articles or Polymers like PC which can contribute to emissions to the environment during their live cycle should be considered when emissions of BPA to the environment will be assessed. These volumes are not covered by REACH and are therefore not included in the calculated volumes for production and import. Against this background, it is not possible to gain from registration dossiers information on amounts of BPA available on the European market in form of thermal paper and PVC articles.

2.4 Identified uses

Identification of uses in IUCLID section 3.5 is based on predefined use descriptors, mainly intended to give a general description of uses to build exposure scenarios. Almost all dossiers reported uses by workers in industrial settings and professional workers as well as identified uses by consumers. In total 19 uses have been identified and reported in the lead registrant dossier. There were no uses advised against (see Table 1).

Table 1: Identified uses reportedby registrants

Short ES title
Industrial Manufacturing of Bisphenol A
Industrial Repackaging of Bisphenol A
Professional Repackaging of Bisphenol A
Industrial Use of Bisphenol A for Manufacturing Polycarbonate
Industrial Use of Bisphenol A for Manufacturing Epoxy Resins
Industrial Use of Bisphenol A for Manufacturing Polymers
Industrial Use of Bisphenol A for Manufacturing Coating Materials
Industrial Use of Bisphenol A for Manufacturing Chemicals
Industrial Use of Bisphenol A for Manufacturing Thermal Paper
Industrial Use of Bisphenol A as Anti- Oxidant for Processing PVC
Professional Use of Bisphenol A as Anti-Oxidant for Processing PVC
Industrial Use of Bisphenol A for Manufacturing Epoxy Resin Hardeners
Industrial Use of Bisphenol A in Epoxy Resin Hardeners
Professional Use of Bisphenol A in Epoxy Resin Hardeners
Industrial Use of Bisphenol A as Laboratory Reagent
Professional Use of Thermal Paper
Professional Use of Articles made of PVC
Consumer Use of Bisphenol A in Thermal Paper
Consumer Use of Bisphenol A in Articles made of PVC
Importation and storage
An intermediate (monomer) in production of other chemicals (resins/polymers) (industrial use)

2.5 Chemical safety assessment (CSA)

The content of this chapter is considered confidential.

2.5.1 CSA opt-out dossier

The content of this chapter is considered confidential.

2.5.2 CSA lead dossier

The content of this chapter is considered confidential.

2.6 Mass flow for BPA based on data from registration dossiers

The content of this chapter is considered confidential.

3 Evaluation of known uses for emissions to the environment

3.1 Production, import and export of BPA

3.1.1 Production of BPA in Europe

According to information from industry and the EU RAR [EU RAR 2008], BPA is produced in Germany, The Netherlands, Belgium and Spain. The total amount of BPA manufactured within the EU, based upon registration dossiers submitted to ECHA, is 1 000 000 – 10 000 000 tonnes/year (estimation for 2011). This figure fits quite well with the production volume of 1,150,000 tonnes reported in the EU [EU RAR 2008] for BPA.

3.1.2 Import and Export of BPA

Information regarding import of BPA to the EU is available from REACH registrations and the EUROSTAT database. Registrants have reported imports of BPA of 100 000 – 1 000 000 tonnes per year (estimation for 2011). As already explained in section 2.3, it is not possible to calculate the amount of BPA imported as such, as the tonnage for imports also cover the import in polymeric form (e.g. in form of PC granule).

According to the EU RAR [EU RAR 2003] total imports of BPA into the EU in 1997 were 8,010 tonnes/year and exports from the EU were 1,887 tonnes/year. Figures from the American Society of the Plastics Industry indicate that in 1997 American manufacturers exported 5,855 tonnes of BPA to Europe, while imports from Europe were 8,509 tonnes. From the data submitted by the EU manufacturers net exports were in the range of 25,000 tonnes/year for 1998 and net imports in the region of 3,000 tonnes/year. Obviously there were some discrepancies between the EU and American import and export values, which are based upon 1997/98 industry data. More recent estimates (i.e. 2005/06), made by Plastics Europe, indicate 65,000 tonnes/year as net exports of BPA from the EU in 2005/06 [EU RAR 2008].

The statistical office of the European Union (Eurostat) provides import and export data for 4,4'-Isopropylidenediphenol 'Bisphenol A, Diphenylolpropane' and its salts. Detailed and aggregated external trade data can be accessed and downloaded for the Euro area, the European Union and for each EU Member State separately. The statistics cover both, the EU-Extra and EU-Intra trade. EU-Extra trade statistics cover the trading of goods between a particular Member State or the entire EU (e.g. EU27, EU25) and a non-member country(ies). EU-Intra statistics cover the trading of goods between EU Member States [EUSTAT 2012a].

The statistical information is mainly provided by the traders on the basis of Customs (EU-Extra) and Intrastat (EU-Intra) declarations. Data is collected by the competent national authorities of the Member States and compiled according to a harmonized methodology established by EU regulations before transmission to Eurostat.

Within external trade statistics standardized classifications are applied to data on commodities and on countries. Regarding the product classification the Combined Nomenclature (CN) is applied for the detailed data whereas the Standard International Trade Classification (SITC) or the Broad Economic Categories (BEC) are used for aggregated data [EUSTAT 2012a].

Table 3 contains extracted import figures of BPA from EU27-Extra to the EU27 for the years 2008-2011. As described previously, the EU-Extra trade statistics cover exclusively the trading between, in this particular case, the EU27 and non-EU27 countries. It does not take into account the internal trade of BPA (e.g. import of BPA from Germany to Spain).

As it can be seen, the total import figures of BPA to the EU27 increased gradually from 22,457 tonnes in 2008 to 26,006 tonnes in 2009 to 30,289 tonnes in 2010. The latest available annual import figure is 30,941 tonnes of BPA in 2011.

Table 2: Imports of Bisphenol A (EU 27) [EUSTAT 2012a]

EU27 Trade: 4,4'-ISOPROPYLIDENEDIPHENOL "Bisphenol A, Diphenylopropane" and its salts				
Extracted on	21.03.12			
Source of Data	Eurostat			
PARTNER	EU27-EXTRA			
PRODUCT	29072300			
FLOW	IMPORT			
INDICATORS	Quantity in 100 kg			
Reported period	Jan.-Dec. 2008	Jan.-Dec. 2009	Jan.-Dec. 2010	Jan.-Dec. 2011
EU27	224567	260064	302892	309410

Table 4 on the other side summarizes export figures of BPA from the EU27 to non-member countries (EU27-Extra) for the years 2008-2011. It can be observed that the annual exports of BPA significantly declined from around 78,899 tonnes in 2008 to approximately 18,927 tonnes in 2011. It is also interesting to see that in 2011 a higher amount of BPA was imported to the EU27 than exported during the same year.

Table 3: Exports of Bisphenol A (EU 27) [EUSTAT 2012a]

EU27 Trade: 4,4'-ISOPROPYLIDENEDIPHENOL "Bisphenol A, Diphenylopropane" and its salts				
Extracted on	21.03.12			
Source of Data	Eurostat			
PARTNER	EU27-EXTRA			
PRODUCT	29072300			
FLOW	EXPORT			
INDICATORS	Quantity in 100 kg			
Reported period	Jan.-Dec. 2008	Jan.-Dec. 2009	Jan.-Dec. 2010	Jan.-Dec. 2011
EU27	798991	641964	337637	189269

Industry estimations contained in the EU RAR [EU RAR 2008] seem to be realistic for 2005/06 (i.e. 65,000 tonnes/year as net exports of BPA from the EU compared to 57,442 tonnes/year as net exports of BPA from the EU in 2008). Nevertheless, for the purpose of this study, the newest import/export figures extracted from the Eurostat database will be used. For the year 2011, net imports of BPA as a substance of 12,000 tonnes have been reported. According to the above data, the representative EU consumption of BPA for 2011 is estimated to be approximately 1,160,000 tonnes, which is only slightly higher than the estimation of 1,150,000 tonnes made in the EU RAR [EU RAR 2008].

3.2 Inventory of uses of BPA

BPA is a mass chemical with various uses in different industrial fields. Different information sources, publications and data bases (Table 54) have been searched to identify uses of BPA with the aim to provide an overview on applications. First of all there are the REACH registration dossiers which cover 19 identified uses of BPA. All these uses have already been addressed in the EU RAR [EU RAR 2003 and 2008] for BPA for which industry has provided updated production and consumption figures for BPA for 2005/2006. These figures have also been taken into account for the estimation of corresponding emissions in the EU RAR [EU RAR 2003 and 2008]. The production and use figures reported in the EU RAR [EU RAR 2008] for BPA are included in Table 5.

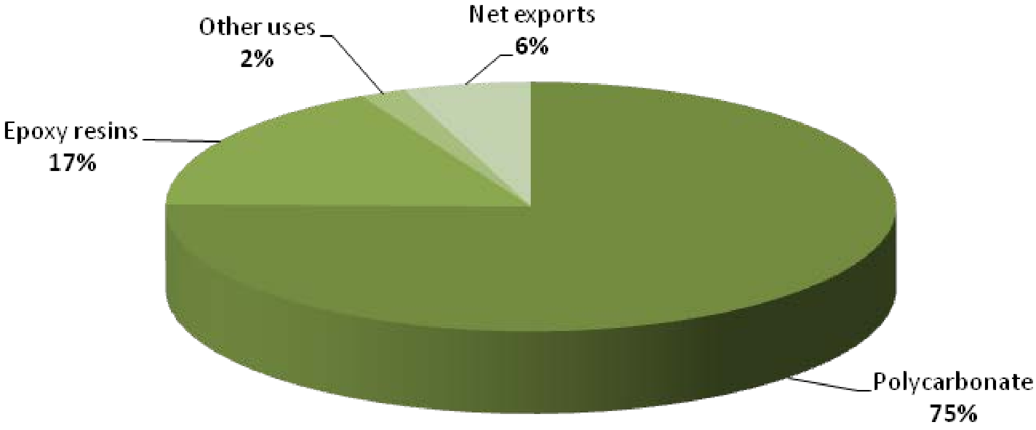
Table 4: Revised production and use tonnages for Western Europe (2005/06) [EU RAR 2008]

Application (production and use for Western Europe 2005/06)	**[tonnes/year]**	**[% of total consumption]**
BPA production	1,150,000	
BPA uses		
Polycarbonate	865,000	75.23
Epoxy resins	191,520	16.66
– can coatings	2,755	0.24
– ethoxylated BPA	2,260	0.20
Phenoplast cast resin processing	8,800	0.77
Unsaturated polyesters	3,600	0.31
Thermal paper	1,890	0.16
PVC – polymerization	0	0.00

Application (production and use for Western Europe 2005/06)	[tonnes/year]	[% of total consumption]
- stabilizer packages	450	0.04
- phthalate plasticizers	900	0.08
- direct stabilization	450	0.04
Other	7,245	0.63
Net exports	65,000	5.65
Total consumption	1,149,870	100.00

As displayed in Fig. 1, showing the uses of BPA, in Western Europe the main use has been in the production of PC, followed by the second largest use in epoxy resin production.Besides, BPA has been used in a range of other application (incl. use in thermal papers). All these ‘other’ applications represented around 2 % of the total BPA use (Fig. 1) whereas the use of BPA in thermal papers only accounts for 0.16 % of the total BPA consumption in 2005/2006.

Fig. 1: Bisphenol A – Application (Western Europe 2005/06)



SPIN is a database on the use of Substances in Products in the Nordic Countries. The database is based on data from the Product Registries of Sweden, Denmark and Finland. SPIN – Substances in Preparations In the Nordic countries – is a database that contains “non-confidential” information on substances from each of the Nordic product register. The information included is for example the number of products containing the substance, the annual tonnage, industrial categories and use categories, the annual tonnage within these categories and the presence or absence of the substance in consumer products. The SPIN database has been searched for BPA applications. The Nordic registers report to SPIN using UC62, a code list of 62 use categories, for chemical substances and preparations which was developed to combine data in a structured way. Furthermore, the Nordic product registers use the NACE (the statistical classification of economic activities in the European Community which was also embodied in the EEA Agreement by the EFTA countries) codes to indicate the branches of industry where the products are used. The results for BPA are summarised in Table 6 and Table 7.

Table 5: SPIN use categories for BPA

Use category UC 62	Year
Lubricants and additives	2009
Construction materials	2009
Adhesives, binding agents	2009
Paints, lacquers and varnishes	2009
Surface treatment	2009
Softeners	2009
Process regulators	2009
Hydraulic fluids and additives	2009
Fillers	2009
Stabilizers	2009
Anti-static agents	2009
Insulating materials	2009
Intermediates	2009
Viscosity adjustors	2009
Non-agricultural pesticides and preservatives	2007
Reprographic agents	2007

Reported uses between 2007 and 2009 (latest data available) have been collected and listed. Uses reported for several years have been included only once. Applications with the highest reported tonnages in Nordic countries in 2009 have been “lubricants and additives”, “construction materials”, “adhesives and binding agents”, “paints/lacquers” and “varnishes as well as process regulators”. NACE use categories give an overview on the industrial sectors where BPA is used in Nordic countries.

The various applications of BPA can be categorized in the following main use classes which will be discussed in more detail in the following section:

- polycarbonate
- epoxy resins
- other polymers (e.g. polysulfone, polyacrylates, polyetherimide, unsaturated polyesters, BPA-formaldehyde resins)
- production of other chemicals (e.g. Tetrabrombisphenol-A)
- production of thermal papers
- miscellaneous minor uses

Table 6: SPIN NACE use categories for BPA

Industrial Use (Nace)	Year
Specialised construction activities	2009
Wholesale and retail trade and repair of motor vehicles and	2009

Industrial Use (Nace)	**Year**
Manufacture of chemical and chemical products	2009
Manufacture of rubber and plastic products	2009
Manufacture of fabricated metal products, expect machinery a	2009
Manufacture of basic metals	2009
Manufacture of electrical equipment	2009
Construction of buildings	2009
Civil engineering	2009
Other manufacturing	2009
Manufacture of wood and products of wood and cork, expect	2009
Manufacture of machinery and equipment n.e.c.	2009
Repair and installation of machinery and equipment	2009
Extraction of crude petroleum and natural gas	2009
Manufacture of motor vehicles, trailers and semi-trailers	2009
Manufacture of other transport equipment	2009
Manufacture of computer, electronic and optical products	2009
Undifferentiated goods- and services-producing activities of	2009
Manufacture of paper and paper products	2009
Manufacture of other non-metallic mineral products	2009
Air transport	2009
Mining support service activities	2008
Retail trade, expect of motor vehicles and motorcycles	2008
Construction	2007
Manufacture of electrical machinery and apparatus	2007
Manufacture of furniture; manufacturing n.e.c.	2007
Sale maintenance and repair of motor vehicles and motorcycles	2007
Extra-territorial organisations and bodies	2007
Publishing, printing and reproduction of recorded media	2007
Manufacture of radio, television and communication equipment	2007

Production and use of polycarbonate (PC)

The most **important use of BPA is in the production of** PC. World-wide production of PC is estimated at 3 million tonnes/year (data for 2009) [PE 2012]. The PC is then sold on to processors who form it into finished products for consumer use. In the EU, according to data from the EU RAR [EU RAR 2008], approximately 870,000 tonnes/year BPA is used in the production of PC.

Imports and exports of PC are not evaluated within the EU RAR [EU RAR 2003 and 2008] and cannot be calculated from tonnages reported by registrants. Therefore, recent data on imports and exports of PC in primary forms has been summarized in Table 8 and Table 9.

The presented data has been obtained from the Eurostat database [EUSTAT 2012b].

Table 8 contains import statistics of PC in primary forms from EU27-Extra to the EU27 for the years 2008-2011. Again, the statistics do not take into account the internal trade of PC in primary forms between EU27 Member States. As it can be seen, most of the PC was imported in 2008 and 2010, in particular 107,463 tonnes/year and 98,134 tonnes/year respectively, whereas a considerably lower tonnage of PC was imported in 2009 (i.e. 66,986 tonnes). The latest available annual import figure of PC in primary forms is 81,590 tonnes of BPA in 2011.

Table 7: Imports of PC in primary forms (EU 27) [EUSTAT 2012b]

EU27 Trade POLYCARBONATES, IN PRIMARY FORMS (IMPORT EU 27)				
Extracted on	21.03.12			
Source of Data	Eurostat			
PARTNER	EU27_EXTRA			
PRODUCT	390740			
FLOW	IMPORT			
INDICATORS	QUANTITY_IN_100KG			
REPORTER/PERIOD	Jan.-Dec. 2008	Jan.-Dec. 2009	Jan.-Dec. 2010	Jan.-Dec. 2011
EU27	1074632	669864	981347	815896

Table 9 on the other side contains export statistics of PC in primary forms from the EU 27 to non-EU27 countries for the years 2008-2011. As indicated, most of the PC was exported in 2009 and 2010 with around 320,000 tonnes in each year. Lower export figures have been reported in 2008 and 2011 with 260,866 tonnes and 273,061 tonnes, respectively.

Table 8: Exports of PC in primary forms (EU 27) [EUSTAT 2012b]

EU27 Trade POLYCARBONATES, IN PRIMARY FORMS (EXPORT EU27)				
Extracted on	21.03.12			
Source of Data	Eurostat			
PARTNER	EU27_EXTRA			
PRODUCT	390740			
FLOW	EXPORT			
INDICATORS	QUANTITY_IN_100KG			
REPORTER/PERIOD	Jan.-Dec. 2008	Jan.-Dec. 2009	Jan.-Dec. 2010	Jan.-Dec. 2011
EU27	2608666	3205517	3217475	2730619

In general it can be concluded that a significantly higher amount of PC in primary forms was exported from the EU27 than imported to the EU27 during the observed period of time, which results in high net exports of PC in primary forms from the EU27 (e.g. net export of 191,472 tonnes in 2011). The figures, however, exclusively consider the annual imports and exports of PC in primary forms and do not take imports and exports of PC in finished products into account.

PC produced from BPA generally has good optical clarity, impact resistance and ductility at room temperature and below. This makes them ideally suited to a wide range of end applications and a good substituent for glass where weight is an important factor (e. g. energy efficiency of cars). PC can be processed by conventional thermoplastic processing operations like extrusion or moulding and is therefore a good raw material for a wide range of uses.

According to the EU [EU RAR 2003 and 2008], the maximum residual content of BPA in PC is reported as 50 mg/kg. Typically the residual content is < 10 mg/kg [EU RAR 2003].

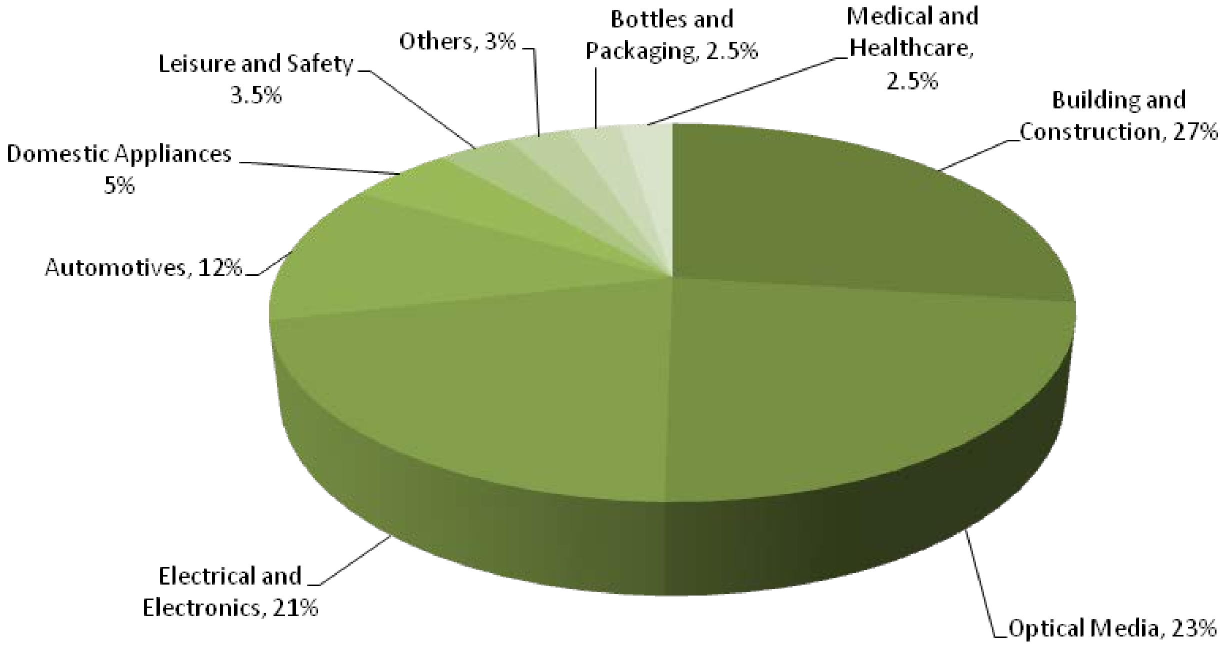
PC is then processed to various articles. Different end uses of PC products are summarised and categorised in Table 10 and Fig. 2.

Table 9: Uses of BPA in polycarbonate [Bisphenol A Europe, 2012] [Plastics Europe, 2012]

Polymer	Application class	Application
Polycarbonate	Optical Media	compact discs, CD´s, DVD´s, HD-DVD´s, Blue-Ray Discs, Holography Discs, Innovative Data Storage Technology, forgery-proof holographic shadow pictures in ID cards
	Electrical and Electronics	housing for cell phones, alarm devices, SLR cameras, electrical razors, hairdryers, steam irons, mixers, computers, monitors, TVs, copiers, printers, telephones, microwaves, coffee makers, front panels for electric cookers, electrical kettles, transparent front panels for vending machines, interior lighting panels for trains and airplanes, backlight units for TVs, housing for switch modules, distributor boxes, fuses, battery power stations, sockets, electrical meters, illuminated rotary switches, plug connectors, switches, sockets, plugs, lamp holders, fax machines, pagers, circuit breakers, cable sockets, displays, relays, LED´s, safety switches, fluorescent lightning diffusers, fridges
	Blends	mainly used in automotive and electrical and electronics
	Construction	sheets for roofing, conservatory glazing, architectural glazing, greenhouse glazing, safety galzing, rooflights, cover for solar panels, noise reduction walls for roads and train tracks, carport covers, glazing for bus stop shelter, road signs, internal safety shields for stadiums, housing and fitting for halogen lightning systems, front panels for advertising posters, sign boards (e.g. fuel stations), large advertising displays, dust & water-proof luminaries for streetlights and lamp globes, diffusing reflectors for traffic lights
	Automotive	fixed side windows, transparent and retractable roof modules, windstops and convertibles, rear windows, transparent rear body parts, headlamp lenses, headlamp, tail light, indicator reflectors, foglamps, interior light covers, high-mount brake lights, housing for licence-plate lights, bumpers, radiator and ventilation grills, dashboards, rear light reflectors, coverings, moulded mirror housings, turn signals
	Bottles and Packaging	reusable water bottles, unbreakable, reusable milk bottles, cutlery, food containers, drinking water generators, pitchers, water carboys, storage containers, tableware, water cooler bottles
	Medical and Healthcare	blood oxygenators, cardiotomy reservoirs, dialysers, respirators, dentists´operating lamps, breastpumps, inhaler housings, presription spectacles, i.v. connectors, scalpel cases, laparoscope handles, contact lens holders, syringe tops, medical packaging film, ampoules, three-way stopcocks and stopcocks manifolds, tweezers with integrated lighting, single-use operating instruments , eyeglass lenses
	Others	Safety safety goggles, protective visors for welding or handling of hazardous substances, protective visors for motorbikes or snowmobiles, motorbike and cycle helmets, fencing helmets, safety shields for policemen, guards to protect from moving machine parts Leisure ski goggles, sun glasses, transparent building blocks in toys, mouthpieces for

Polymer	Application class	Application
		musical instruments, compass housings, binocular housings, seats for sleighs ballpoint pen chasings, transparent roof modules in caravans, instrumentation housings in boats, suitcase shells

Fig. 2: Uses of PC made from BPA [PE, 2012b]



There are a lot of consumer uses of BPA in form of PC which have controversy been discussed in relation with human exposure like baby bottles or applications with food contacts like storage or microwave containers. Usually, polymeric PC is very stable and does only contain very small amounts of monomeric BPA. Emissions to the environment might occur in case of outdoor uses of PC articles or indoor uses which enhance leaching of BPA from PC articles and thus release to waste water or air. Outdoor uses for which a high proportion of PC is used and which therefore might result in considerable emissions to the environment are first of all construction applications like sheets for roofing, conservatory glazing, architectural glazing, greenhouse glazing, safety glazing, rooflights, cover for solar panels, noise reduction walls for roads and train tracks, carport covers, glazing for bus stop shelter and road signs. PC used in these applications might release BPA due to weathering and ageing processes when being exposed to rain water and sunlight. Another important outdoor application might be the use for automotive parts like windows, roof modules, rear windows, transparent rear body parts, lights and reflectors (foglamps, interior light covers and brake lights) radiator and ventilation grills. Here, besides weathering and ageing processes, abrasion due to flying stones or car washing might be relevant although it is assumed that life cycle of cars is limited and materials produced for these applications are resistant against weathering. Relevant in-house uses are bottles and packaging as there exists a potential for releases during cleaning processes.

Conclusion:

It becomes clear that PC made from BPA is used to produce a huge number of different products for professional and consumer use in indoor and outdoor applications. There are at least some uses where release of BPA to the environment due to leaching of residual BPA or due to depolymerisation for example caused by weathering in outdoor applications can be expected. This may result in underestimation of the environmental concentrations.

Production and use of epoxy resins

Epoxy resin production is the second largest use of bisphenol-A in the EU. According to information from the EU RAR [EU RAR 2008], approximately 200,000 tonnes/year of BPA is used in the production of epoxy resins per year. Against the background that registrants do not have to report tonnages for import of epoxy resins but only total volumes of imported BPA (combining import as such, import in mixtures and import of polymers)it is not clear from dossier data which proportion of BPA is imported in form of epoxy resins. Therefore, recent data on imports and exports of epoxy resins in primary forms available from EUROSTAT has been summarized in Table 11 and Table 12. The presented data has been obtained from the Eurostat database (EUSTAT 2012c).Table 11 contains import statistics of epoxy resins in primary forms from non-EU27 countries to the EU27 for the years 2008-2011. Most of the epoxy resins in primary forms were imported during 2008 with around 136,717 tonnes. The lowest annual import figure was 94,035 tonnes in the subsequent year. The 2010/11 import figures are comparable with more than 121,500 tonnes of epoxy resins in primary forms imported to the EU27.

Table 10: Imports of epoxy resins in primary forms (EU 27) [EUSTAT 2012c]

EU27 Trade EPOXIDE RESINS, IN PRIMARY FORMS (IMPORT EU 27)				
Extracted on	21.03.12			
Source of Data	Eurostat			
PARTNER	EU27_EXTRA			
PRODUCT	390730			
FLOW	IMPORT			
INDICATORS	QUANTITY_IN_100KG			
REPORTER/PERIOD	Jan.-Dec. 2008	Jan.-Dec. 2009	Jan.-Dec. 2010	Jan.-Dec. 2011
EU27	1367166	940354	1218057	1215787

Table 12 contains export statistics of epoxy resins in primary forms from the EU 27 to non-EU27 countries for the years 2008-2011. As it can be seen, most of the epoxy resins in primary forms were exported in 2008 and 2010. Lower figures have been reported in 2009 and 2011 with more than 140,000 tonnes and almost 150,000 tonnes, respectively.

Table 11: Exports of epoxy resins in primary forms (EU 27) [EUSTAT 2012c]

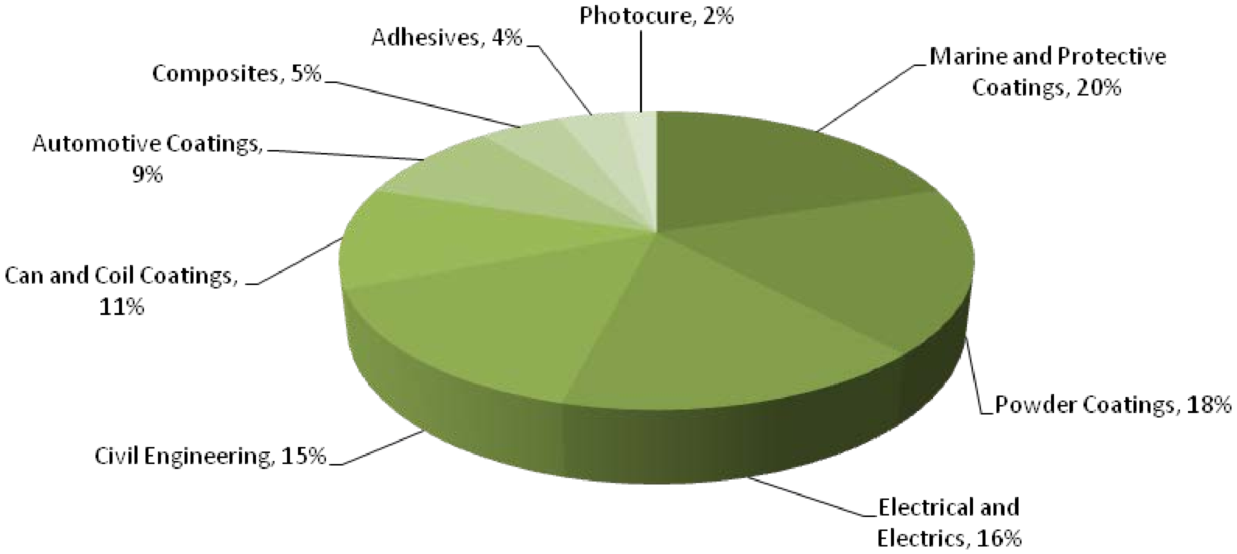
EU27 Trade EPOXIDE RESINS, IN PRIMARY FORMS (EXPORT EU 27)	
Extracted on	21.03.12
Source of Data	Eurostat
PARTNER	EU27_EXTRA
PRODUCT	390730
FLOW	EXPORT
INDICATORS	QUANTITY_IN_100KG

REPORTER/PERIOD	Jan.-Dec. 2008	Jan.-Dec. 2009	Jan.-Dec. 2010	Jan.-Dec. 2011
EU27	1538021	1420550	1690627	1495242

The figures in Table 11 and Table 12 also show that the net exports of epoxy resins in primary forms are comparably low (e.g. net export of 27,945 tonnes in 2011). Again, these figures do not take into consideration imports and exports of epoxy resins in finished products.

There are a number of different epoxy resins, which vary depending upon the starting materials. However, diglycidyl ethers of BPA derived from BPA and epichlorohydrin are among the most widely used epoxy resins [EU RAR 2003]. 90 % of the world production (1.7 million tonnes in 2008) of epoxy is produced based on BPA [BmVBS 2012]. Other than BPA and bisphenol F based epoxy resins are cycloalphatic epoxy resins [Plastic Europe 2006]. For use the resins must be cross-linked with a curing agent or hardener. The choice of curing agent is of paramount importance in designing an epoxy resin for a given application. The major reactive groups in the resin can react with many other groups so that many types of chemical substances can be used as curing agents. These include acid anhydrides, aliphatic and aromatic amines and polyaminoamides. Some curing agents will cross-link the resin at ambient temperature while others require the application of heat. However, the simple mixture of resin and curing agent rarely provides a material containing all the desired properties for a specific application. Other materials are therefore added in formulating the system. The bisphenol-A derived epoxy resins are most frequently cured with anhydrides, aliphatic amines, or polyamides, depending on the desired end properties. Some of the desired properties are superior electrical properties, chemical resistance, heat resistance, and adhesion. Epoxy resins are a family of synthetic resins, including products which range from viscous liquids to high melting point solids. Epoxy resins are selected because of their corrosion protection, thermal stability and mechanical strength and are used primarily as coatings for consumer and industrial applications, such as food and drinks cans and protective coatings for automotive and marine uses, electrical and electronic laminates, adhesives and paving applications, protective coatings, structural composites, electrical laminates, electrical applications and adhesives [EU RAR 2003][PE 2006][Geens et al. 2011]. An overview on the use of epoxy resins is given in Fig. 3 and Table 13.

Fig. 3: Uses of epoxy resins made from BPA [Bisphenol A Europe, 2012]



There are also some consumer uses of BPA in form of epoxy resins, which have been discussed controversial in relation with human exposure like can coatings or lining of water pipes. Epoxy can coatings are based on high molecular weight epoxy resins made by advancing liquid epoxy resin with BPA. Higher molecular weight grades of epoxy resins are used for can coatings, while the lower molecular weight grades are used in powder coatings. In the EU RAR [EU RAR 2008], it was reported that there are approximately 5 sites within the EU carrying out can coating operations and that the total tonnage of BPA used is 2,460 tonnes/year (data for 2005/2006). The collected end uses of epoxy resins have been screened for potential emissions to the environment. Based on information from production sites, the EU RAR [EU RAR 2003 and 2008] has concluded that no relevant emissions are expected from production of can coatings and powder coatings. However, emissions to the environment might occur during production of epoxy resins, in case of outdoor uses of epoxy resins in form of lacquers, paints or coatings or indoor uses with leaching of BPA from floor sealing or articles and thus release to waste water.

Table 12: Uses of BPA in epoxy resins [Bisphenol A Europe, 2012] [Plastics Europe, 2012] [Geens et al., 2011]

Polymer	Application class	Application
Epoxy Resins	Marine and Protective Coatings	water ballast tanks, underwater ship hulls, cargo tank linings, offshore oil drilling platforms, supporting steel structures, sea containers, steel bridges, storage tanks (metal and concrete), power plant scrubbers, electric motors, engines, machinery, drinking water distribution pipes (metal and concrete), gas pipes
	Powder Coatings	construction panels (cladding, metal roofing, ceiling, garage doors), radiators, rebars (concrete reinforcement), gardening tools and equipment, engine blocks, automotive parts, steel furniture, steel racks, frames beds, office furniture (shelves, metal desks, filling cabinets), pipes, valves and fittings
	Electrical and Electronics	potting / encapsulation electronic parts (transformers, inductors), printed circuit boards

Polymer	Application class	Application
	Civil Engineering	flooring (industrial / public buildings), food / catering industry, chemical plants, pharmaceutical industry, hospitals), mortars grouting (tile and brick linings), fillers, crack repair, coatings concrete bridges (seal against water and de-icing chemicals), coatings secondary containment walls (ground water protection), anti-skid coatings for park desks
	Can and Coil Coatings	Can food and drink cans / can ends, menue trays, food trays, craps and closure, crown cork, drums, pails, general line cans (oil, hairspray), collapsible tubes (toothpaste, cream) Coil construction panels (cladding, metal roofing, ceilings, garage doors), cookers, mobile homes, caravans, heat – ventilation- air conditioning equipment, office furniture (metal desks, shelves, filing cabinets, cupboards), fridges and freezers, dishwashers, washing machines, dryers, household appliances (e.g. vacuum cleaners)
	Automotive Coatings	waterborne primers for cars, buses, railcars
	Composites	rackets (tennis, badminton, squash), hockeysticks and golf clubs, ski, ski poles, snowboards, surfboards, boats, canoes, hang gliders, helmets, lightweight bicycles, pipes, valves and fittings, storage tanks, containers, gas bottles, windmill blades, scrubbers, pultruded structural parts (rods, bars, shafts, beams, grating), cars parts (body panels, cabin, spoiler, leaf springs, drive shafts), railcars, boats, yachts, aviation (aircraft), aerospace, military (helicopters)
	Adhesives	DIY repair kits (adhesives, fillers), structural adhesives for buildings and constructions, adhesives for cars, boats, aircrafts
	Photocure	printing inks, wood coatings, paper and board varnish incl. food packaging, coatings for plastics an primed metals

Conclusion:

According to the information available from the EU RAR [EU RAR 2003 and 2008], can coating materials and powder coating materials are based on epoxy resins and data from industry publications [Bisphenol A Europe, 2012] indicate that 11% of produced epoxy resins is used for can and coil coatings and 18% of produced epoxy resin is used for powder coating. Taking into account a total volume of BPA used for production of epoxy resins of approximately 195,000 tonnes per year, this would result in 56,550 tonnes of BPA (29 % of total production) which are annually used for production of can coatings and powder coatings.

There are a lot of applications where surfaces coated with epoxy resins may contribute to emission of BPA to the environment either due to release of residual monomeric BPA or due to depolymerisation (e.g. weathering in outdoor applications like marine and protective coating of ships. This might result in underestimation of emissions to the environment resulting from use of epoxy resins.

Use of BPA in the production of other polymers

BPA is also used in the production of a number of other polymers and resins including phenoplast resins, phenolic resins, and unsaturated polyester resins. In the EU RAR [EU RAR

2008] it was estimated that 8,800 tonnes/year BPA was used in the production of phenoplast resins, and that 3,600 tonnes/year BPA was used in the production of unsaturated polyester resin (data for 2005/2006). No values were available for use of BPA in the production of phenolic resins.

BPA formaldehyde resins or phenoplast resins are based on the reaction products of a phenol (BPA) and formaldehyde. After dilution with water, they are used for the impregnation of paper or coating of wood fibres in the manufacturing of high pressure laminated compact panels. These phenoplast resins may be used in parts for electrical applications; electrical parts for electronics, aviation, radio engineering; antifrictional parts and constructive and insulating parts [Geens et al. 2011]. According to the EU RAR [EU RAR 2003 and 2008], based on site specific data, no emissions are expected from production of phenoplast resins as closed systems are used. However, use of phenoplast resins for impregnation processes has been identified as source for BPA emissions in the EU RAR [EU RAR 2003 and 2008].

Unsaturated polyesters resins based on BPA include BPA fumarates and BPA dimethylacrylates. Propoxylated BPA fumarate unsaturated polyester resin provides good resistance against highly corrosive environments and is therefore used as storage tanks and process vessels. Glass reinforced composite resins are used in the manufacture of boats, swimming pools and translucent roof sheet (Table 14). Ethoxylated BPA dimethacrylate is a cross-linker for anaerobic adhesives and dental compounds [Geens et al. 2011]. According to the EU RAR [EU RAR 2003 and 2008], production of unsaturated polyester resins is a dry process and therefore no emissions have to be expected. Furthermore, against the background that both resins are used only in special applications, production volumes are assumed to be still low (3000 tonnes BPA/year). Due to their resistance against corrosive environments BPA fumarates are not considered to release relevant amounts of BPA to the environment. The use of BPA dimethylacrylate is also assumed not to result in releases of BPA to the environment.

Polysulfone is a thermoplastic polymer synthesized by the condensation of BPA and bis(4-chlorophenyl)sulfone. It is used due to its toughness and stability at high temperatures. It offers a higher heat resistance and better hydrolytic stability than Polycarbonate (PC) polymers and preserves its good mechanical properties when exposed to steam and other sterilization techniques. It can be used as a highly transparent, sterilizable, long-term dishwasher safe and impact resistant alternative for PC. Possible applications are summarized in Table 14 [Geens et al. 2011]. Environmental emissions might occur during production of polysulfone polymers but due to the comparably high price tonnages are assumed to be low although no precise figures are available. Identified uses are not expected to result in relevant emissions.

Table 13: Use of BPA in other polymers [Bisphenol A Europe, 2012] [Plastics Europe, 2012] [Geens et al., 2011]

Polymer	Application class	Application
Polysulfone	Membranes	hemodialysis, drinking and ultra-pure waters, gas separation, food & beverage concentration, dairy
	Medical and Healthcare	surgical trays, nebulizers, humidifiers
	Food service	microwave cookware, beverage and food dispensers, milking machine parts
	Plumbing	hot water fittings, manifolds, mixer tape

Polymer	Application class	Application
		cartridges
Polyacrylates	Medical and Healthcare	Dental composite resins (BPA as impurity)
Polyetherimide		Electronic and Electrical, Automotive, aircraft industries, microwave applications
Unsaturated polyesters	Bottles and Packaging Adhesives, Medical and Healthcare	BPA fumarates: storage tanks, process vessels BPA dimethylarcylates: adhesives, dental compounds
Benzoxazines	Composites, Coatings, Adhesives, Encapsulant´s Manufacturing	Variety of uses, capability to exhibit the thermal and flame retardant properties of phenolics along with mechanical performance and molecular design flexibility

Polyacrylate dental composite resins (Table 14) consist of a mixture of monomers and are most commonly based on bisphenol-A glycidyl methacrylate (bis-GMA). In addition to bis-GMA, these resins contain other monomers to modify the properties, e.g. bisphenol-A dimethacrylate (bis-DMA). Although BPA is not used itself in composite resins, it might be present as an impurity of these monomers. Once sealants are applied to tooth structures, they are polymerized in situ through a chemical curing process or photoactivation [Geens et al. 2011]. Production and use of polyacrylate dental composite resins is not assumed to result in relevant environmental emissions.

BPA is also used as precursor in the synthesis of benzoxazines monomers. Polybenzoxazines are a new type of addition-cure phenolic system. They have gained interest because of their capability to exhibit the thermal and flame retardant properties of phenolics along with mechanical performance and molecular design flexibility. Therefore they can be used in a variety of applications in the industry of composites, coatings, adhesives and encapsulant's manufacturing [Geens et. al, 2011].

Conclusion:

According to the EU RAR, production of these polymers is not expected to result in relevant emissions to the environment and it is therefore expected that the production of polymers, does not result in relevant environmental emissions. It remains unclear whether use of these polymers contributes to emissions of BPA to the environment. The available information on properties and uses of these polymers, on first view, would lead to the conclusion that relevant emissions are not expected.

Miscellaneous

PVC

A small quantity of BPA is used in soft PVC. Three different uses have been described in the EU RAR [EU RAR 2008]: as an anti-oxidant in PVC processing (450 tonnes/year); as a constituent of an additive package used in PVC processing (900 tonnes/year); and as an antioxidant in the production of plasticisers used in PVC processing (450 tonnes/year).

Conclusion:

Thermal paper

BPA is used as developing agent in the coating of thermal paper [Bisphenol A Europe 2012]. The main function of BPA is as a developing agent, when the paper is heated. The bisphenol-A in the paper reacts when it is heated, but as in most cases only a minor part of the paper is developed residual bisphenol-A remains. One tonne of bisphenol-A is used to produce approximately 75 tonnes of thermal paper. Emissions to the environment are not only expected during production but also during recycling and other end-of-live fates of thermal paper.

Conclusion:

Tetrabrombisphenol-A

BPA is also used in the production of the flame retardant tetrabromobisphenol-A (TBBPA). Production of TBBPA in the EU ceased in early 1998 [EU RAR 2003]. Production of TBBPA is therefore no relevant use of BPA in Europe and releases of BPA from this process are not expected. Most of TBBPA (58%) is used as reactive monomer in the production of epoxy, PC and phenolic resins which are flame retardant polymers for printed circuit boards. Residual levels of TBBPA are usually below 100 ppm. Since residual BPA in TBBPA can also react during the polymerization process, free BPA levels present in the polymeric material are very low. Around 18% of TBBPA is used for the production of TBBPA-derivatives and oligomers and the same amount of TBBPA is used as additive flame retardant [Geens et al. 2011]. Against the background that BPA can be built by degradation of TBBPA in the environment, TBBPA might be a source for BPA in sediment and soils.

Conclusion:

Minor uses

Furthermore, small amounts (in total approximately 6,000 tonnes per year) of BPA are used for chain oil, break fluids, heat transfer fluids, lubricant formulations and in the production of tyres [Environment Canada 2012][EU RAR 2003]. Although some of these applications might suggest releases to the environment (e.g. tyres or brake fluids), concentrations of BAP in these fluids/articles are very low and total amounts of BPA used for production are not high. Furthermore, BPA is either integrated in matrices or fluids containing BPA are disposed as chemical waste.

Conclusion:

3.3 Environmental releases during Production and use of BPA

3.3.1 Emissions to the Environment from production of BPA

As explained above, the amount of BPA produced per year has obviously not changed very much since elaboration of the RAR [EU RAR 2008]. This leads to the conclusion that the emissions from production of BPA estimated in the EU RAR [EU RAR 2008] are still valid. Emissions to the water compartment occur as emissions to surface water after waste water treatment at on-site WWTP. Exposure of soil and groundwater could occur either via atmospheric deposition or application of sewage sludge to land. As half-life of BPA in the atmosphere is reported to be short (0.2 days)[EU, 2010], atmospheric deposition can be considered to be negligible. It is considered reasonable that sewage sludge from industrial sewage treatment plants is no applied to land. EU RAR also does assume that manufacturing of BPA is not a significant contribution to the environmental compartments soil and groundwater [EU 2003 and 2008]. Therefore, no emissions to soil and ground water is expected from production of BPA.

Table 14: Emissions from production of BPA

	Emissions to surface water (kg/year)		**Emissions to air (kg/year)**	
	Regional	**Continental**	**Regional**	**Continental**
Production of BPA	113	148	575	418

Conclusion:

Main emission pathways for this life cycle step are emissions to surface water and emissions to air. The estimated regional and continental emissions are based on measurement results provided by operators of the seven BPA production sites in Europe. Although emissions to air are comparably high at some production sites, it is assumed that due to the low atmospheric half live of BPA atmospheric deposition to soil does not result in relevant BPA concentrations in soil and groundwater.

3.3.2 Emissions during production of PC articles

As already shown in section 3.2, PC is used for production of various articles used in different industrial sectors and consumer applications. Emissions to the environment might occur during processing of PC, during use of articles and at the end of the life-cycle during recycling and after disposal of products made from PC (see mass flow in Fig. 14).

Main transformation techniques for PC resins are:

- extrusion into tubes, rods and other profiles,
- extrusion with cylinders into sheets (0.5–15 mm (0.020–0.59 in)) and films (below 1 mm (0.039 in)), which can be used directly or manufactured into other shapes using thermoforming or secondary fabrication techniques, such as bending, drilling, routing, laser cutting etc, or
- injection molding into ready articles.

The EU RAR [EU 2003] mentions two publications [Ligon et al. 1997, 1998] related to emissions of BPA during processing of PC polymers. No BPA was detected in the vent gases from extrusion apparatus during extrusion operations with different PC polymers. Furthermore, no BPA was detected in the vent gases from moulding apparatus during moulding of PC polymers. In the EU RAR [EU RAR 2003] it is also mentioned that operating conditions might have an influence on residual BPA levels in the produced articles due to degradation. Rhodes et al. [2002] developed emission factors for selected organic compounds including BPA during extrusion by processing eight commercial grades of PC and one grade of a PC/acrylonitrile-butadiene-styrene blend. Emissions during the extrusion processes were measured using GC techniques and very low BPA emissions between 0.11 and 0.65 µg/g have been achieved.

Assuming that all the PC produced (, would be processed by extrusion, a worst case scenario for emissions from processing, calculated based on an average emission rate of 0.325 µg/g would result in emissions to air of approximately 0.22 kg/year. Against this background, emissions from processing of BPA are considered to be of no relevance for the environment. No emissions to the water compartment expected from processing of PC as usually no water is used in the process. Site specific emissions to air cannot be calculated as no information is available how many sites perform extrusion processes. Against the background that only very low emissions to the atmosphere are expected at dedicated sites, no emissions to soil and ground water due to atmospheric deposition are expected.

Table 15: Emissions from processing of PC to water.

	Emissions from processing of PC (kg/year)	
	Regional	**Continental**
Emissions to air	-	0.22
Emissions to water	0	0

Conclusion:

Main emission pathways for this life cycle step are emissions to air. The estimated continental emissions are based on information taken from scientific publications and the estimated amount of PC produced in Europe. Although it is not possible to estimate site specific concentrations, it is assumed that this life cycle step does not result in relevant local emissions as the total emissions (0.22 kg/year) are very low.

3.3.3 Emissions during use of PC articles

Emissions of BPA during use of PC articles may result from residual BPA not bound in the PC matrix or from hydrolysis or degradation of PC. However, in the EU RAR [EU RAR 2003], emissions from bottle washing and release due to hydrolysis of outdoor applications have been discussed. The maximum residual content of BPA in PC is reported as 50 mg/kg. Typically the residual content is < 10 mg/kg [EU RAR 2003]. BPA is retained effectively in the PC matrix, resulting in low extractability by aqueous, alcohol or fat containing media. Table 17 shows the distribution of the worldwide production of PC to different applications.

Table 16: Global PC production and application areas [PE 2012b]

Global polycarbonate production volume 2009: approximately 3 million tonnes (data provided by industry)	
Application areas	**Percentage of the total volume produced [%]**
Building and Construction	27
Optical media	23
Electrical and electronic	21
Automotive	12
Domestic Appliances	5
Leisure and safety	3.5
Bottles and packaging	2.5
Medical devices	2.5

Indoor uses of PC articles

During indoor use of most of the articles made of PC or including PC parts, no emissions to the environment are expected as no water contact is expected under foreseeable conditions of use. This applies for example to optical media electrical and electronical applications, medical devices and domestic appliances. However, there are also some applications where contact with water occurs.

Several studies have raised potential migration of BPA from bottles or containers to food. These emissions are usually considered to be of relevance only for exposure of humans via food. However, food containers and bottles consisting of PC are cleaned in dish washers at elevated temperatures using detergents. This might lead to leaching of small amounts of BPA from these products. In a laboratory study, it was evaluated whether BPA migrated into water stored in new or used high-quality PC bottles used by consumers. Using a sensitive and quantitative competitive enzyme-linked immunosorbent assay, BPA was found to migrate from PC water bottles at rates ranging from 0.20 ng/h to 0.79 ng/h. At room temperature the migration of BPA was independent of whether or not the bottle had been previously used. Exposure to boiling water (100 °C) increased the rate of BPA migration by up to 55-fold [Le et al. 2008].

Some studies in Japan have reported that more BPA can leach from PC that has been scratched or is more than four years old. Other scientists showed that up to 6.5 µg/kg leached from old PC baby bottles heated up to 95°C for 30 minutes, but new bottles only leached up to 3.5 µg/kg (ppb). It has been reported that scratched bottles from the Philippines leached approximately 30 µg/kg (ppb) of BPA and those from Korea leached over 15 µg/kg, more than 5 times the amount leached by new bottles. Other Japanese researchers have found increased levels of BPA leaching from old PC tableware. BPA levels increased to 1.8-7.9 ppb (µg/kg) for older products, as compared to 1-1.9 ppb for new tableware. The leaching of BPA into soup was tested by using new and used PC soup bowls, and filling them with water and other liquids at temperatures of 60-95°C, then allowing these liquids to cool for 30 minutes. Both new bowls and old bowls (used for up to 6 years) tested with water at 95°C were found to leach between 0.5 - 2 ppb BPA, whereas at 85°C, only older bowls leached BPA [Lyons 2000].

Biles et al. investigated leaching of BPA from five gallon water carboys. The amount of BPA in water from the five gallon carboys was found to range from ND (not detectable) to 5 µg/l (in water stored for 39 weeks). Other scientists have found BPA and other contaminants in mineral water stored in plastic bottles [Biles et al. 1997].

In another study, it was examined whether new and used PC animal cages passively release bioactive levels of BPA into water at room temperature and neutral pH. Purified water was incubated at room temperature in new PC and polysulfone cages and used (discoloured) PC cages, as well as control (glass and used polypropylene) containers. The resulting water samples were characterized with GC/MS and tested for estrogenic activity. Significant estrogenic activity, identifiable as BPA by GC/MS (up to 310 µg/L), was released from used PC animal cages. Detectable levels of BPA were released from new PC cages (up to 0.3 µg/L) as well as new polysulfone cages (1.5 µg/L), whereas no BPA was detected in water incubated in glass and used polypropylene cages [Howdeshell et al. 2003].

It is difficult to evaluate emissions from dishes and drink ware made from PC (e. g. plates, mugs, jugs, beakers), microwave ovenware, storage containers, returnable water and milk bottles), as exact figures about production volumes are not available and only very limited information about migration rates under varying conditions exists. However, there are several studies which report migration of BPA from PC articles under conditions which occur during foreseeable use of household articles made of PC like dishes. Environmental emissions resulting from professional or consumer use of PC articles most likely result from washing processes. Dish washers work at temperatures up to 65°C in combination with detergents. This may lead to BPA leaching out of PC articles during cleaning and thus emissions to waste water. Used PC articles are assumed to emit more BPA than new products.

The EU RAR [EU 2003] includes an assessment of emissions from washing of PC bottles during their service live based on results of Howe and Borodinski [1998] who reported that in migration studies with water no BPA was detected in the extract after 6 hours at 100°C. The detection limit was used to calculate a worst case scenario based on the assumption that 7,500 tonnes of PC is used to produce bottles each year and 18,750,000 bottles are in use. This resulted in emission of 1.6 kg per year from this use. As production of PC has increased by 78 % between 2003 and 2008, the total emissions from bottle washing are assumed to have increased at least in the same ratio, resulting in total release of 2.28 kg per year to waste water treatment plants.

However, according to Plastics Europe (see above) 2.5 % of amount of PC annually produced worldwide is used for production of bottles and packaging. It is assumed that this distribution can be considered to be representative also for the EU. If this is the case, approximately 25,000 tonnes of PC are used to produce bottles and packaging per year. Using the data basis presented in the EU RAR [EU RAR 2003] and assuming that emissions from table ware are identical to leaching from PC bottles, to calculate emissions based on the amount of PC used for production of bottles and packaging every year, emissions of 5.3 kg/year BPA from washing of bottles and packaging can be expected.

Another scenario can be calculated assuming that leaching 5 ppb BPA from used PC bottles and dishes per washing process appears (see reported migration rates above). Again assuming a lifetime of 2 years, bottles and dishes of about 50,000 tonnes PC are in use. In case of 25 washings per year, an annual migration rate of 125 µg/kg will result in emissions to waste water of 6.25 kg/year.

For a worst case scenario calculation, it has been assumed that the maximum residual content of BPA in PC is 50 mg/kg (typically the residual content is < 10 mg/kg) as reported in the EU RAR [EU RAR 2003]. It is further assumed that all residual BPA leaches from PC articles during service life and that not only bottles and packages (2.5 % of produced PC) but also all other PC articles used in domestic applications (5% of produced PC) is cleaned and gets in contact with water.

Information on exact production volumes for PC in Europe is not available. It it is known from statistical data that 191,000 tons of PC in primary forms are exported. Assuming that use of BPA for production of PC results in an equal amount of PC produced, the amount of PC used in Europe for processing is approximately 674,000 tons. Assuming that 7.5 % of this amount is used in domestic applications, 50,550 tons of PC in form of articles used in-house are produced every year. Assuming a life time of 2 years for articles like dishes and bottles etc. 101,100 tons of such articles are in use and release BPA to wastewater during cleaning processes. Taking into account that up to 10 ppm residual BPA can be present in such articles which might completely released during use of these articles an annual release of 1,011 kg BPA to waste water can be expected.

Emissions from cleaning of PC articles are not assumed to be point emissions resulting in environmental concentrations of concern. Nevertheless, continuous, low emissions from these uses may contribute to the total concentrations of BPA found in waste water and STPs. Due to lack of detailed information; it is at the moment not possible to calculate exact releases for indoor use of PC articles. The emissions calculated for washing of PC bottles, presented in the EU RAR [EU 2003], seem to underestimate releases from PC articles. Emissions from use of PC articles are considered to be of low relevance compared to other uses although the worst case calculation demonstrates that there exists a potential for release of BPA in case high concenmtrations of residual monomeric BPA remain in articles made from PC.

Emissions to the water compartment occur as emissions to waste water treatment plants and then to surface water after waste water treatment at WWTP. In accordance with the EU RAR [EU RAR 2008], a factor of 10:90 has been used to calculate regional and continental emissions and a factor of 80:20 has been used to calculate releases to waste water treatment and to surface water [EU 2008] based on the worst case scenario resulting in the highest emissions. Taking into account data from scientific literature, efficiency of WWTPs in elimination of BPA from water differs from case to case and does in some cases reach nearly 100 %. However, there are also reports of efficiencies far below 80 % so that this estimation is regarded as valid. Emissions are summarised in Table 18.

Table 17: Emissions from indoor use of PC articles to water (best case scenario – worst case scenario)

	Emissions from indoor use of PC articles (kg/year)	
	Regional	**Continental**
Emissions to WWTP	0.63 – 101.1	5.63 -909.9
Emissions to surface water	0.13 – 20.2	1.13 – 181.9
Emissions to air	0	0
Emissions to soil	0	0

Conclusion:

During indoor use of most of the articles made of PC or including PC parts, no emissions to the environment are expected as no water contact is expected under foreseeable conditions of use. Relevant emissions of BPA can occur during use of PC articles like use of PC bottles for drinking water and food containers as these articles are reused several times and therefore cleaned/washed. To ensure that the bottles/boxes are clean before they get in contact with food again, comparably harsh conditions (e.g. washing with acids) are necessary which can result in leaching of BPA from the polymeric matrix.

Outdoor uses of PC articles

27 % of the production volume of PC is used for construction applications and 12 % are used for automotive parts. PC is used as alternative to glass as it allows high light transmission, is stable against stroke and lighter than glass. Here weathering effects might cause release of BPA by breakdown of the polymer which might be relevant against the background of the high volumes of PC used and the long service life of these articles. In some cases, PC shields for outdoor applications may be coated by lacquers to protect them from environmental impacts. The EU RAR [EU 2003] mentions that laboratory studies have shown that thermo, thermo-oxidative, hydrolytic and UV-radiation induced ageing processes did not lead to BPA formation from PC.

Howdeshell et al. (2003) examined whether new and used PC animal cages passively release bioactive levels of BPA into water at room temperature and neutral pH. Significant amounts of BPA (up to 310 µg/L), were released from used PC animal cages. Lower levels of BPA were released from new PC cages (up to 0.3 µg/L) as well as new polysulfone cages (1.5 µg/L) demonstrating that leaching of BPA can increase with the duration of use [Howdeshell et al. 2003].

It has been shown that stabilized PC sheets subjected to outdoor weathering for relatively short periods of time developed a network of surface microcracks on the side exposed to solar radiation. Microcracking occurred under the influence of light radiation in conjunction with cycling of either temperature and moisture or temperature alone. The resin of the exposed surface undergoes, with weathering, a gradual reduction in strength owing to a lowering of its molecular weight as a result of photochemical degradation. Cyclic variation of temperature and humidity in natural and artificial weathering imposes on the surface material a type of stress fatigue. Such stress fatigue is caused by the varying dimensional changes that result from thermal and moisture content gradients between the surface and the bulk of the resin and from inhomogeneities and defects [Blaga and Yamasaki 1976].

In a study about weathering of PC sheet samples, conducted by a producer, 204 PC sample sheets were exposed to high UV and rainwater weathering conditions. More specifically, two hundred four samples of PC sheet with a total surface area of 0.98 m^2, a weight of 2.038 kg, and a residual BPA content of 6 ppm were exposed to different amounts of light, heat, and water in order to simulate different weather conditions equivalent to over 9 years in European climate conditions. The results indicated that the BPA concentration released after 2000 hours of weathering to the circulating water was 1.35 mg/m^2 exposed PC. Therefore, the yearly PC degradation was estimated to be 0.15 mg/m^2 [EU RAR 2003].

Based on the information of a European producer that their PC production for sheets is 20,750 tonnes which yields a total surface area of 8.7 km^2, it was concluded in the EU RAR [EU RAR

2003] that based on an annual release factor of 0.15 mg/m^2, this would result in a BPA release of 1.3 kg/year. Against the background that 27 % of PC produced every year is used for construction applications and more or less all these applications are outdoor uses, the amount of PC used for outdoor construction applications today is estimated to be approximately 233,000 tonnes per year. In the RAR [EU RAR 2003], the annual production volume of one producer has been used as basis for calculation of total annual releases from PC shields in outdoor applications. Taking into account that production of PC has slightly increased and the use for construction has more than doubled since 2006, annual growth rates of 15 % seem to be realistic. Assuming a lifetime of 9 years (which might be even higher), 1,193,555 tonnes of PC shields are in use. Assuming the same surface area factor as in the EU RAR [EU RAR 2003], this would result in a total surface area of 500 km^2 and thus annual release of BPA of 75.1 kg.

These estimations, although being a worst case scenario as PC sheets may also be used indoors or be varnished to protect them from weathering, demonstrates that based on the available information, continuous low emissions from these uses may contribute to the total concentrations of BPA found in the environment, although the outdoor use of PC cannot be considered to be a point emission resulting in environmental concentrations of concern,. Emissions to waste water and STP as well as to ground water and soil may arise. It also has to be considered that construction is not the only outdoor application of PC. Automotive parts like head lamps or sun roofs are also made from PC and are also exposed to weathering. Due to lack of detailed information, it is at the moment not possible to precisely calculate total releases for outdoor use of PC articles. The emissions calculated for plastic roofs, presented in the EU RAR [EU RAR 2003], seem to underestimate releases from PC articles in outdoor applications although releases to single points are assumed to be very low compared to other uses/life cycle steps like for example BPA or thermal paper production.

For a worst case scenario calculation, it has been assumed that the average annual release of BPA from PC sheets is approximately 0.15 mg/m^2 [EU RAR 2003]. It is furthermore assumed that PC use in construction and automotive industry completely results in outdoor applications and thus is exposed to weathering conditions. Information on exact production volumes for PC in Europe is not available (see above). Assuming that use of BPA for production of PC results in an equal amount of PC produced, the amount of PC used in Europe for processing is approximately 674,000 tons. Assuming that 27 % of this amount is used in construction applications and 12 % is used in automotive applications; 262,860 tons of PC in form of panels/sheets used in construction and automotive industry are produced every year. Assuming a life time of 9 years for articles like sheets, 2,365,740 tons of such articles are in use today and may release BPA to water during ageing. Based on the information of a European producer on its web page, that their PC production for sheets is 20,750 tonnes which yields a total surface area of 8.7 km2, the calculated average surface area per ton PC is 419.3 m^2 (average weight 2.4 kg/m^2). This would result in a total PC surface area of 991,245,060 m^2. Taking into account a BPA release factor of 0.15 mg/m^2 148.7 kg BPA would be released to the environment.

Another scenario based on the data reported above can be calculated assuming that the concentration of monomeric BPA in PC is 10 ppm and all monomeric BPA is released during service life. In this case, 262,860 tons of PC used every year can be assumed to release 2,628 kg BPA.

Emissions to the water compartment from outdoor use of PC articles are considered to occur in most cases as direct emissions to surface waters and not to waste water treatment plants. As in the EU RAR [EU RAR 2008], a factor of 10:90 % is used to calculate distribution between regional and continental emissions although even at point sources like green houses or soccer stadiums concentrations are assumed to be below 10 % of the total emissions. No relevant emissions to air or soil (due to atmospheric deposition) are expected from outdoor use of PC articles Emissions from outdoor use of PC articles are summarised in Table 19.

Table 18: Emissions from outdoor use of PC articles to water

	Emissions from outdoor use of PC articles (kg/year)	
	Regional (best case – worst case)	**Continental (best case – worst case)**
Emissions to WWTP	-	-
Emissions to surface water	7.5 – 262.8	67.6 – 2,365.2
Emissions to air	0	0
Emissions to soil	0	0

Conclusion:

During outdoor use of articles made of PC emissions to the environment are expected due to weathering and release of monomeric BPA. There is only a limited data basis available regarding migration rates for BPA from PC under environmental conditions. Furthermore, it is difficult to estimate the amount of BPA in outdoor applications based on publicly available data. Industry information on migration rates and volumes of PC used in outdoor applications might allow a more precise calculation of emissions from PC articles.

3.3.4 Emissions during use of BPA in the Production of epoxy resins

BPA is used in the production of epoxy resins within the EU, and information on releases of eight production sites provided by the operators of these sites has been included in the EU RAR [EU RAR 2003]. As there is no other information available from scientific literature or other publications, information provided in the EU RAR [EU RAR 2003] (site specific data on releases) and information obtained from registration dossiers (e.g. tonnage) has been used to estimate emissions. For sites where BPA production and manufacturing of epoxy resins take place, the releases of BPA have been assumed to be already covered by releases from BPA production sites. The total amount of BPA used in the production of epoxy resins has been estimated in the EU RAR [EU RAR 2003] at 171,095 tonnes/year from company submissions. For use sites representing 92% of total tonnage site-specific information has been used to calculate emissions to the environment Emissions from WWTPs of production sites to surface water have been reported to be between 0 and 0.72 kg/day. The regional and continental emissions have been calculated using the sum of site-specific data and application of a release factor to the remaining tonnage. The sum of release to water after wastewater treatment from the site-specific data was estimated to be 290.25 kg/year. From the site-specific data the highest release factor for BPA to water after wastewater treatment is $8.64.10^{-3}$ kg/tonne BPA processed. Applying this factor to the tonnage for sites for which no release information was available gave a release of 113 kg/year. The sum of site-specific and the calculated release data was 1.335 kg/day (403.25 kg/year), this was taken as the total release. For modelling in EUSES the largest release to surface water from site-specific data (216 kg/year) has been used for the regional releases and the remaining releases from site-specific data and calculated release data (187.25 kg/year) have been used for the continental releases after wastewater treatment [EU RAR 2003].

As there is no information available about new risk reduction measures in place at epoxy resin production sites, calculations made in the EU RAR are considered to be still valid. Just the slightly increased tonnage has to be considered when emissions from epoxy production are calculated based on data from the ER RAR [EU RAR 2003]. Therefore, it is assumed that the increase is equally shared between the production sites, emissions should have increased by 11%. No relevant emissions to air or soil and ground water are expected from production of epoxy resins as according to the EU RAR [EU RAR 2003] all production sites have reported to have on-site WWTPs with subsequent incineration of sludges.

Table 19: Emissions to water from epoxy resin production sites

	Emissions from production of epoxy resins(kg/year)	
	Regional	Continental
Emissions to surface water	246.1	213.4
Emissions to air	0	0
Emissions to soil	0	0

Conclusion:

Data on emission from production of epoxy resins has been provided in the EU RAR [EU RAR 2003]. Against the background that new information on volumes of BPA used for production of epoxy resins was available, the calculations made in the EU RAR [EU RAR 2003] were adapted and slightly higher emissions as reported in the EU RAR [EU RAR 2003] are expected.

3.3.5 Emissions during use of epoxy resins

Neither the EU RAR [EU RAR 2003 and 2008] nor the CSA provided by REACH registrants does address releases of BPA from epoxy resins in use. In the EU RAR [EU RAR 2003] it is stated that epoxy resins are used in a range of applications including the electrical and electronic industry, building and construction industry. Most of the world wide produced epoxy resins are used as part of paints or lacquers (marine and protective coatings 20%, powder coatings 18%, civil engineering 15% (flooring), can and coil coatings 11%, automotive coating 9%)(Table 13).

In all these coating applications, BPA containing epoxy resins are used due to their good resistance against weathering and to protect surfaces from water. Release of BPA from epoxy resins may occur due to accelerated weathering after prolonged time. Emissions to waste water of epoxy resin and thus BPA may also occur due to consumer use of paints or lacquers containing epoxy resins. Professional and consumer use may result in disposal of paint residues to waste water by cleaning of brushes and other painters and varnisher equipment. Furthermore, there are also indoor applications which might result in leaching of BPA. Epoxy resins are for example used for floor sealing in industrial and professional sites where it is essential that floors are easy to clean (production areas of food industry/pharmacy industry, hospitals). Furthermore, waste is produced in case floor ceilings are renewed/changed. Potential releases from waste deposit on landfills is addressed later in this report.

The potential for release of BPA from epoxy resins is low as the residual monomer content of BPA in the epoxy resin as produced is a maximum of 1,000 ppm. The residual BPA will be further reacted when the product is used (i.e. when the epoxy resin is cured [EU RAR 2003]. However, it is known that BPA can migrate from cans coated with epoxy resins and from water pipes lined with epoxy resins (see section below). The potential for release of BPA seems to be high in case epoxy resins are not used in the right way, which means that for example the ratio between curing agent and resin was incorrect or the temperature and dry time have not been sufficient to allow complete polymerisation and thus hardening of the resin. Also in case sealed surfaces like surfaces in cans show scratches, increased leaching has been observed.

Compared to scientific information about migration of BPA from epoxy resins to food, there is only very little information about leaching of BPA from epoxy resins to water or environmental samples. Some Bae et al. measured BPA leaching from three epoxy resins at 20, 50, 75 and

100°C both in deionised water and specified test water, respectively. BPA leached to the test water was identified using GC-MS and quantified with GC-FID after a sequential extraction and concentration. The results showed that BPA leaching has occurred in all three samples tested. The quantity of BPA from unit area of epoxy resin coating was in the range of 1.68 and 1,734.05 $\mu g/m^2$ depending on the test temperature and the sample material. In general, the amount of BPA leaching increased as the water temperature increases [Bae et al. 2002]. Cooper et al. evaluated whether BPA migrates into water stored in different lined or unlined metallic reusable water bottles using a sensitive and quantitative BPA-specific competitive enzyme-linked immunosorbent assay. At room temperature the concentration of BPA migrating from aluminium bottles lined with epoxy-based resins was variable depending on the manufacturer ranging from 0.08 to 1.9 mg/L. Boiling water significantly increased migration of BPA from the epoxy lined bottles [Cooper et al. 2011].

Sakamoto et al. investigated the leaching characteristics of BPA from two kinds of epoxy-resin pavement materials; one containing epoxy resins (EPs) and the other containing epoxy-acrylate resins (EPAs). Both samples contained residual BPA monomer, at levels of 9.0 mg/g for the EP resin sample and 4.4 mg/g for the EPA resin sample. The amount of BPA leached from the samples increased with temperature and contact time, and approached an equilibrium value after 24 h. The leaching of BPA from EP was more strongly affected by temperature than the leaching from EPA. The pH also affected the amount of leached BPA. The maximum leached amount was observed under alkaline conditions (pH 10.8) for both sample types. The leached amount of BPA was also increased by the electrolyte effect of $NaPO_4$ ions, which were present in the phosphate buffer that was added to maintain the pH at 6.6. Other divalent or trivalent ions may increase the levels of leached BPA in aqueous dilute solutions, because these ions increase the ionic strength of the test solution. The amounts of BPA that might leach from pavement materials during 1 h of heavy rain were estimated to be 0.9 mg/m^2 for EP and 3.5 mg/m^2 for EPA. The authors concluded that EPs disposed of in waste landfills without any treatment may be a source of BPA in leachate at landfill sites [Sakamoto et al. 2004].

It is very difficult to estimate the total release of BPA from epoxy resins to the environment due to several reasons:

- There exist different types of epoxy resins containing different proportions of BPA. Therefore, it is not possible to calculate the amount of epoxy resins produced/used in Europe from the amount of BPA used for production of epoxy resins. Taking further into account the described uncertainty regarding import/export of epoxy resins in/from the EU, it is very difficult to estimate the total amount of epoxy resins used in the EU.
- There are various applications where epoxy resins are used to protect surfaces. Depending from the different requirements, compositions of the used resins are different and the concentrations of residual BPA in these products vary within a wide range.
- It is not possible to calculate the amount of epoxy resins in paints or lacquers used for single application without detailed knowledge of the composition and the amount of paint used.
- Conditions under which epoxy resins are used are quite different. In case of marine protective coatings, epoxy resins are continuously exposed to salt water, which might result in higher release of BPA than epoxy resins only exposed to rain on a few days of

the year. The dilution factor in oceans is however much higher than in case of rain water collected from a painted roofing.

- It is not possible to estimate the total outdoor surface area covered by epoxy resins to calculate releases on an area basis. Furthermore, mean thickness of varnishes, epoxy resins are used for is not known which prevents calculations based on tonnages.
- For some applications like use of epoxy resins in adhesives or composites, direct contact with water is not assumed in most cases. Surfaces for example of wind wheels or boat hulls are protected with a second lacquer layer. This might also be true for automotive coating where only the outside lacquer layer will get in contact with water.
- Emissions might also occur from unprofessional consumer use of epoxy resins and disposal of waste (for example via effluent water).
- In indoor-applications like floorings, cleaning procedures may influence the extent of release of BPA and thus emissions to waste water.
- Waste containing epoxy resins may also result in emissions to the environment. This topic is addresses later in this report.

There are a lot of uncertainties, which prevent an assessment of total release of BPA from epoxy resins. Information on exact production volumes for epoxy resins in Europe is not available and no information about the amount of BPA required to produce a certain amount of a typical epoxy resin is available as various different types of epoxy resins are produced. However, according to the information on uses of epoxy resins presented in chapter 3.2 at least 50 % of the epoxy resins produced every year can be assumed to be used in outdoor applications (e.g. 20 % marine and protective coatings). This means that 97,500 tonnes of BPA are used to produce epoxy resins for outdoor applications every year. Assuming that the average life time of lacquer lining is 3 years (1 year as assumed for antifouling paints in the EU RAR [EU RAR 2003] seems to be very short), a total amount of 292,500 tonnes BPA are in use in form of marine and other coatings (3 times the annual production). The EU RAR [EU RAR 2003] has evaluated Marine antifouling paints used in the consumer sector for the protection and decoration of yachts and boats. The paints are applied by brush or roller. In the UK these paints are typically applied once per year. There are some measured data on consumer exposure arising from the brush application of these products. Calculations of BPA exposure as a result of brush application of antifouling paints are based on a paint containing 40% epoxy-resin and a residual level of 10 ppm BPA in the resin. Also for other purposes (wood varnish, wood fillers) a residual BPA level of 10 ppm was assumed [EU RAR 2003]. Based on this information, it can be estimated that 10 ppm of the 292,500 tonnes BPA in use in form of marine and other coatings is available as monomer. In case these 10 ppm residual BPA are completely released during the 3 year life, this would result in total emissions of 292.5 kg per year to surface waters. In addition, releases due to weathering are expected but a final calculation is not possible based on the available data basis.

Based on the same information as already mentioned above, a worst case scenario has been calculated. The amount of BPA used for production of epoxy resins is 195,000 tonnes/year and the amount of BPA used to produce epoxy resin hardeners is 5,000 tonnes/year. Assuming that use of 200,000 tonnes of BPA for production of epoxy resins and epoxy resin hardeners results in an equal amount of epoxy resins produced, the amount of BPA used in Europe for epoxy resin applications is approximately 200,000 tonnes. Most of the produced epoxy resins are used as part of paints or lacquers (marine and protective coatings 20%, powder coatings 18%, civil engineering 15% (flooring), automotive coating 9%). It can be assumed that up to 62 % of epoxy resin annually produced is used for these applications, which is equivalent to 124,000 tonnes. It has been assumed that the residual monomer content of BPA in the epoxy resins is 10 ppm. In case it is furthermore assumed that all uses of epoxy resins related to coating, surface sealing, or painting are outdoor uses where the resulting lacquer layer is exposed to weathering or water. In case the average life time of lacquer layers is assumed to be 5 years, 620,000 tonnes of BPA are in use in form of lacquer layers. In case all monomeric BPA is released during the 5 year service life, it can be expected that 1,240 kg BPA are annually released to surface waters.

Emissions to the water compartment from outdoor use of epoxy resins are considered to occur in most cases as direct emissions to surface waters without waste water treatment. No relevant emissions to air or soil (due to atmospheric deposition) are expected from outdoor use of epoxy resins. Although local emissions are expected to be low, a 90:10 distribution has been assumed between local and regional emissions. It can be assumed that local emission sources contribute less than 10 % to the total emissions. Emissions from outdoor use of epoxy resins are summarised in Table 21.

Table 20: Emissions from outdoor use of epoxy resins to water

	Emissions from outdoor use of epoxy resins (kg/year)	
	Regional (best case – worst case)	**Continental (best case – worst case)**
Emissions to WWTP	-	-
Emissions to surface water	29.3 – 124.0	263.3 – 1,116.0
Emissions to air	0	0
Emissions to soil	0	0

Conclusion:

Releases of BPA to the environment are expected only from very few indoor applications like floor linings in case of cleaning in amounts which are not assumed to be of relevance for environmental health. More relevant seem to be emissions from outdoor use of paints and lacquers including epoxy resins like marine and protective coatings and potentially other coatings which get in contact with rainwater. Here on the one hand leaching of monomers and on the other hand weathering effects can contribute to release of BPA. The provided estimation for releases is a very rough estimation with high uncertainties and it is not possible to calculate local concentrations from this figure. Due to the wide dispersive use of paints it is assumed that the potential for relevant point concentrations is very low. This becomes more evident when taking into account the high dilution factor for releases from marine coatings to the oceans. Nevertheless, more data on emission rates from epoxy resins and paints made from epoxy resins under environmental conditions are required to conclude on the relevance of emissions from this life cycle step.

3.3.6 Use of BPA in relining of water pipes with epoxy resins

One application of Epoxy resin is to rehabilitate water pipes. There are two major epoxy resin types. One contains solvents and the other is solvent free. In case of solvent free coatings the coating can be as thick as 2,000 µm. [UBA Beschichtungsleitlinie 2010]. For the rehabilitation of water pipes with epoxy resin different techniques have been developed, which are discussed in the following:

Vacuum technique:

The vacuum technique is performed in four steps:

- Preparing the pipe; the pipe string to be repaired is separated from the remaining pipe system.
- Blowing the pipe; cold-dried and re-heated air is blown into the string to ensure that the string system is absolutely dry
- Sandblasting the pipe; a special granulated material is blasted into the pipe using a special sandblast apparatus, to remove internal corrosion without harming the material.
- Coating the pipe; after sandblasting and blowing to remove the granulated material with air, the pipe is coated with an epoxy resin. After 12-14 hours, the pipe can be put into operation again [Donpro 2012].

Liner technique:

A needled felt tube made of Polyurethane or Polyethylene is glued with a solvent free Epoxy resin inside of the pipe. A mobile impregnation station at site is used directly before the installation.

During the impregnation, which is carried out under vacuum, the tube is inversed into the prepared pipe with water pressure. The curing of the epoxy resin system is performed by heating-up the water, which is used during the inversion [DUS 2012].

The epoxy resin is between the needled felt tube and the iron pipe and therefore not in contact with the floating water inside the pipe.

The application of this technique and the structural design of such a rehabilitated pipe can be found in the literature [Berliner Rohrsanierungstage 2011].

Epoxy resin pipes

Epoxy resin is not only used to repair existing pipes, but also for the production of new pipes [Dueker 2012]. They are typically used for grease containing waste waters. The epoxy is both on the inside as well as on the outside of the pipe.

Evaluation of epoxy resin coated pipes:

Within Europe, besides Great Britain, especially Germany has a strong awareness regarding the use of epoxy resin for the rehabilitation of water pipes. The UBA coating Guideline [UBA Beschichtungsrichtlinie 2010] is a voluntary guideline, which deals with the hygienic evaluation of coatings of drinking water pipes, containers or tanks, fittings and repair systems made of epoxy (resin), polyurethane, polyacrylate and polyesters. The guideline sets a threshold limit value for BPA of 30 µg/l Drinking water positive list limit (DWPLL).

Depending on the hardening process and the corresponding curing quality, the concentration of BPA monomers in the cured epoxy resin can vary [information provided by companies]. According to a German study levels of BPA up to 280 µg/l could be measured in a warm water pipe. However, this coating was not performed in a professional way and the water was circulated in the process leading to the enrichment of BPA in the system [UBA 2010]. The federal government of Germany considers, that in non heated drinking water, and pipes which are coated in a properly and professional manner with epoxy resin, the concentration of BPA in water should be non existing of below 1 µg/l. Regarding to the response of the parliamentary to a raised inquiry, the federal government states that the BPA amount from the drinking water are negligible compared to other known emission paths [AdB 2009].

It is known [UBA 2010] that the water temperature has a strong influence onto the leachability of BPA from epoxy resin into water. However, the leakage of BPA from epoxy resin into water depends also on other parameters, such as the resin surface (including diameter and length of coated pipe) to water volume ratio and resin quality. Further variables influencing the permeation of piping materials are stated by the US EPA to be: Solute properties (composition, phase), Medium properties (composition, pore structure, swollenness), Solute-Medium interaction (equilibrium partitioning, diffuse coefficient), Pipe flow hydrodynamics (Reynold number), Transfer geometry (medium thickness) and environmental conditions (temperature) [US-EPA 2002].

Different measurements were performed in a Risk Assessment Report for BPA migrations into water (spring water), with different shape, size and material. The cans were either not heated or heat treated for 30 minutes. For all unheated cans a BPA migration of less than 2 µg/l were found. At 80°C a BPA concentration of 5µg/l and at 100°C a BPA concentration of 30 µg/l were found [EU RAR 2003], indicating the strong influence of temperature onto the leaching behaviour of BPA from epoxy resin.

The UBA has performed several measurements of BPA contaminations in water pipes, which are listed in Table 22. The following abbreviations have been used: CW: cold water; WW: warm water; CS: comparison sample (taken at the water meter after long flowing of the water to guarantee that no BPA is coming from the water supply).

Table 21: Water measurements from water pipes in buildings

Number of samples	**WW-Circulation**	**WW-Recovery**	**Result in ↔g/l**	**Comment**
3	Yes	Central heating	CS < 0,015; CW 0,017; WW < 0,015	It is not clear if an Epoxy resin coating was applied. No complains
3	Yes	centralised WW-supply	KW 0,49; WW1 & WW2 overloaded – not evaluable (>DWPLL)	Particles in flow regulator. Strong awareness of residents
6	Yes	Central heating	CS < 0,015; CW1 0,042; cW2 < 0,015; WW1 0,03; WW2 0,21; WW3 0,03	Complaints of several tenants: - Cloudiness - "strange taste" - red particles - "water smells" Strong awareness of Residents

6	Yes	Central heating	CS < 0,015; WW1 9,6; WW2 8,1;	Uneven coating Material dissolves, rust water is set free
	No	Central heating	CS < 0,015; CW1 < 0,015; CW2 0,034	
4	No	5 l continuous-flow water heater	CS < 0,015; CW1 0,21; CW2 < 0,015; WW2 < 0,015	Bath and kitchen on 2 cycles. Complaint: water coloured and particles in water after completion of rehabilitation
5	No	Apartment boiler, 5 l continuous-flow water heater	CS < 0,015; CW1 < 0,015; CW2 < 0,015; WW1 < 0,015; WW2 < 0,015	No compliance

As can be seen from the gathered information the concentration of BPA in the water varies in a wide range. Especially in case of warm water circulation the BPA concentration tends to be higher compared to cold water or in case of missing circulation. As indicated above parameters such as composition of the resin, curing and ambient conditions can influence the properties of epoxy resin.

For the estimation of the emission of BPA from Epoxy resins used for water pipes or the concentration of BPA in water, some specific information would be needed. First would be the migration and leaching behaviour of epoxy resins at different conditions (temperature, pH-value, water quality…). However this information would only be helpful if at the same time the practical conditions of epoxy resin rehabilitated water pipes would be known Europe wide. Data such as pipe diameter, length of rehabilitation, water quality, temperature, flow rate and so on would be needed. As such complex data is not available; the performed measurements can only indicate maximum BPA concentration for different applications. Regarding Table 22, BPA levels of nearly 10 µg/l can be found in warm water pipes. However, even this concentration can be exceeded in case of low quality rehabilitation as concentrations of 280 µg/l have also already been detected.

Emission of BPA from epoxy resins used to coat water pipes

For a rough estimation of BPA emissions from epoxy resin coated pipes the total amount of epoxy resins used for this purpose can be taken and combined with a typical migration rate.

As a first step to calculate the emission of BPA from epoxy coated tubes the total amount of epoxy resin used for this purpose has to be estimated.

The amount of Epoxy resin used in Germany for water pipes has been estimated to be about 3,923 t in 2011 [information provided by companies]. For this estimation it is assumed, that for 1 m of epoxy coated pipe 2.4 kg of epoxy resin is needed. For house connection lines about 3,120 t/year of epoxy resin are used, for waste water main sewer 558 t/year and for drinking water pipes 245 t/year (see Table 23).

As Germany represents about 16 % of the EU 27 it is assumed that it consumption of Epoxy resin used for water pipes also represents about 16 % of the EU 27. Therefore the total amount of epoxy resin used for water pipes in the EU 27 is estimated to be about 24,518 t/year.

Considering 25 years of production [LSE 2012] and use of epoxy resin for water pipe rehabilitation, 612,950 t are currently existent in the pipes (very tolerant assumption as in the first years the consumption was for sure much less, however some might have already started earlier).

In a second step an average migration of BPA from Epoxy resins used for water pipes has to be found. For this purpose migration rates from Epoxy resins for other applications are investigated.

The European Food Standard Authority considers a migration value of 100 µg BPA /kg (0.1 ppm) for canned solid food and for canned beverages. They concluded that for beverages the estimation would provide an overly conservative assessment of chronic dietary exposure [EURAR 2003]. For the calculation of a BPA concentration in a 1.500 litre vat a migration of BPA in epoxy resins was estimated to be 100 mg/kg (100 ppm) resin [EU RAR 2003]. At another calculation for the BPA exposure of brush application of paint containing 40 % epoxy resin, a residual level of 10 ppm BPA in the resin was considered. Also for other purposes (wood varnish, wood fillers) a residual BPA level of 10 ppm was considered.

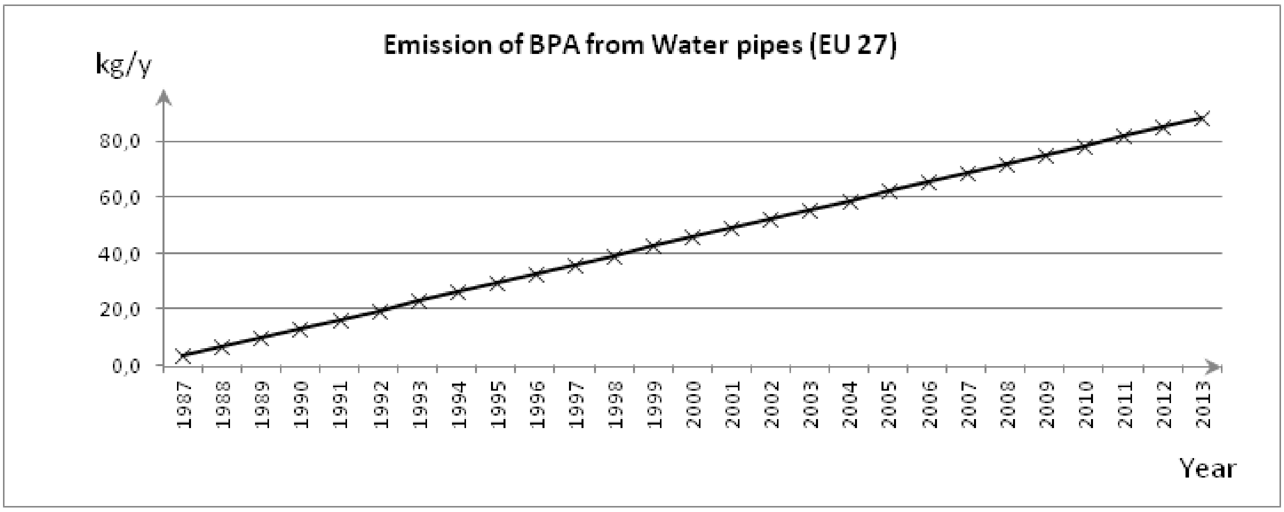
From the above migration rates an average of 10 ppm is considered for this calculation. Using the total amount of 612,950 t of epoxy resin which are currently in use in water pipes, the migration of BPA from this Application is considered to be in total about 6,129 kg during its lifetime.

Table 22: Use of Epoxy resin for water pipes [information provided by companies] in 2011.

	Distance [km]	**Consumption of epoxy resin [t]**
House connection lines		
Company 1	250	600
Company 2	200	480
Company 3	150	360
Company 4	300	720
Company 5	200	480
Others	200	480
Waste water main sewer		
Company 1	100	450
Others	30	108
Epoxy resin consumption for waste water		3.678 t
Drinking water		
Vacuum Technique	1000	150
Liner Technique	40	72
Epoxy resin pipes	5	22,5
Epoxy resin consumption for drinking water		245 t
Epoxy resin consumption Germany		3.923 t

Considering a lifetime of 50 – 100 years (average 75) [information provided by companies] about 81.7 kg of BPA are emitted currently every year. For this calculation it is assumed, that the migration is a linear process. However it should be considered, that in the first years the migration will be higher than in the last years. As define numbers are missing, the linear approach is taken. The emission will increase, due to the ongoing use of Epoxy resin of 24,518 tonnes/year annually, by 3.27 kg as shown in Fig. 4.

Fig. 4: Time trend for emissions from epoxy lining of water pipes



Conclusion:

According to industry information, use of epoxy resins for lining of water pipes has increased during the last years and is assumed to grow in future. Information about migration rates of BPA from epoxy resins is very rare and according to industry epoxy resins are used for this application due to their high resistance against all types of water. It is known that in case linings are not completely hardened before they get in contact with water, high amounts of BPA can be released. In contrary, in case lining is performed in a professional way emissions of BPA from epoxy linings to water are low. However, publicly available data on migration rates from epoxy resins under different conditions (fresh water, waste water, temperature) is very limited and information on the surface of water pipes lined with epoxy resins is not available. Industry data and testing would be required for a precise calculation. Therefore, emissions had to be calculated based on information on the total use of epoxy resins for lining of water pipes in Europe per year and estimated mean migration rates. The estimated total emission of BPA to the environment from lining of water pipes for 2012 was 81.7 kg. It was not possible to calculate local concentrations as the BPA concentration in water depends on the migration rate, water flow through volume, are coated and other factors.

3.3.7 Production and use of other polymers

New information on emissions of BPA during production of polymers was not available in the scientific literature. Industry data on measurement results would have to be collected to provide up-to-date information. The only use of BPA for production of other polymers besides PC and epoxy resins, which has been reported in the EU RAR [EU RAR 2003] to result in emissions to the environment, is the processing of phenoplast cast resins.

According to the EU RAR [EU RAR 2008], approximately 8,800 tonnes/year of BPA are used for the production of phenoplast cast resins. Phenoplast cast resins are produced by three companies within the EU. For one company, joint emissions from the total resin production were reported under epoxy resin. For the other two manufacturing facilities, which used around 93 % of the BPA for resin production, the following emission estimations are presented within the EU RAR [EU RAR 2003]. On one site the resin was prepared in batch operated reflux reactor using a closed loop reflux system for cooling the boiling reactor mixture. It was reported that the emissions during the production process are negligible. At this site, the resin was processes in the manufacture of high-pressure laminate compact panels, which were either prepared by impregnating paper or coating wood fibres with a resin diluted in water. The final stage was the panel pressing. Gases from the paper impregnation process are passed to a thermal incineration plant. Consequently, no emissions of BPA to air were reported by the company. During the coating of wood fibres with resin, process gases were passed over a condenser. The accumulated wastewater from the condenser was regarded as hazardous waste and was sent to an off-site WWTP for the final treatment. The concentration of BPA in the wastewater sent for off-site treatment was 10 mg/l and after the treatment the total concentration of phenols was 0.1 µg/l. The wastewater from the off-site WWTP was subsequently treated in a municipal WWTP. Based on the information supplied by the company a release factor of BPA to wastewater of 0.000027 was calculated [EU RAR 2003].

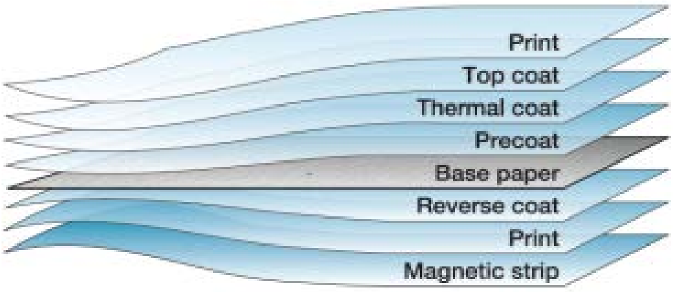
At the second manufacturing facility the resin was prepared via a batch process in a closed system. No releases of BPA to the environment were reported as the effluent from the process was by default incinerated. Based on the available information, it was concluded that no BPA emissions to the environment are expected during the production of phenoplast cast resins. However, it was reported that there is a potential for releases of BPA to the environment during the processing of phenoplast resins [EU RAR 2003].

Applying the calculated release factor (i.e. 0.000027) a local release of 60 kg/year or 0.24 kg/day (averaged over 250 days) was estimated in the EU RAR [EU RAR 2003]. For the continental and regional scenarios a 90/10 % distribution was applied (averaged over 365 days), which resulted in releases of 54 kg/year (0.15 kg/day) for the continental scenario and 6 kg/year (0.016 kg/day) for the regional scenario.

3.3.8 Use of BPA in thermal paper applications

BPA is used for coating of thermal paper where print is developed by the heat impact from a print head. The colour is developed by the reaction between a pigment and a developer which often is BPA, but could also be Bisphenol S (BPS) or other substances. Other known or expected functional BPA alternatives for use in thermal paper, as reported by the US EPA (2010), are Bisphenol F, Pergafast 201, TGSA, D-90, etc. The thermo coating containing BPA is only on one side of the paper. The paper can also encompass a top coat above the thermal BPA–containing layer as shown in Fig. 5.

Fig. 4: Thermal paper (Mitsubishi HiTec Paper Flensburg GmbH) [DME 2011; p. 12]



Thermal paper can be used for cash register receipts, paper for certain printers, tickets, lottery tickets, stickers, fax paper, etc. Suppliers of thermal paper point out the following qualities of thermal print: soundless, reliable, low current costs, no use of toner or ink, easy to use, no solvents and compact printer unit. Another quality, often mentioned in connection with thermal paper, is that it is practically impossible to change the print without trace [DME 2011].

Manufacturers of thermal paper are organized in the European Thermal Paper Association (ETPA). In 2003, ETPA assessed that 70-80 % of all thermal paper sold in the EU contained BPA.

In the beginning of 2000, approximately 1,400 tons BPA were used for production on 105,000 tons of thermal paper. In average the paper contained approximately 13,000 mg BPA/kg thermal paper [DME 2011].

Industry has provided updated production and consumption figures for BPA for 2005/2006. According to industry information, 1,890 tons of BPA were used for the production of 168,000 tonnes thermal paper in Western Europe in 2005/06. This represented an increase of 35 % compared to the figure from 2000, but only around 0.16 % of the total BPA consumption [EU RAR 2008]. Based on these figures the paper contains approximately 11,000 mg BPA/kg on average.

According to the most recent information supplied by industry, 2,400 tonnes of BPA are currently used within the EU for the production of thermal papers [pers. com. ETPA, 2012]. This represents an increase of 510 t compared to the figure from 2005/06.

In 2010 a study of BPA use in thermal paper for various purposes was conducted in Sweden. The analysis of cash register receipts was made at different families collecting receipts over a certain period of time. BPA was found in concentrations ranging from 5,000 mg/kg in labels to 32,000 mg/kg in parking tickets with an average of 15,800 mg BPA/kg thermal paper. In addition, up to 2,000 mg/kg was found in the lining of a wallet and up to 86 mg/kg in 20 kr. bank notes.

Table 24 summarizes the test results of the BPA analysis in different kinds of thermal paper [DME 2011].

Table 23: Test results for BPA in thermal paper (Östberg & Noaksson, 2010) [DME 2011]

Description	**BPA [mg/kg]**	**BPA [%]**
Receipts - family 1	14,000	1.40
Receipts - family 2	18,000	1.80
Receipts - family 3	14,000	1.40
Receipts - family 4	9,500	0.95
Receipts – wallet 1	19,000	1.90
Receipts – wallet 2	11,000	1.10
Parking tickets	32,000	3.20
Labels	5,000	0.50
Queue tickets	16,000	1.60
Cash point receipts	19,000	1.90
Print from local authority	16,000	1.60
Air tickets	5,800	0.58
Train ticket	14,000	1.40
Bus ticket	23,000	2.30
Game ticket	18,000	1.80
Medico technical paper slip	18,000	1.80

Liao and Kannan [2011] measured BPA concentrations in 202 different samples, representing several types of papers and paper products, with the aim of establishing baseline concentrations in paper products and estimating potential exposure doses to BPA from the handling of papers. Thermal receipt paper samples were collected from 58 locations, including supermarkets, grocery stores, banks, public libraries, gas stations, restaurants, and fast food restaurants in the USA and from retail stores in Japan, Korea, and Vietnam in 2010/11. Other paper and paper products were grouped into 14 categories: flyers (e.g. advertisement brochures, store coupons, gift cards, bus schedule), magazines, tickets (e.g. train and bus tickets), mailing envelopes, newspapers, food contact papers (e.g., fast-food wrappers, paper cups, paper plates), food cartons (e.g. pizza paperboards, food buckets, snack food boxes), airplane boarding passes, airplane luggage tags, printing paper (e.g. regular copy paper), business cards, facial tissue (referred to as napkins in this study), paper towels (or kitchen rolls), and toilet paper. Most of those paper products were made from recycled papers.

In summary, BPA was found in 94 % of thermal receipt papers at concentrations ranging from below the limit of quantification (LOQ, 1 ng/g) to 13.9 mg/g. The majority (81 %) of other paper products contained BPA at concentrations ranging from below the LOQ to 14.4 µg/g. While thermal receipt papers contained the highest concentrations of BPA (mg/g), some paper products, including napkins and toilet paper, made from recycled papers contained µg/g concentrations of BPA. The authors therefore concluded that it is likely that paper products made from recycled papers contain BPA due to contamination arising from the recycling process [Liao and Kannan 2011].

The uses of thermal paper have been changing in recent years. Use for industrial fax paper was once a major application, but has declined recently. In 2005/06, ETPA provided more detailed information on the use pattern of thermal paper. According to ETPA, the major use area was in point-of-sale (POS) receipts (e.g. supermarket receipts), followed by self-adhesive labels. Two minor uses were in lottery tickets and fax paper [EU RAR 2008]. These uses are still the main application areas of thermal paper [pers. com. ETPA, 2012].

The degree to which each of these types of paper is recycled has also been estimated by ETPA in consultation with the Institute for Paper Science and Technology at the Technical University of Darmstadt. Estimations for the four major uses are presented in Table 25 [EU RAR 2008].

Table 24: Use and recycling pattern for thermal paper [EU RAR 2008]

Use area	Use percentage [%]	Fraction recycled	Percentage of total recycled [%]
Point-of-sale receipts	50	0.3	15
Self-adhesive labels	30	0.1	3
Lottery	10	0.2	2
Fax	10	1	10

All estimations presented in Table 25 have been reconfirmed by ETPA in 2012 [pers. com. ETPA, 2012].

Based on these estimations, in total around 30 % of the used thermal paper will enter recycling streams. 10 % of the paper from the production process is waste (due to trimmings, etc.). This waste material is called ‘broke’ and is sent directly to a small number of recycling plants and therefore never actually enters commercial use. In particular, it has been estimated that 190 tonnes of BPA will be sent for recycling by the thermal paper production sites each year. This means that in total around 700 tonnes of BPA (i.e. 190 tonnes BPA contained in ‘broke’ and 510 tonnes BPA from different recycling paper streams) will find its way to paper recycling sites each year [EU RAR 2008]. However, this figure has increased, considering that the BPA consumption in thermal paper production has increased over the last years.

The published assessment includes further assumptions related to thermal paper recycling, largely based on information provided by ETPA. In order to test the assumptions, ETPA commissioned a number of studies. In particular, measurements were carried out at three sites that process recovered thermal paper. These included two sites receiving waste from the thermal paper production process (known as ‘broke’), and a site receiving a general mixed recovered waste paper stream. The sites included ‘de-inking’ and ‘non-de-inking’ treatment of the recovered paper. An important point common to all of the investigations is that they were carried out at times when the plants were operating under normal operating conditions [EU RAR 2008].

Conclusion:

The use of BPA for the production of thermal papers has increased during the last few years. Thermal papers contain around 11,000 mg BPA/kg on average and are used in various applications all over the world. Studies confirmed that different paper products made from recycled papers may contain BPA due to contamination arising from the recycling process and that BPA may again circulate through use, disposal and recycling. Concentrations in paper products made from recycled paper (e.g. napkins, toilet paper) have been reported in a dimension of µg BPA/g. However, this will very much depend upon whether 'de-inking' is performed or not during recycling of paper, as shown in the following.

Sites with 'de-inking'

Two sites were selected (one in Germany and one in Austria) as they each receive a high input of BPA in the form of thermal paper 'broke' from different thermal paper manufacturers. The handling of thermal paper broke takes place on a batch basis, and the measurements were conducted during the handling of batches of this waste and therefore represent a worst case scenario for each of the selected sites [EU RAR 2008].

'De-inking' takes place as part of the process to reduce the recovered paper down to fibres. Measurements were carried out on the concentration of BPA in the waste paper fed to the process and on the fiber produced. These showed removal efficiency for the process of 95 % (the default value used in the original assessment was 100 %). The water from the de-inking process is treated before it is passed to the biological treatment plant. Here the concentrations of BPA in the water from the de-inking process were compared to the concentration following the primary treatment. This showed a removal of 95.9 % from water (the default value used in the original assessment was 50 %). The removed BPA is included in the de-inking sludge produced from this process (no specific measurements were made on this sludge at these sites) [EU RAR 2008].

The removal rate in the waste water treatment plant (WWTP) was estimated by measuring the concentration of BPA in the influent and in the effluent. The measurements were carried out over a certain period of time so that any variation in the levels would be detected. The timing of the sampling was arranged so that it covered the expected residence time in the treatment plant where batch paper processes were used. Sampling at regular intervals was employed where the production was continuous. The removal rates were calculated from the lowest influent concentrations and the highest effluent concentrations for each site. The results indicate a removal level of 99.99 % in the WWTP for the two sites [EU RAR 2008].

The results of measurements on mixed samples of effluent (taken over four-hour periods) at both sites showed similar average concentrations of around 20 ng/l. Higher levels were found in a small number of individual spot samples, with maximum concentrations of 170 and 159 ng/l. These higher levels were thought to be due to a release of BPA when pulping of a batch was completed. These reported levels were not corrected for recovery; this was >95 % for the influent samples, but only 33-35 % for the effluent samples. Correcting the values for the lower recovery, the maximum effluent concentrations are in fact 500 and 467 ng/l [EU RAR 2008]. The process sludges from both sites are incinerated. This is described as standard practice for the countries where the sites are located, Austria and Germany [EU RAR 2008].

Sites with no 'de-inking'

A site in Germany that uses a representative mixed waste paper stream was chosen for further analysis. The site was identified as a representative site by the Institute for Paper Science and Technology, Technical University of Darmstadt. The site produces corrugated packaging materials and does not operate a deinking process. It operates continuously, and the mixed waste paper stream is checked for consistency. The site has suitable access to monitoring points, and various internal parameters are routinely monitored [EU RAR 2008].

The average concentration of BPA in the waste paper input to the plant was 14.7 mg/kg over the period of the study. This is the equivalent of a level of thermal paper in the waste of 0.1 %, and gives a daily input of 15 kg of BPA [EU RAR 2008].

Pulping is the equivalent step to 'de-inking' introduced above, where the recovered paper is reduced to fibres. The concentration of BPA was measured in the input materials and in the final paper. The difference indicates that only 10 % of the BPA in the waste paper feed was removed at this stage. This shows that without a 'deinking' step most of the BPA is retained in the recovered paper products [EU RAR 2008].

A comparison of the concentrations in water before and after the flotation treatment, which was used as a primary treatment, indicates a removal rate from water of 50 %. Measurements were also carried out on the sludge produced by this treatment. The concentrations measured in sludge, together with the quantity of sludge produced, indicated that 18 % of the input amount was present in the sludge. This leaves 32 % of the input amount not accounted for. It is not clear what happens to this. The measurements in water are considered to be reliable, and so a removal rate from water of 50 % is assumed for this process. The rest of the substance is assumed to be removed with the solid material for the purposes of this assessment. This leads to a higher concentration in sludge than was actually measured. For comparison, the measured level in the sludge will also be considered in the calculations. The amount of sludge produced at this stage is 22.68 tonnes per day, which from the pulp production rate is a rate of 22.9 kg/tonne [EU RAR 2008].

The concentrations of BPA in the influent and effluent of the WWTP were also measured. The average values were 193 µg/l and 42.7 ng/l respectively, indicating a removal of 99.98 %. Measurements on the sludge produced in the WWTP indicate that this contained 0.98 % of the BPA entering the WWTP. The fate of BPA in the WWTP is therefore 0.02 % to water, 0.98 % to sludge with 99 % degraded [EU RAR 2008].

All sludges and rejects from the processes are incinerated at the site. This is described as standard practice in Germany [EU RAR 2008].

In all three example sites, the sludges from the paper processing steps are incinerated (as are the biological sludges at some sites). This is described as standard practice for the relevant countries (Germany and Austria). It is, however, known that these sludges are applied to land in other parts of the EU. Therefore, this route has been considered in the calculations for generic sites. Calculations have been carried out for the application of the paper and biological sludges individually and as a mixture in the proportions in which they are produced [EU RAR 2008].

Revised regional and continental emissions – thermal paper recycling

The regional emissions from thermal paper recycling have been recalculated according to the new information presented above. Recovered thermal paper from fax and lottery use is assumed to be 'de-inked', whereas recovered POS receipts and labels are assumed not to pass through a 'de-inking' step. Thermal paper broke is assumed to be 'de-inked' as well. The emission factors described in Section 3.1.2.5.4 of the EU RAR [EU RAR 2008] have been used to estimate the annual amounts of BPA released to surface water, to biological sludges and to paper sludges (see Table 26).

Table 25: Annual Bisphenol A releases [EU RAR 2008]

	De-inking route	Non-de-inking route	Thermal paper broke
Amount	204 tonnes	306 tonnes	160 tonnes
To paper sludge	187 tonnes	15.3 tonnes	
To biological sludge	78 kg	150 kg	
To surface water	1.9 kg	3.5 kg	1.6 kg

Sludges from sites processing thermal paper broke assumed to be incinerated

The total amount to sludge (combined) is therefore 202.5 tonnes per year, and the emissions to surface water are 7 kg/year. The emission scenario document for paper (Environment Agency, 2002) suggests that 80% of sludge from paper recycling may be applied to land; hence the emission of BPA to land from this route is 162 tonnes. Both the surface water and soil emissions are assumed to be distributed as 10 % to the region and 90 % to the continental scale [EU RAR 2008].

The annual BPA releases have been adjusted in accordance to the most recent consumption figure provided by the industry. The following BPA releases to surface water, to biological sludge and to paper sludge have been estimated (see Table 27).

Table 26: Updated annual Bisphenol A releases

	De-inking route	Non-de-inking route	Thermal paper broke
Amount	259.2 tonnes	388.8 tonnes	240 tonnes
To paper sludge	237.6 tonnes	19.44 tonnes	
To biological sludge	99 kg	190 kg	
To surface water	3 kg	5 kg	3 kg

Sludges from sites processing thermal paper broke assumed to be incinerated

The assumption that 80 % of sludge from paper recycling may be applied to land is highly questionable.

The Eurostat data set on the treatment of waste has a breakdown in the type of treatment, waste category and region. The waste categories are in accordance with the European Waste Classification for statistical purposes (EWC-Stat.), which is a manly substance oriented classification, and distinguishes between hazardous and non-hazardous waste. The classification is linked to the administrative classification List of Wastes (LoW).

The Eurostat database contains information on the treatment of common sludges (listed under the waste code 11) within the EU27 for the years 2004, 2006 and 2008. Common sludges consist of sludges from WWTP, biodegradable sludges from treatment of other waste water, sludges from purification of drinking and process water, etc. The available data on common sludge treatment is summarized in Table 28.

Table 27: Treatment of common sludges in the EU 27 [EUSTAT 2012d]

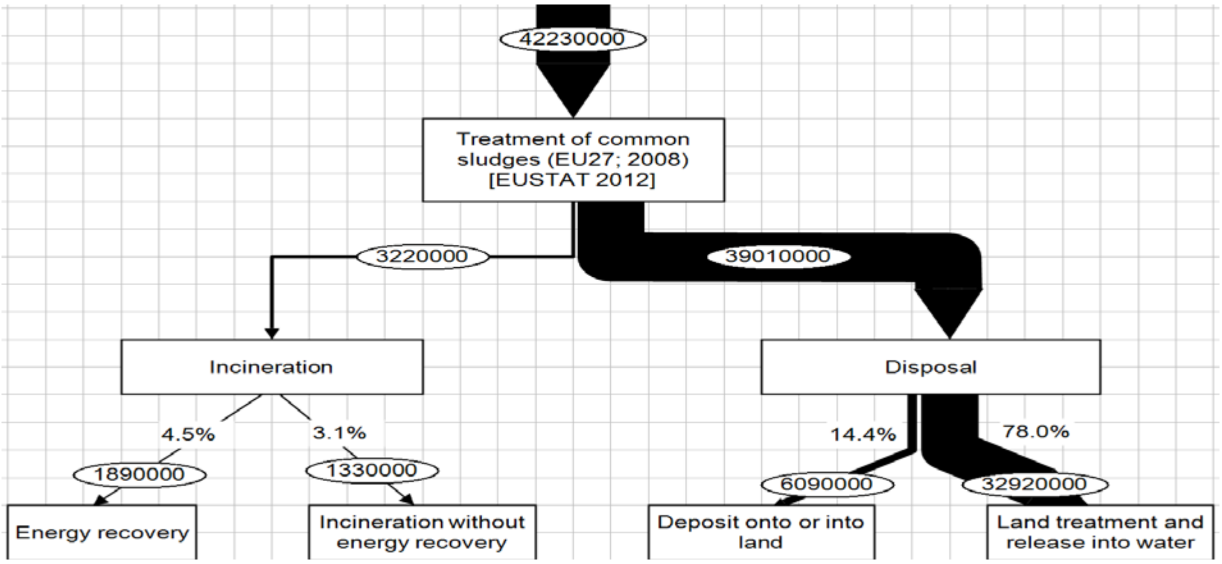
Treatment of waste (tonnes) [env_wastrt]		COMMON SLUDGES
Last update	06.03.12	
Extracted on	29.03.12	

Source of Data	**Eurostat**		
HAZARD	**Total**		
WST_OPER	**Total waste treatment (Common sludges)**		
GEO/TIME	2004	2006	2008
European Union (27 countries)	39060000	42190000	42230000
WST_OPER	**Energy recovery**		
GEO/TIME	2004	2006	2008
European Union (27 countries)	1040000	1850000	1890000
WST_OPER	**Incineration without energy recovery**		
GEO/TIME	2004	2006	2008
European Union (27 countries)	950000	1440000	1330000
WST_OPER	**Disposal**		
GEO/TIME	2004	2006	2008
European Union (27 countries)	37070000	38900000	39010000
WST_OPER	**Deposit onto or into land**		
GEO/TIME	2004	2006	2008
European Union (27 countries)	5400000	7410000	6090000
WST_OPER	**Land treatment and release into water bodies**		
GEO/TIME	2004	2006	2008
European Union (27 countries)	31660000	31480000	32920000

In 2008, around 42 million tonnes of common sludges were treated in the EU27. According to Eurostat (2012d), most of the common sludges were applied to land followed by the deposit of sludges onto or into land (incl. landfilling). A rather small proportion of the total common sludge was incinerated with (R1 operation) or without (D10 operation) energy recovery (Table 28).

Fig. 6 represents a graphical overview on the treatment of common sludges within the EU27 in 2008. As mentioned, most of the common sludge was disposed by means of land treatment and deposit onto or into land (i.e. 78 % and 14.4 % respectively). Only around 7.6 % of the common sludge was incinerated in the EU27 in 2008.

Fig. 5: Treatment of common sludges within the EU27 [in tonnes]

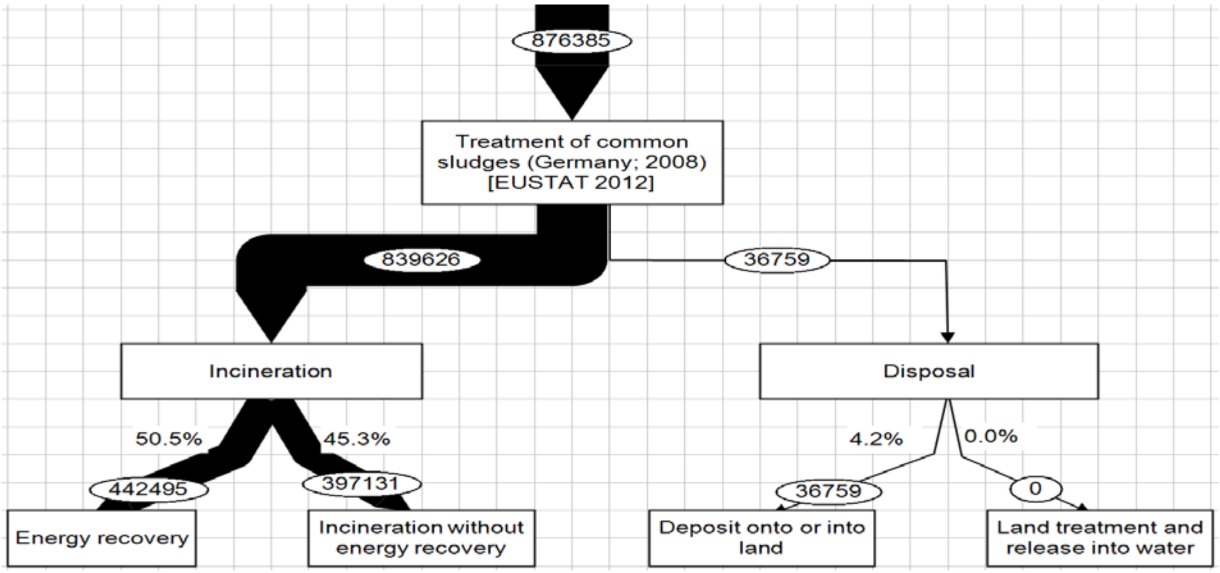


In this connection, one should be aware that the treatment operations applied may vary to a great extent within different EU Member States. Germany for instance, incinerated most of the common sludges in 2008 (i.e. 95.8 %). Only around 4 % was landfilled and no common sludge was applied to land (compare with 78 % applied to land within the EU27).

The EU RAR [EU RAR 2008] suggests that 80 % of sludge from paper recycling may be applied to land. A figure of 80 % would be in fact true for common sludges (see Fig. 6), however in case of sludge from paper recycling this figure may be overestimated.

Sludges from paper recycling are listed under the waste category ‘Sludges from industrial processes and effluent treatment’ within the European list of waste (i.e. 030305 de-inking sludges from paper recycling) and are considered in Eurostat within the waste codes 01-03 ‘Chemical wastes’ and not within the code 11 which applies for common sludges. Only around 1 % of the total ’01-03 Chemical wastes (non-hazardous)’ were applied to land within the EU in 2008. Most of the ’01-03 Chemical wastes’ were landfilled and incinerated.

Fig. 6: Treatment of common sludges in Germany [in tonnes]



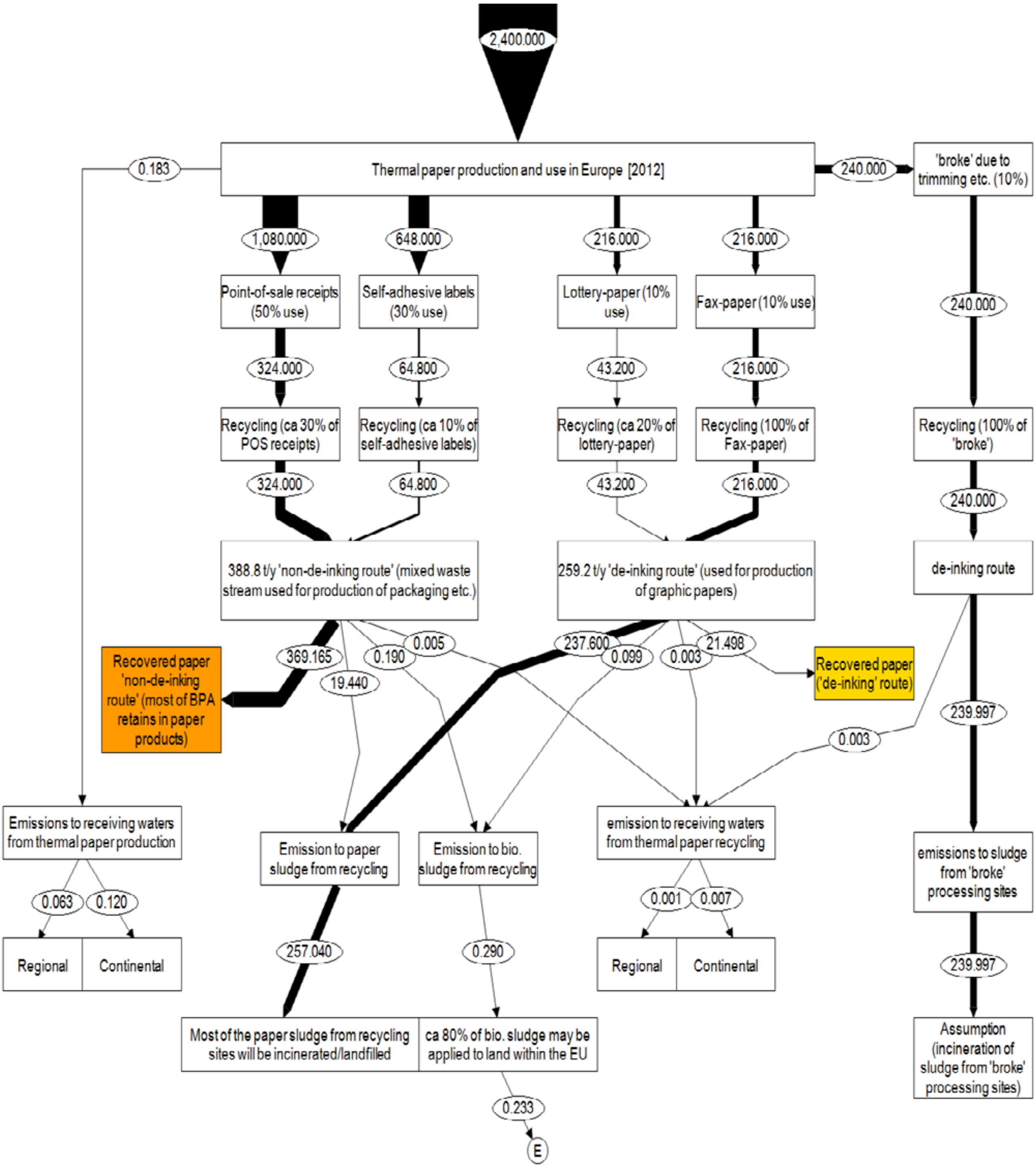
However, information on the treatment of such wastes in the EU27 can be extracted only for the entire ‘Chemical wastes’ which also include other industrial sludges and not merely de-inking sludges from paper recycling. Therefore, it is not possible to create a reliable overview on the treatment of de-inking sludges in the EU27 from the figures supplied by Eurostat. Nevertheless, it can be concluded that a figure of 80 %, as proposed in the EU RAR [EU RAR 2008], is overestimated and that probably most of those sludges are incinerated or landfilled within the EU.

Based on the available information from the EU Risk Assessment Report, the information obtained from additional literature sources and recent data received by the industry, the following BPA substance flow diagram has been developed (see Fig. 8).

The developed substance flow diagram indicates that especially in case of the ‘non-de-inking’ route significant amounts of BPA (˜369 tonnes/year) may retain in paper products from recovered paper which may again circulate through use, disposal, and recycling and may release BPA to the environment. Therefore, especially in this connection, further investigations will be required.

The Pacific Northwest Pollution Prevention Resource Center (PPRC) stated that thermal paper production is one of the smallest industrial uses of BPA, however, due to intensive water use and the free available chemical nature of BPA in paper coatings, recycling of thermal paper generates the largest industrial source of BPA entering wastewater treatment plants (WWTPs). BPA is relatively well-removed in modern WWTPS (90+ % removal rates are common), but given the large entering volumes, recycling is still a significant source of surface water emissions [PPRC 2010].

Fig. 7: Bisphenol A substance flow in thermal paper [in tonnes]

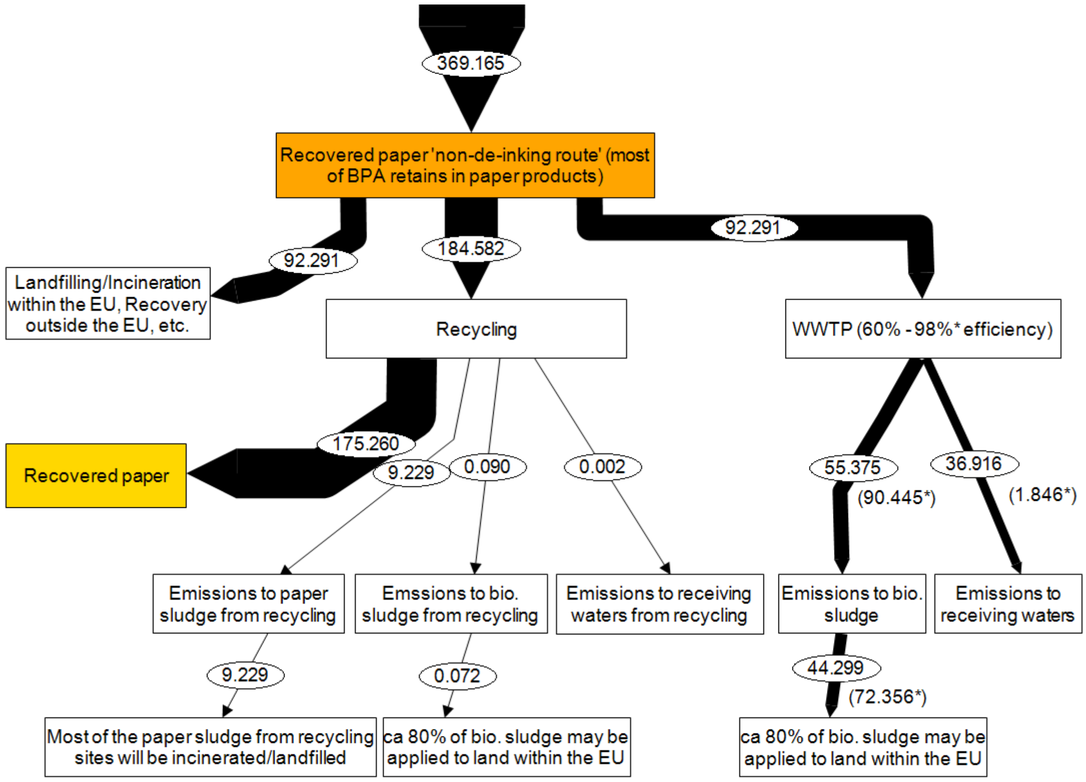


The PPRC (2010) further stipulate that depending on the need, recycled paper may be cleaned (de-inked) and bleached, as it is before addition to very bright and white paper grades, or left relatively dirty, as it is before addition to the corrugated 'medium' between cardboard box paper layers. As a result, the levels of BPA in new paper production can vary substantially. It was reported that containerboard (for corrugated boxes) and carton board (used for cereal, rice, small boxed parts, etc.) were highest in BPA. It was also reported that recycled products contain BPA at ten or more times the level of BPA in virgin products.

Through the recycling of thermal paper, BPA is expected in recycled paper products. Gehring et al. (2004) found BPA in toilet paper made from recycled paper in concentrations between 3.2 and 46.1 µg/g dry matter and in waste paper in concentrations between 0.09 and 4.23 µg/g dry matter. This implies that toilet paper can be an important source of BPA emission to wastewater. Moreover, BPA was found to occur in aquatic systems and landfill leachate [Crain et al., 2007]. Lopez-Espinosa et al. (2007) found BPA levels in paper and cardboard containers used for take-away food to range from 0.05 to 1817 ng/g at a detection frequency of 45 %. BPA could also be detected in kitchen roll from recycled paper (0.6–24 µg/g), while kitchen roll from virgin paper contained no or negligible BPA concentrations [Vinggaard et al., 2000] [Geens et al. 2011].

With regard to the 'non-de-inking' route it has been estimated that around 369 tonnes/year of BPA may retain in various paper products from recovered paper. The recovered paper may again circulate through use, disposal, and recycling and release BPA to the environment.

Fig. 8: **Bisphenol A substance flow diagram in recovered paper streams [in tonnes]**



As shown in Fig. 9 it has been assumed that 50 % of the paper products from recovered paper may be recycled within the EU (˜185 tonnes/year of BPA). For the remaining 50 % an equal distribution has been assumed between the paper fractions which are disposed off within the EU, recovered outside the EU (containing ˜92.3 tonnes/year of BPA) and the paper fraction which directly goes to the sewer network such as toilet paper (containing ˜92.3 tonnes/year of BPA).For the emission estimations from recycling the transfer coefficients provided in the EU (2010) have been applied. For the estimation of emissions from WWTPs it has been taken into consideration that plant efficiencies may vary (i.e. 60-98 %). Furthermore, similar to the previous estimations, it has been assumed that most of the paper sludge from recycling sites will be incinerated and landfilled and that large amounts of biological sludges may be applied to land within the EU (i.e. 80 %).

As indicated in Fig. 9, most of the BPA will remain in recovered paper products and may again circulate through use, disposal, and recycling (˜175 tonnes of BPA per year). Approximately 9.2 tonnes/year of BPA has been estimated to be released to paper sludge from recycling, which will be finally incinerated and landfilled in the EU. Around 90 kg of BPA is released annually to biological sludge from recycling, which may subsequently be applied to land (up to 72 kg per year). Besides, it has been estimated that only around 2 kg of BPA from recycling will find its way to receiving waters every year (see Fig. 9).

On the other side, significant amounts of BPA may be released to biological sludge and receiving waters from WWTPs. In particular, around 55.4 tonnes/year (˜90.4* tonnes/year) and around 36.9 tonnes/year (˜1.8* tonnes/year) respectively, depending on actual WWTP efficiencies. The biological sludge may be applied to land within the EU (i.e. 44.3-72.4* tonnes/year). In this connection it should be mentioned that it is not quite certain to what extent BPA degrades in WWTPs and consequently which amount of BPA remain in biological sludges of WWTPs.

The ‘de-inking’ route has not been further considered within this report due to the comparatively low tonnages of BPA in recovered papers from this route (i.e. ˜21.5 tonnes/year) and due to the fact that most of the BPA will be emitted to ‘de-inking’ sludge, which is assumed to be incinerated and landfilled within the EU. Therefore, no significant emissions to the environment are expected from this route. Nevertheless, one should be aware that within the [EU RAR 2008] considerably high removal efficiencies of BPA have been assumed during the ‘de-inking’ process step. In a possible worst-case scenario significantly higher amounts of BPA could retain in recovered paper streams from this route (e.g. ˜ 80 tonnes BPA/year at a removal rate of ˜70 %). However, in the absence of more reliable information regarding removal efficiencies, the assumptions made within the [EU RAR 2008] have been taken into consideration for the purpose of this study.

3.3.9 Use of BPA in PVC

Volumes

As reported in the EU RAR [EU RAR 2008], approximately 1,800 tonnes/year of BPA were used for PVC production and processing in Europe. There are three reported uses of BPA within the PVC industry, in particular as an anti-oxidant in PVC processing, as a constituent of an additive package used in PVC processing and as an anti-oxidant in the production of plasticisers used in PVC processing [EU RAR 2008].

The use as an anti-oxidant during the processing of PVC accounted for around 450 tonnes/year and a large number of sites using BPA for this purpose was reported (industry estimates vary from 200-500 sites within the EU). Consequently the amount of BPA used per site was reported to be approximately 1-3 tonnes/year. Around 450 tonnes/year of BPA were incorporated into additive packages which are subsequently sold to PVC processors for further use. There were approximately 10-20 sites within the EU making additive packages that incorporate BPA, however, no further information on the end use of these packages was reported. The usage is thought to be similar to the direct use of BPA as an anti-oxidant. The use as an anti-oxidant in the production of plasticisers used in PVC processing accounted for approximately 900 tonnes/year and there were seven sites within the EU that undertake this process [EU RAR 2008].

The EU RAR [EU RAR 2003] contains site specific data for two PVC production sites accounting for 112 tonnes/year BPA use. Both sites apply BPA as an inhibitor during the production of PVC. As mentioned, this use ceased voluntarily in the EU, so there are no longer any emissions from this application and it is therefore not further considered in this report. Furthermore, site specific data is also included for a typical plant using BPA as an anti-oxidant in the production of plasticisers. Dust emissions were calculated as 81 kg/year, assuming that these are washed to drain and end up in the wastewater stream. The emission factor for release of BPA from this process to wastewater was calculated as 0.001.

Updated production and consumption tonnages of BPA in PVC have been supplied by industry associations in 2005/06 (i.e. European Council of Vinyl Manufacturers, European Stabiliser Producers Association, European Council for Plasticisers and Intermediates and European Plastics Converters). The updated data on production and use figure for Western Europe is summarised in Table 29.

Table 28: Revised production and use tonnage for Western Europe (2005/06) [EU RAR 2008]

Application	Tonnes/year	% change from published report
PVC-polymerization	0	
- stabilizer packages	450	-10
- phthalate plasticizers	900	-10
- direct stabilization	450	-10
Total	1,800	

As shown in Table 29, the total production and use tonnage declined from 2,250 tonnes/year (during the period 1996-1999) to approximately 1,800 tonnes/year reported in 2005/06, which represents less than 0.2 % of the total BPA consumption in the EU. This is partly due to the voluntarily phase out of the use of BPA as an inhibitor during the polymerisation stage of PVC production and partly due to the declining usage of BPA in other reported applications.

Emissions to the Environment

For the calculation of generic emissions, for the use of BPA in the PVC industry the information contained in the 'Use category document on plastic additives' was used. This document provides information on the potential releases of plastic additives such as for anti-oxidants and plasticisers [EU RAR 2003].

BPA is used as an anti-oxidant either on its own or as part of an additive package during PVC processing and during production of plasticisers for use in PVC. According to EU RAR [EU RAR 2003], anti-oxidants are applied in rigid PVC formulations and in particular for PVC destined for building purposes. The typical concentration of anti-oxidants in PVC is 0.2 %. The following release factors are given for anti-oxidants during use. For BPA, losses for powders with a particle size > 40 µm and low volatile compounds are taken as representative. Besides, for BPA all volatile losses are taken as condensing out and passing to wastewater, which is thought to be realistic worst-case scenario [EU RAR 2003].

Initially, during raw material handling, some emissions will be to air, but finally, as a result of wash down, all particulates will be removed or settle and losses will be to solid waste or to wastewater. Material remaining in packaging will be assumed to go to solid waste from the processing sites and has therefore not been further considered in the assessment. For powders of particle size > 40 µm losses of 0.2 % to solid waste/water are estimated, which will be considered as going to wastewater. A loss of 0.01 % of solid waste as residue in bags will also occur. During compounding, initial losses will be to atmosphere, but ultimately to solid waste and wastewater. For powders of particle size > 40 µm losses to solid waste/water of 0.01 % are estimated. For low volatility compound losses of 0.002 % are estimated. Assuming that both losses ultimately result in losses to wastewater gives a total loss of 0.012 % to wastewater during compounding. For use of anti-oxidants in PVC processing, closed processes are the most common and will be taken as the default. For a low volatile compound in a closed process the losses are estimated as 0.002 % to air. These will be taken as condensing and going to wastewater. For smaller sites the release factors should be increased by a factor of 10 [EU RAR 2003].

Emissions during use as an anti-oxidant in PVC processing

Approximately 500 tonnes/year BPA was used as a stabiliser in the processing of PVC within a large number of sites in the EU (industry estimates 200-400 sites). The amount used per site was estimated as being 1-3 tonnes/year. Assuming that 3 tonnes of BPA was used per year on-site at the concentrations of 0.2 % in the PVC the total amount of PVC produced would be 1,500 tonnes/year. By applying the ‘Use category document’ the following releases were estimated [EU RAR 2008].

Local (3 tonnes/year per site, 250 days use per year);

Total: 6.42 kg/year (0.0256 kg/day) to wastewater

For continental and regional scenarios the loss factors were applied to the total tonnage used (i.e. 500 tonnes/year). The regional tonnage was taken as 10 % of the continental tonnage and was subtracted from the continental tonnage to avoid double counting of emissions, resulting in total continental releases of 963 kg/year and total regional releases of 107 kg/year to wastewater [EU RAR 2008].

Emissions during preparation of additive packages for PVC production

Approximately 500 tonnes/year of BPA were incorporated into additive packages for PVC production. It was estimated that 10-20 sites within the EU prepared such additive packages. Releases of BPA may occur during the preparation of additive packages and the subsequent use of the additive packages. Releases during use of the additive packages will be taken as the same as use of BPA as an anti-oxidant in PVC processing. This is because the function of BPA is the same in the additive packages as if it was used directly and the numbers of sites and amount used is thought to be similar for direct use and additive package use [EU RAR 2003].

As there is no information on releases during the production stage, it was treated as a compounding stage (i.e. mixing of different materials together to form a master batch). No information on the tonnages of BPA used per site is available. However, assuming that the amount was distributed equally at 10 production sites, 50 tonnes/year would be used at each site. As a worst case it was assumed that one site uses five times the average amount (i.e. 250 tonnes/year). The following local, regional and continental releases were estimated [EU RAR 2008]:

Local (250 tonnes/year per site, 250 days use per year);

Total: 530 kg/year to wastewater (losses during raw material handling and compounding);
Losses during use: same as for BPA use as an anti-oxidant in PVC processing

Continental (450 tonnes/year, 365 days use per year);

Total: 963 kg/year to wastewater (losses during raw material handling, compounding and conversion)

Regional (50 tonnes/year, 365 days use per year);

Total: 107 kg/year (losses during raw material handling, compounding and conversion)

Emissions during use as anti-oxidant in the production of plasticisers used for PCV processing

Information on the use of BPA as an anti oxidant for plasticiser used in the processing of PVC has been supplied by the European Council for Plasticisers and Intermediates (ECPI). Site specific releases during production of the plasticiser were calculated as 81 kg/year for a local site, which results in a total release of BPA of 112 kg/year, assuming that the emission factor from the typical site applies for all sites using BPA as an anti-oxidant. Based upon these release estimates 81 kg/year was used for the local and regional estimations and 31 kg/year for the continental scenario. Site specific estimates were used in preference to the default emissions contained in the 'Use category document on plastic additives' [EU RAR 2008].

In addition to losses during the production of the plasticiser there may also be additional losses during the use stage. As no information regarding the amount of plasticiser used per site is available it was assumed that all the flexible PVC used for electrical applications (53,900 tonnes/year based upon UK data in the UCD on plastics additives) is processed at one site (worst case scenario). The BPA is present in the plasticiser at a concentration of 0.2 % and the plasticiser is present in the PVC at 30 %. Therefore, the total amount of plasticiser used on the site was approximately 16,170 tonnes/year and consequently around 32 tonnes/year of BPA [EU RAR 2008].

The use category document on plastics additives gives the following releases for plasticisers during use. As with the releases associated with anti-oxidant use, solid wastes and volatile losses to the atmosphere are taken as ultimately being lost to wastewater. Besides, it should be noticed that in the Risk Assessment Report for di-isodecyl phthalate and di-isononyl phthalate the amounts of plasticisers used on sites were around 4,600 tonnes/year, which is a lower tonnage than assumed in the EU RAR [EU RAR 2003]. Therefore, the local, continental and regional releases below may be over-estimated [EU RAR 2003].

Local (32 tonnes/year, 250 days processing per year);

Total: 4.48 kg/year (0.0179 kg/day) to wastewater (losses during raw material handling, compounding and conversion)

Continental (900 tonnes/year, 365 days processing per year);

Total: 126 kg/year to wastewater (losses during raw material handling, compounding and conversion)

Regional (100 tonnes/year, 365 days processing per year);

Total: 14 kg/year to wastewater (losses during raw material handling, compounding and conversion)

Emissions during the service life of PVC articles

The estimates of losses during the service life of PVC articles within the EU (2010) document are based on factors used in other assessments dealing with PVC additives. These assessments include specific emission factors related to products such as roofing (insulation) and cabling (sheeting of electrical cables), which are according to industry information the most relevant application areas of plasticisers containing BPA as an anti-oxidant. It was assumed that both applications are single sided in terms of emission surfaces and apply PVC in similar thicknesses. The outdoor loss factor of 1.05 g/m^2/year is considered to apply to open-air uses and not to buried cables, where releases are not expected to be significant. Indoor losses (i.e. 9.5 mg/m^2/year) are considered to occur only through evaporation, as cables are not subject to washing or polishing. The distribution among indoor and outdoor uses was estimated to be equal, 50:50. With regard to outdoor uses, 80 % (i.e. 40 % of the total use) is applied underground [EU RAR 2003].

The surface area of cables and roofing sheet in relation to the amount of plasticiser used was taken as 532 m^2/tonne of plasticiser, and the BPA content of the plasticiser is taken as 0.5 %. A service life of 30 years was assumed for cables [EU RAR 2003].

For indoor uses, BPA losses to air of 0.1 tonnes/year (indoor plasticiser usage: 135,000 tonnes/year; surface area: 2.15*10^9 m^2) were calculated, whereas outdoor uses accounted for 1.5 tonnes/year of BPA emissions to air (outdoor plasticiser usage: 18,200 tonnes/year; surface area: 0.29*10^9 m^2). It was further assumed that losses of BPA from outdoor cables will be distributed equally between air, surface water and soil [EU RAR 2003].

For the other areas of use for BPA in PVC, the annual losses were taken to be 0.05 % to air and 0.15 % through leaching, which were assume to be equally distributed to soil and surface water. The factors for leaching emissions apply to external use. A lifetime of 30 years was proposed, which may be an over-estimate for particular uses, but it has been used to maintain consistency with previous calculations and assessments [EU RAR 2003].

The emission rates of 1.5 % per year to air, 4.5% leached per year, 2.25 % to water and 2.25 % to soil were used, which finally resulted in the total emissions estimation from PVC products in use (also including the use in plasticizers as calculated above) [EU RAR 2003].

Table 29: Emissions from use of PVC products containing BPA [EU RAR 2003]

	Regional (tonnes/year)			Continental (tonnes/year)		
Use	**Air**	**Surface water**	**Soil**	**Air**	**Surface water**	**Soil**
Anti-oxidant in PVC processing	0.75	1.1	1.1	6.75	10	10
Preparation of additive packages for PVC processing	0.75	1.1	1.1	6.75	10	10
Anti-oxidant in the production of plasticizers	0.06	0.05	0.05	0.54	0.45	0.45
Total	1.56	2.25	2.25	14.04	20.45	20.45

Summary of regional and continental releases (PVC)

The emission estimates included in the published risk assessment report were mainly based on site specific information. In case this was not possible, default emission factors were applied [EU RAR 2003].

Table 30: Summary of regional and continental releases [EU RAR 2003]

Process	**Air (kg/year)**		**Emissions to wastewater treatment plants (kg/year)**		**Emission to surface water (kg/year)**	
	Reg.	Cont.	Reg.	Cont.	Reg.	Cont.

Process	Air (kg/year)		Emissions to wastewater treatment plants (kg/year)		Emission to surface water (kg/year)	
	Reg.	Cont.	Reg.	Cont.	Reg.	Cont.
PVC – Inhibitor during production process			5,810	52,290	2,490	22,410
PVC – Anti-oxidant during processing			75	674	32	289
PVC – Preparation of additive packages			74	668	32	286
PVC –Use of additive package			75	674	32	289
PVC – Anti-oxidant in plasticizer production			81	31		
PVC – Plasticizer use			10	88	4	38
Losses from PVC articles in use	1,560	14,040			2,250	20,450

Updated information on emissions from production sites has been provided by industry for 2006 (personal communication from Plastics Europe, 2007).

Table 31: Revised regional and continental emissions [EU RAR 2008]

Process	Air (kg/year)		Emissions to wastewater treatment plants (kg/year)		Emission to surface water (kg/year)	
	Reg.	Cont.	Reg.	Cont.	Reg.	Cont.
PVC – Inhibitor during production process (voluntarily ceased in 2003)	-	-	-	-	-	-
PVC – Anti-oxidant during processing			77	693	19	174
PVC – Preparation of additive packages			37	44	2.76	0.79
PVC –Use of additive package			77	693	19	174
PVC – Anti-oxidant in plasticizer production			73	28		
PVC – Plasticizer use			10	91	2.7	23
Losses from PVC articles in use	1,560	14,040			2,250	20,450

The PVC additive industry (represented by the European Stabilizer Producers Association) has carried out two sampling exercises at sites producing PVC additive packages containing BPA. In addition, information on other sites has been collected relating to cleaning operations, water handling and treatment, water flows, tonnage used, etc. [EU RAR 2008].

A total of 13 sites are involved in the production of these packages in the EU. Measurements have been conducted at seven of these, accounting for 82 % of the tonnage used in this area. (The tonnage in this area is now estimated at ~1,400 tonnes, which is an increase from the value used in the original risk assessment). The results of the measurements have been used to estimate the amounts of BPA released, and hence to derive emission factors. The arrangements on the sites have led to three factors being derived, emissions from all sources to an off-site treatment plant, emissions from all sources after on-site treatment (i.e. release to surface water) and release in rainwater run-off [EU RAR 2008].

The measurements indicate lower emission figures for the preparation of additive packages. Especially the continental emissions to wastewater treatment plants and the emissions to surface water declined drastically (compare emissions in Table 31 with those provided in Table 32).

In addition, as already mentioned, use of BPA as an inhibitor in the production of PVC ceased voluntarily in the EU in 2003, so no emissions from this application are included in Table 32.

Besides, no updated information is available on losses from PVC articles in use.

3.3.10 Emissions of BPA from TBBPA

Bisphenol-A is also used in the production of tetrabromobisphenol-A (TBBPA), which is used as a flame retardant. As TBBPA only contains trace amounts of BPA (typically less than 3 ppm) the amount of BPA present in TBBPA containing products is negligible. The possible formation of BPA from the breakdown of TBBPA under certain circumstances is discussed in detail in the EU risk assessment of TBBPA. The risk assessment for TBBPA [EU 2007] concludes that there is strong evidence that TBBPA can degrade to give BPA under certain anaerobic conditions. This has been demonstrated conclusively for marine or saline sediments, freshwater sediments and anaerobic sewage sludge, and it is possible that it could also occur in other anaerobic systems. The main routes by which this could lead to BPA in the environment are through degradation in anaerobic sediments and through the application of anaerobically digested sludge to soil. Therefore, BPA in the environment may result from released TBBPA. TBBPA emissions might occur during production of TBBPA and due to leaching of TBBPA from products. Another possible source might be emissions due to packaging waste disposal [VECAP 2009].

Since 2000 there is no production of TBBPA in the EU. Today TBBPA is produced in Israel, the United States, Jordan, Japan and China [EU RAR 2008][BSEF 2009]. Therefore, there are no emissions of BPA from production of TBBPA. TBBPA is the brominated flame retardant with the largest global production volume today and is used to improve fire safety, mainly of printed wiring boards (PWBs) in electrical and electronic equipment. TBBPA contributes to the fire safety of electrical and electronic equipment and installations where printed circuit boards are used, such as consumer electronics (TVs, vacuum cleaners, washing machines), office and communication equipment (for example photocopiers, computers, printers, fax machines, radios), automotive, mass transportation, aviation and entertainment equipment. The main application of TBBPA is in laminates used for PWB. It is used in more than 90% of printed circuit boards, the most commonly used board in electronic devices. In this application TBBPA is used as a ‘reactive’ flame retardant and is fully reacted in the polymer backbone it therefore no longer exists as a free chemical in the final board but forms part of the polymeric resin (residual TBBPA levels in the brominated epoxy resins are typically below 100 ppm). Unbound TBBPA can could leach out from the polymer matrix into the environment and subsequently result in exposure to the environment. However, nearly all the applications listed above are indoor applications without contact to water. Therefore, release of unbound TBBPA is not very likely. Most of the electronical equipment will be recycled today without significant releases to the environment, but in former years electronical equipment might have been disposed at landfills. Therefore, TBBPA may theoretically be found in landfill leachates which will result in emissions to WWTPs. However, against the background that TBBPA is converted to BPA under anaerobic conditions it is unclear to which extent BPA is built during the passage through the landfill. There is no data available to make estimations.

TBBPA is also used as a non-reactive ‘additive’ flame retardant mainly in acrylonitrile butadiene styrene (ABS) which is a common thermoplastic used to make light and rigid moulded products such as electrical & electronic equipment exterior casings. TBBPA is considered as an alternative additive flame retardant to octabromodiphenyl ether in ABS. As an additive flame retardant, TBBPA may more or less readily leach out of the polymer matrix. Additive use accounts for approximately 10 % of the total use of TBBPA. Again, repeated contact with water, which might result in leaching of TBBPA from electrical equipment casings is unlikely for electronical equipment [EU RAR 2008][BSEF 2009].

In addition, TBBPA is used as an intermediate in the production of other brominated FR systems, derivatives and brominated epoxy oligomers where it is integrated into the resin as well. The main use of these derivatives is as flame retardants, usually in niche applications. The total amount of TBBPA derivatives used is less than the amount of TBBPA used [EU RAR 2008][BSEF 2009].

The EU RAR [EU RAR 2008] made some assumptions and calculations regarding BPA in sediment and sludge resulting from degradation of TBBPA. Levels of BPA in sediments resulting from TBBPA have been calculated based on the levels of TBBPA in sediment reported in the EU RAR [EU RAR 2008] for TBBPA assuming that all TBBPA in anaerobic parts of the sediment is converted (see Table 33).

In a second more realistic approach, environmental fate of BPA (absorption /desorption and biodegradation) have been included in the calculation resulting in much lower concentrations. However, although these calculations are very speculative, it is clear that releases from sites where TBBPA is used may result in emissions of TBBPA to sediments which can cause the formation of BPA.

Table 32: Estimated concentrations of BPA in sediment resulting from degradation of TBBPA [EU RAR 2008]

Scenario		**Estimated conc. of TBBPA in sediment (mg/kg wet wt.)**	**Worst case estimated max. conc. of BPA in sediment (mg/kg wet wt.)**	**Realistic estimated max. conc. of BPA in sediment (↔g/kg wet wt.)**
Reactive flame retardant use	Manufacture of epoxy / polycarbonate resins	0.36-0.44	0.13-0.16	0.142-0.195
	Processing of epoxy resins	0.0027-0.0049	0.001-0.0019	0.0012-0.0017
Additive flame retardant use ABS	Compounding	14.6-17.8	5.5-6.7	5.75-7.9
	Conversion	0.66-0.81	0.25-0.31	0.26-0.36

According to the EU RAR [EU RAR 2008], a further possible exposure route for the soil compartment is the degradation of TBBPA during anaerobic wastewater treatment processes, in particular anaerobic sludge digestion. The BPA formed could be applied to agricultural land with the digested sludge. A rough estimate has been made of the maximum possible concentration of BPA that would be present in soil if it was formed from TBBPA during sludge digestion. However, it is not certain that this reaction occurs during anaerobic sludge digestion as data in the EU RAR [EU RAR 2008] for TBBPA is conflicting and the calculations did not take into account the rate of the reaction. Furthermore, not all the sludge from WWTP receiving waste waters from TBBPA use sites is applied to land. It has been reported that sludge from the eight major brominated epoxy resin producers in the EU is not applied to land. The estimated concentrations in agricultural soil resulting from degradation of TBBPA are summarized in Table 34 [EU RAR 2008].

Table 33: Estimated concentrations of BPA in soil resulting from degradation of TBBPA [EU RAR 2008]

Scenario		**Estimated conc. of TBBPA in sewage sludge (mg/kg dry wt.)**	**Estimated max. conc. of BPA in sewage sludge (mg/kg dry wt.)**	**Estimated max. conc. of BPA in agricultural soil (mg/kg wet wt.)**
Reactive flame retardant use	Manufacture of epoxy / polycarbonate resins	28-30	12. 6	0.142-0.195
	Processing of epoxy resins	0.052-0.056	0.024	0.000025
Additive flame retardant use ABS	Compounding	0.0011-0.0012	512	0.54
	Conversion	51.6-55.6	23. 3	0.025

3.3.11 Emissions of BPA from waste disposal

PC is typically used in the production of functional parts in long life applications like construction or automotive parts. Use periods are in the range of 5 to 20 years, in some cases even longer. At the end of their lifetime direct reuse of the product in another application is not usually possible. However, PC plastic is recyclable (recycling code 7) with large demands for example in China and some used PC is collected for processing into recycled material where it is economically feasible. Waste material may be directly processed into articles, which have inferior properties or used as a secondary raw material added to virgin material for the production of recycled grades. There are some applications like CDs which can be produced from recycled PC from old CDs together with PC waste from production processes. Recycling of

PC from some applications is not feasible without significant prior treatment (for example material which is dirty or significantly discoloured due to weathering). PC which is not recycled is likely to be disposed of to landfill or via municipal waste incineration. Articles containing epoxy resins are typically disposed of via landfill or municipal waste incineration.

There is not thought to be any recycling or recovery of epoxy resins, though some products (especially electronic parts) containing them may be recycled. Emissions to waste water of epoxy resin and thus BPA may occur due to consumer use of paints or lacquers containing epoxy resins. Professional and consumer use may result in disposal of paint residues to waste water from household by cleaning of brushes and other painters and varnisher equipment.

Incineration of products containing BPA will effectively destroy any free BPA present in the product. There may be potential for residual BPA to leach from materials disposed of to landfill.

Landfills have historically been the most common methods of organized waste disposal and still remain so in many regions of the world. Thus, they may contain wastes including materials made from BPA resulting from several decades of disposal and decomposition with subsequent release of BPA. Products containing BPA as additive or made from BPA like PC articles are in daily use. However, when these products are decomposed, additives may be released into the environment. During the course of stacking fermentation, and degradation a hydrolytic or leaching process may occur to release the BPA from these wastes to the leachate. Conditions in waste landfills may accelerate ageing of plastic materials and thus release of BPA. The ester bond linking BPA molecules in PC and resins is subject to hydrolysis, resulting in leaching of BPA monomer even from new PC into water at room temperature. The rate of leaching due to hydrolysis of the ester bonds (which link BPA molecules in PC and resins) increases as temperature increases and in response to acidic or basic conditions. The consequence is that as PC begins to show signs of wear, the rate of leaching can increase over 1000-fold relative to the rate of leaching from new products [vom Saal et al. 2005]. Many municipal landfills discharge directly into waste water treatment plants (WWTPs) without prior treatment, resulting in environmental spreading of BPA. There are scientific reports from all over the world, demonstrating that BPA is found in landfill leachate waters in varying concentrations. Studies conducted in Japan [Kawagoshi et al. 2003] and in Germany [Coors et al. 2003] show that BPA accounts for the majority of estrogenic activity that leaches from landfills into the surrounding ecosystem. Kawagoshi et al. evaluated a landfill leachate, collected from the groundwater of the North Landfill, a sea based landfill site which is located at Osaka North Port, Japan and was used for the disposal of incinerator ash and incombustible waste from 1973 to 1986, for estrogenic activity and composition. BPA was found in a concentration of 740 µg/L and was the greatest contributor to estrogenic activity among the chemicals identified in leachate extract, with an estimated contribution ratio of 84% [Kawagoshi et al. 2003]. Coors et al. measured the estrogenic activity of leachate from an MSW landfill in West Germany which was in operation from 1983 to 1998 using a subline of MCF-7 cells (MVLN cells) and established that the estradiol equivalent (EEQ) of raw leachate was 57.7 ng/L, mostly contributed to by BPA (concentration of BPA in the raw leachate 3.61 mg/L). Kang et al. [2007] assumed that the primary route of BPA contamination in the aquatic environment is effluent from wastewater treatment plants and landfill sites. Some publications, providing information about emissions of BPA to waste water rare summarised below.

Baderna et al. found BPA in a concentration of 33.5 mg/L in the leachate of an industrial waste landfill in northern Italy. Composition of the leachate of this site has been monitored in 55 campaigns during 11 years. Five campaigns were done yearly (one every 2 months excluding July and August). BPA was the compound most frequently detected in 90.0 % of the samples [Baderna et al. 2011].

In 1998, Schwarzbauer et al. [2001] took two seepage wastewater samples from a waste deposit landfill in Germany. Sampling was performed at two different haulings directly at the top of the landfill. In addition, a water sample of leakage water was taken in the underlying mining system. BPA was detected with concentrations between 13 and 25 mg/L in seepage water samples. The amount in the leakage water sample was significantly lower (4.2 mg/L) indicating a rapid degradation during the short soil passage. Investigations at two different German landfill leachate treatment plants with a variety of process configurations were conducted by Wintgens et al. [2003]. BPA was detected in high µg/L-ranges in raw landfill leachate (up to approx. 7 mg/L). Membrane bioreactors (MBRs) were capable of removing more than 80% of the nonylphenol load. Final effluent concentrations range between 3–30 mg/L BPA respectively. Eggen et al. investigated three differently engineered landfills (location not reported). Leachate samples were collected at and downstream of landfills and at the point of discharge to wastewater treatment drainage. It was reported that in all samples BPA has been detected although no concentrations were given [Eggen et al. 2010].

In 2009, Kamata et al. sampled leachates at 3 leachate-uncontrolled type landfill sites located in mountainous areas of Fukushima prefecture in north-eastern Japan. LC–MS analyses gave BPA concentrations between not detected and 105 µg/L [Kamata et al. 2011]. Urase et al. measured BPA in landfill leachates from solid waste disposal sites in Japan. The concentrations of BPA contained in leachates from industrial waste sites were in the range below the detection limit to 2,800 µg/L, while those from municipal sites were in the range 26–8,400 µg/L. A 7-year survey on a site in Japan showed neither a decrease nor an increase in the concentration of BPA during on-going reclamation. A major portion of the BPA in leachates was found in dissolved and organic unassociated fractions, which cannot be precipitated by coagulation. More than 99.9% of the BPA contained in raw leachates was removed by a conventional series of treatment processes consisting of biological treatment, coagulation, sedimentation, sand filtration, and activated carbon adsorption [Urase et al. 2003]. The levels of BPA in hazardous waste landfll leachates collected in Japan in 1996 were determined by gas chromatograph/mass spectrometer (GC/MS) by Yamamoto et al. BPA was found in seven of 10 sites investigated. All the hazardous waste landfills with leachates contaminated by BPA were controlled. The concentrations of BPA ranged from 1.3 to 17,200 µg/L with a median concentration of 269 µg/L. Sakamoto et al. reported that BPA in landfill leachate originates mainly from plasticized PVC and that the concentration of BPA in leachate is increased by co-disposal of PVC/PC with alkaline waste such as incineration ash. BPA in leachate and treated water from municipal solid waste landfills and industrial waste landfills were analyzed. In leachate of municipal solid waste disposal sites, the level of BPA was <0.05-4,960 µg/L and in treated water <0.05-19.8.µ g/L, respectively. High concentration of BPA was detected from a co-disposal site of shredded incombustible/large waste and incinerator ash. On the other hand, the level of BPA was <0.05-494 µg/L in leachate, and <0.05-55.2.µg/L in treated water from industrial waste disposal sites. According to the results of repeated leaching tests on waste samples, BPA was easily and continuously leached from products made of plasticized polyvinyl chloride (PVC) and the total amount of leached BPA was higher than from products made of PC [

Four wells downgradient from a landfill near Elkhart, Indiana, USA, used for disposal of commercial, industrial, and medical waste, and general refuse on the land surface or in 10–15 feet deep trenches from 1960 to 1976, were sampled during 2000–2002 to evaluate the presence of waste-indicator compounds in landfill-leachate-affected ground water. Compounds detected in leachate-affected ground water included BPA in low concentrations up to 1.3 µg/L [Buszka et al. 2009]. Barnes et al. reported BPA concentrations between not detectable and 0.8 µg/L in ground water samples collected at five sites, four of which are located downstream from the Norman Landfill research site in central Oklahoma [Barnes et al. 2004].

He et al. collected fresh leachate samples from a sanitary landfill site in Shanghai City, loaded with MSW since January 2007 and mature leachate samples from a full-scale MSW bioreactor landfill in Hangzhou City, which had been operated for more than 3 years with leachate recirculation. BPA concentrations ranged between 5 and 60 µg/L [He et al. 2009]. Deng et al. analysed three leachate samples from Qingshan landfill and Liufang landfill in China. The average concentrations of BPA were 0.0164 mg/L, 0.0222 mg/L, and 0.0384 mg/L respectively [Deng et al. 2006].

Against the background of these data, it can be concluded that leaching of BPA occurs at most landfills in different concentrations. While concentration of BPA in direct leachates is high in most cases, ground water samples for locations near landfills only showed small concentrations of BPA. It is assumed that all landfills in Europe are controlled and leachates from landfills are treated in WWTP before release to surface water. However, efficiency of WWTP in reduction of BPA vary and it is still not clear whether BPA is degraded during waste water treatment or adsorbed to sludge in high amounts. Efficiencies of industrial WWTPs have been reported to be more effective in the reduction of BPA (up to 99.5 %) than municipal WWTPs (61-98 %)[Weltin et al. 2002]. In case BPA is adsorbed to sludge and the sludge is subsequently applied to land, emissions to soil will appear. However, sludges from onsite WWTPs of landfills are regarded as waste and thus are assumed to be incinerated in Europe. In case of low efficiency of WWTPs, relevant concentrations of BPA might be released to surface water. Higher emissions are to be expected from landfills where besides municipal waste industrial waste like incineration ashes have been stored as this might result in conditions allowing degradation of BPA containing polymers like PC or epoxy resins and also release of BPA from other sources like PVC products. Although, today, most plastic waste in Western Europe is recycled (either to recover the monomers or to produce new materials/articles) or burned for energy recovery, in former years, huge amounts of indirectly BPA containing wastes have been land filled. The total amount of BPA released to surface water from leachates of landfills is unknown and cannot be calculated based on the available information. Landfill leachates under certain circumstances may in local areas contribute significantly to BPA concentration in water bodies.

4 Environmental monitoring data

4.1 Summary of environmental monitoring data on BPA available in the Risk Assessment Report

Based on the information given in the revised European Risk Assessment Report on BPA [EU RAR 2008], the industry performed a review on available monitoring studies for BPA until the year 2007 published by Plastics Europe [Plastics Europe, 2007].

The studies were reviewed by the industry for their quality in two ways. Firstly, the completeness of the information reported in the studies was considered (on methods, locations, quality assurance (QA) procedures, etc.). Secondly the quality of the analytical methods and quality assurance, etc., was assessed. Only studies that were considered as reliable or very reliable in both assessments were included in the further analysis. A total of 99 papers were reviewed initially, with 79 retained for the further analysis. The majority of the samples came from the years 1998 – 2003.

A summary of the review results is given in Table 35.

Table 34: Summary of measured levels data for water and sediment available in the Risk Assessment Report

	Freshwater	**Freshwater sediment**	**Marine water**	**Marine sediment**
Observations:				
Total number of weighted observations	848	249	115	67
Number of weighted observations below detection limit	415	75	58	44
Number of imputed observations[a]	10	65	0	0
Concentrations:	(µg/l)	**(ng/g dw)**	(µg/l)	**(ng/g dw)**
Median	0.01	16	0.0016	8.5
Mean	0.13	60	0.017	75
SD	1.5	134	0.062	2.09
5th percentile	0.0005	0.5	0.00005	1.1
95th percentile	0.35	256	0.088	566

[a] Where individual data points were not available, representative points were imputed from the summary statistics where possible.

For detailed information, such as single studies, please refer to the revised Risk Assessment Report [EU RAR 2008].

4.2 Environmental monitoring data on BPA

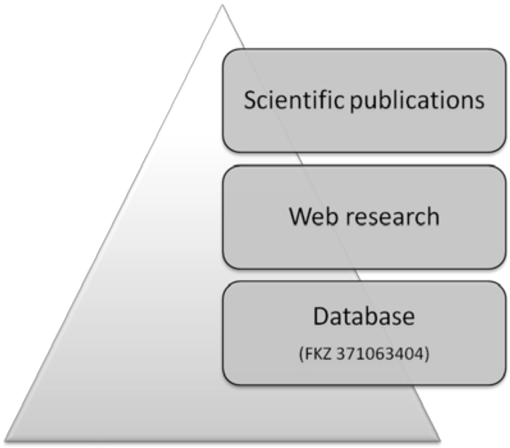
In the framework of this project, a review of existing environmental monitoring programmes in the EU has been conducted, whereas the focus was set on available environmental monitoring programmes in Germany. Only little information was available on environmental monitoring programmes measuring BPA concentrations in environmental matrices.

For this reason, scientific publications from 2007 to 2012 delivering relevant information of BPA concentrations in environmental compartments were included within the review. A detailed overview in regard to sampling and analytical aspects on each scientific publication taken into account is given in the Annex 7.5.

4.2.1 Review approach

The review of existing environmental monitoring programmes on BPA was based on three pillars (see Fig. 10), which are described in the following.

Fig. 10: Basis for the generation of environmental monitoring data on BPA



As basis of the review an internal existing database on environmental monitoring programmes has been screened, which has been elaborated in the framework of a research project of the German Federal Environment Agency (FKZ 371063404) [BiPRO 2012]. The database was completed in December 2011 and includes comprehensive data on ca. 250 environmental monitoring programmes conducted in Germany (regional, federal state and national level), on EU Member State as well as EU wide level.

Besides the screening of the database, a thorough web research has been performed, on the one hand side using keywords as well as combinations of keywords such as `environmental monitoring´, `environmental monitoring programmes´ and `Bisphenol A´, on the other hand side by targeted screening of web pages from ministries in Germany, EU Member States and EU authorities, web pages from existing environmental monitoring programmes and projects, as well as (EU) databases aggregating environmental monitoring data.

Further, scientific publications from 2007 to 2012 delivering relevant information of BPA concentrations in environmental compartments were included within this review, in order to update and complete the information available in the Risk Assessment Report [EU RAR 2008].

The following information on BPA environmental monitoring programmes was collected and aggregated into an excel-file, which can be found as separate Annex to the report:

- Information source
- Short and full title of the programme
- Programme description
- Investigated medium (environmental compartment / human / product)
- Value measured / unit
- Geographical area (local, regional, national, international)
- Programme duration
- Sampling procedure (defined, representative, grab sample, etc.)
- Sampling frequency (continuously, monthly, annually, single measurement, etc.)
- Total number of samples

- Analytical method (LOD, LOQ)
- Quality assurance / validation system
- Reporting obligation / voluntary data collection
- Data supplier (e.g. company, agency)
- Data storage (locality and type, e.g. electronic)
- Data accessibility (public, restricted) and possible data use
- Contact person

Regarding the reviewed scientific publications, only publications published between 2007 and 2012 were investigated. The following information for each publication was summarised (see Table 58) following the structure in the Risk Assessment Report [EU RAR 2008]:

- Country
- Author
- Sample date(s)
- Sample description
- Number of samples
- Minimum detection limit
- Frequency of detection
- Summary statistics.

4.2.2 Information sources

A thorough web search has been conducted in order to identify environmental monitoring programmes including BPA.

In a first step, the web pages of the environmental federal state ministries in Germany (BW, BY, B, BB, HB, HH, HE, MV, NI, NW, RP, SL, SN, ST, SH, TH) including the regional authorities have been screened [BW 2012, BW LUBW 2012, BY 2012, BY LFU 2012, B 2012, BB 2012, BB LUGV 2012, HB 2012, HH 2012, HE 2012, HE HLUG 2012, MV 2012,MV LUNG 2012, NI 2012, NW 2012, NW LANUV 2012, RP 2012, RP LUWG 2012, SL 2012, SL LUA 2012, SN 2012, SN LFULG 2012, ST 2012, ST LAU 2012, SH 2012, SH LLUR 2012, TH 2012, TH TLUG 2012].

On a EU wide level, the screening included the web sides of the national environmental agencies of Austria, Belgium, Bulgaria, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Portugal, Slovakia, Slovenia, Spain, Sweden and UK [AT 2012, be 2012, BG 2012, HR 2012, DK 2012,EE 2012, FI 2012, FR 2012, DE 2012, EL 2012, IS 2012, IE 2012, IT 2012, LV 2012, LT 2012, LU 2012, MT 2012, NL 2012, NO 2012, PT 2012, SK 2012, SI 2012, ES 2012, SE 2012, UK 2012].

Screening of web pages from existing environmental monitoring programmes and (EU) databases aggregating environmental monitoring data were limited to the following sources, since most of relevant sources were considered to be included in the internal excel-database [BiPRO 2012].

- Monitoring Network in the Alpine Region for Persistent and other Organic Pollutants [MONARPOP 2012]
- The Trilateral Cooperation on the Protection of the Wadden Sea [TMAP 2012]
- The Water Information System for Europe [WISE 2012] including
    - the EEA Waterbase [EEA Waterbase 2012] and
    - the FATE Interactive Map Viewer [FATE 2012]
- the EEA European air quality database [EEA AirBase 2012]
- the European Pollutant Release and Transfer Register [E-PRTR 2012]

- the air monitoring network of the German Federal Environment Agency [UBA Luftmessnetz 2012]

However, BPA is not included in these programmes, except for the FATE database. The FATE database is the only programme which delivers BPA concentrations reported by EU Member States based on a screening procedure in surface water, groundwater and wastewater. Programmes, which monitor BPA concentrations on a regular basis, were not identified.

Further, scientific journals were screened in the electronically accessible Bavarian State Library using different keywords (“environment”, “environmental”, “bisphenol”, “pollution”, “monitoring”, “contaminant”, “contamination”). A total number of 67 journals were identified and further investigated using a targeted keyword search on “bisphenol”. Screened journals are listed in the Annex 7.2.

The following journals were identified to be relevant scientific publications on BPA published between the years 2007 and 2012:

- Archives of Environmental Contamination and Toxicology
- Atmospheric Environment
- Chemosphere
- Environment Science Technology
- Environmental Research
- Environmental Pollution
- Environmental Science and Pollution Research (ESPR)
- Journal of Environmental Science and Health Part A
- Marine Environmental Research
- Marine Pollution Bulletin
- Science of the total Environment

Additionally, scientific publications indicated in the secondary literature of relevant publications were analysed originating from the following journals:

- Aquatic Toxicology
- Analytical and Bioanalytical Chemistry
- Water Research
- Journal of Chromatography
- Green Chemistry Letters and Reviews

4.2.3 Results on BPA environmental monitoring data

Only a small number of 15 environmental monitoring programmes including measurements on BPA concentrations in different environmental compartments have been identified. None of these programmes are classical monitoring programmes in regard to BPA, i.e. regular sampling of environmental samples over a duration of many years and after sampling subsequent analysis of BPA concentrations in these samples. They all rather represent projects and studies, which measured BPA concentrations over a limited timeline, or special investigations analysing BPA concentrations on a screening basis. However, the term environmental programme shall be used within this report. Identified programmes mostly indicate BPA data prior to the year 2007. A summary on the 15 identified programmes is available in the following subchapter 4.2.3.1. A detailed overview is given in a separate excel-file as Annex to the report.

More data on BPA concentrations in the environment was available in scientific journals. In total, 71 publications and reports were investigated, whereas 51 publications and reports published between the years 2007 and 2012 were identified to include relevant information on BPA in regard to concentrations in different environmental compartments published. A summary on the review results is available in the subchapter 4.2.4. A detailed overview is given in the Annex 7.5.

4.2.3.1 Identified programmes

Most of the 15 identified programmes (11) are conducted on a federal state level in Germany (Baden-Württemberg, Bavaria, North Rhine-Westphalia, Rhineland-Palatinate, Hesse and Saxony); the remaining four programmes include two national programmes from Germany (retroperspective monitoring using samples from the German Environmental Specimen Bank (UPB)) and Austria (project ARCEM - Austrian Research Co-operation on Endocrine Modulators), as well as programmes conducted in the Norwegian Arctic (Screening of new contaminants in samples from the Norwegian Arctic) and in the EU (FATE). These programmes are described below.

Programmes on federal state level in Germany – Baden-Württemberg

In Baden-Württemberg three programmes delivered BPA concentrations found in groundwater, fresh water, waste water and sediment sampled at the Lake Constance (German: "Bodensee").

In the framework of a research project on occurrence of pharmaceutical substances and hormones in ground water, fresh water and soil in 1998 to 2001, BPA concentrations were analysed in ground water up to 1600 ng/l. In fresh water samples taken at different sampling stations at the rivers Danube, Rhine, Neckar, Körsch, Blau and Elz, BPA concentrations up to 12 ng/l, 150 ng/l (average: 34 ng/l), 28 ng/l (22 ng/l), 60 ng/l (41 ng/l), 61 ng/l (22 ng/l) and 2 ng/l were measured, respectively. No data was available for BPA in soil samples [LUBW DVGW 2003].

In 1998 a special investigation in the frame of the federal ground water measuring network, BPA concentrations in waste water were analysed. Concentrations ranged from 90-260 ng/l (average of 4 samples: 170 ng/l) [BW Grundwasser 2012].

Sediment samples from Lake Constance sampled during two campaigns in 2004 and 2005 were investigated during a research project. The average BPA concentration found in the sediment samples amounted to 29.5 ng/g, with a maximum value of 75.1 ng/g [IGKB 2009].

Programmes on federal state level in Germany – Bavaria

The Bavarian Environment Agency (LfU) has investigated endocrine disrupting compounds in different environmental matrices in the past ten years. During investigations of fresh water grab samples taken during the years 2002 to 2005 at eight major Bavarian rivers median concentration values ranging from 5 – 49 ng/l were identified for BPA [LfU 2007].

Programmes on federal state level in Germany — North Rhine-Westphalia

For evaluation of the water quality status BPA was investigated among other different organic substances in the rivers Rhine (north), Emscher and Wupper in the year 2000. BPA concentrations amounted to 0.20 µg/L for the river Rhine, 0.95 µg/L for the river Emscher and 0.46 µg/L for the river Wupper [LANUV Gewässergütebericht 2001].

At the beginning of 2005 the regional survey on surface waters for the evaluation of the ecological and the chemical status of surface fresh waters in the context of implementation of the Water Framework Directive were completed. In the course of these investigations, BPA concentrations were measured in different types of samples such as ground water, fresh water, sewage sludge, drainage of a sewage treatment plant and waste water with concentrations reaching up to 0.1 µg/l, 2,700 ng/l, 1.326 µg/kg dw, 118 µg/l and 14.9 µg/l, respectively [Abschlussbericht TU Kaiserslautern 2006].

Programmes on federal state level in Germany — Rhineland-Palatinate

During 2008 and 2009, grab water samples of the river Rhine were taken and investigated on i.a. BPA concentrations (Rheinwasser-Untersuchungsstation Mainz-Wiesbaden Betriebsergebnisse 2009). BPA concentrations ranged from values below the detection limit (0.005 µg/L) to 0.025 µg/L; the average of the BPA concentrations measured was a high as 0.009 µg/L [LUWG 2009].

Programmes on federal state level in Germany — Hesse

In the years 1999 and 2000 the occurrence of organic substances in rivers, waste waters and sewage sludge in Hesse was investigated. In the frame of this investigation BPA was found in fresh water in concentrations up to 0.44 µg/L in 1999, and up to 0.13 µg/L (median: 33 ng/l) in 2000. For discharged waste water of municipal sewage treatment plants BPA values amounted to 0.051-0.26 µg/L in 1999 and 0.07-0.37 µg/L in 2000 [HLUG 2012a].

BPA concentrations in different rivers in Hesse were investigated during the plant protection monitoring programme from 2007 to 2010. Results show that especially surface waters which are exposed to higher loads of waste water have elevated BPA concentrations [HLUG 2012b].

Table 35: Summary of measured BPA concentrations (maxima) for different rivers in North and South Hesse for the years 2007 and 2010 in ↔g/l [HLUG 2012b]

River	BPA concentration maxima in 2007	BPA concentration maxima in 2010
Weschnitz (south)	1.90	0.05
Rinne (south)	0.58	0.15
Rodau (south)	0.73	0.07
Modau (south)	0.08	0.27
Bieber (south)	0.28	0.10
Grenzbach (north)	0.09	0.01
Riedwiesngraben (north)	0.12	0.02
Olmes (north)	0.05	0.06
Ems (north)	0.04	0.03

River	BPA concentration maxima in 2007	BPA concentration maxima in 2010
Efze (north)	0.10	0.01

Programmes on federal state level in Germany – Saxony

Waste water discharges were analysed during 2001 and 2007 with the aim to evaluate the relevance on if and to what extent discharges from municipal sewage treatment plants pose a burden for rivers in Saxony. BPA has been analysed in waste waters of small, medium and large municipal sewage treatment plants, whereas median concentrations were below the detection limit (max. 0.25 µg/L), as high as 0.34 µg/L (max. 2.00 µg/L) and 0.15 µg/L (max. 5.30 µg/L), respectively [LfULG 2009].

River fresh water samples in Saxony were recently investigated (2010) at six different sampling sites in Saxony (Schmilka, Zehren, Dommitzsch, Bad Düben, Görlitz und Böhlen). An overview is given in Table 37 [BfUL 2010].

Table 36: Summary of measured BPA concentrations for different rivers in Saxony for the year 2010 in ng/l [BfUL 2010]

River	Range	Mean	Median
Schmilka	13-100	42	38
Zehren	<10-220	29	23
Dommitzsch	<10-150	39	31
Bad Düben	13-240	78	68
Görlitz	18-950	86	64
Böhlen	-	-	-

Programmes on national state level in Germany – retrospective biomonitoring: German Specimen Bank (UPB)

Results on BPA concentrations in different marine and limnic biota samples supplied by the UPB in Germany have been published in the frame of a research project, in which a retrospective analysis of BPA concentrations in mussels (blue mussel, zebra mussel), algae (kelp), eelpout muscles, herring gull eggs and bream muscles from different sampling years has been conducted. An overview on the measured BPA concentrations is given in Table 38.

Table 37: Summary of measured BPA concentrations in different biota types from different sampling years on the basis of a retroperspective analysis; values in ng/g [UBA-UPB 2001]

Biota type	Sampling year	Range	Mean
kelp	1985-96	~ 1-2	n.a.
herring gull eggs	1994-96	2.4-2.8	2.5
blue mussel	1985-96	1-1.3	n.a.
zebra mussel	1995-96	1-5.3	n.a.
eelpout muscles	1994-96	<1-3.3	2.5
bream muscles	1996	<1-2.4	n.a.

Programmes on national state level in Austria – ARCEM project

In the Austrian research project ARCEM (Austrian Research Co-operation on Endocrine Modulator) a comprehensive survey on occurrence and concentrations of hormonally active substances has been conducted between 2000 and 2003 in Austria. An overview on the measured BPA concentrations in the investigated compartments is given in Table 39.

Table 38: Summary of measured BPA concentrations for the ARCEM project conducted between 2000 and 2003 [ARCEM 2003], [ARCEM 2012]

Matrix	Range	Mean	Median
fresh water	n.a. - 600 ng/l	n.a.	n.a.
groundwater	n.a. - 930 ng/l	67 ng/l	24 ng/l
landfill leachate (suspended solid)	560 - 427000 ng/l	151342 ng/l	5460 ng/l
landfill leachate (filtrate)	660 - 13400 ng/l	4668 ng/l	2305 ng/l
groundwater samples from former landfill sites	n.a. - 7740 ng/l	2074 ng/l	770 ng/l

Programmes on EU level – FATE

The FATE interactive map viewer displays the results of a pan-European screening exercises on whole water samples in 2007, on unfiltered groundwater samples in 2008 and on effluents from selected waste water treatment plants in 2009. A summary of BPA values found in surface water and ground water samples all over Europe is summarised in Table 40 and Table 41, respectively. No data was available for BPA concentrations in waste water.

Table 39: Summary of measured BPA concentrations available in the FATE database for surface water sampled in 2007; values in ng/l; concentrations below detection limit not indicated [FATE 2012]

Country	Sampling location	Concentration	Country	Sampling location	Concentration
AT	Lavamund	246.34	DE	Burkheim	18.28
AT	Spielfeld	97.0	ES	Barcelona	81.75 123.27
BE	not specified	171.94	FR	Solaize	64.36
BE	not specified	56.68	HU	Tiszasziget	10.56
BE	not specified	10.41	MT	not specified	15.07 25.07
BG	Novi Iskar	223.02	NL	Lobith	47.0
CH	Brugg	7.92	NL	Maassluis	30.0
CH	Andelfingen	39.3	NL	Eijsdenat	279
CZ	Hradek nad Nisou	323	NO	Oslo	39.56
CZ	Zidlochovice	23.0	SE	Asbro	17.32
CZ	Bohumin	53	SI	Maribor	21.28
DE	Wesel	34.31	SI	Ljubljana	32.03
DE	Dessau	18.15	SI	Ljubljana	62.84

Country	Sampling location	Concentration	Country	Sampling location	Concentration
DE	Wittenberg	9.54	SI	Before Mun. Novo Mesto	31.73
DE	Koblenz/Rhein	51.97	SI	After Mun Novo Mesto	120.62
DE	Koblenz/Mosel	13.2	UK	Edinburgh	42.86
DE	Worms	46.42			

Table 40: Summary of measured BPA concentrations available in the FATE database for ground water sampled in 2008; values in ng/l; concentrations below detection limit not indicated [FATE 2012]

Country	Sampling location	Concentration	Country	Sampling location	Concentration
BE	Brugge	2298.63	CY	Polis	6.34
BE	Kessel-Lo	212.09	CY	Paphos	8.96
BE	Nismes	45.98	CY	Peristerona	13.12
BE	Ellikom	10.48	CY	Orounda	13.69
BE	Hulst	1817.32	CY	Liopetri	14.32
BE	Boignée	36.49	CY	Limassol	9.86
BE	Tongeren	9.54	DK	Hvinningdal	3.71

Other programmes — Screening of new contaminants in samples from the Norwegian Arctic

On behalf of the Norwegian Pollution Control Authority, a screening of i.a. BPA in the Norwegian Arctic was conducted. The samples were collected on several different cruises performed as parts of other ongoing research projects. BPA was detected below the detection limit in all of the collected samples.

4.2.3.2 Review of scientific journals

Results of the review of relevant journals are summarised in Table 42 for the environmental matrices surface fresh water, marine water, groundwater, waste water (influent and effluent, as far as data was available), biota, soil, sediment (fresh water and marine sediment), sludge, air and waste leachate, respectively. The country, where the measurement(s) was/were conducted, is indicated in the tables. A detailed overview in regard to sampling and analytical aspects on each scientific publication taken into account is given in the Annex 7.5.

Table 41: Summary of measured levels for surface fresh water in ng/l, if not otherwise specified (country specific)

County	Range	Mean	Author
BE	3.00-55.0 ng/l	24.6 ng/l	Loos et al., 2007
CH	2.00-46.0 ng/l	9.40 ng/l (median)	Jonkers et al., 2009
DE	333-4737 ng/l (25th-75th percentile)	2368 ng/l (median)	Musolff et al., 2009
DE	<20.0-1924 ng/l	57.0 ng/l	Quednow et al., 2008
DE	250-620 ng/l (2003)	210 ng/l (2003-2005)	Reinstorf et al., 2008
DE	n.a.	89.0 ng/l	Osenbrück et. al, 2007

County	Range	Mean	Author
ES	24.0-55.0 ng/l	36.5 ng/l	Calderón-Preciado et al., 2011
EU	350 ng/l (95th percentile)	10.0 ng/l (median)	Klecka et al., 2009
EU	<5.00-323 ng/l	25.0 ng/l	Loos et al., 2009
GR	25.0-58.8 ng/l	41.9 ng/l	Arditsoglou et al., 2008
GR	n.a.	138 ng/l (river water) 380 ng/l (canal water)	Arditsoglou et al., 2008
GR	15.0-138 ng/l (rivers) 49.0-460 ng/l (streams/canals)	n.a.	Arditsoglou et al., 2010
GR	55.0-162 ng/l	98.5 ng/l	Stasinakis et al., 2011
IT	10.0-95.0 ng/l	35.4 ng/l	Baggiani et al., 2010
IT	50.0-175 ng/l	87.25 ng/l	Loos et al., 2007
IT	76.1-207 ng/l	n.a.	Urbatzka et al., 2007
IT	3.60-88.0 ng/l (upstream of a WWTP) 2.60-6057 ng/l (downstream of a WWTP)	38.7 ng/l 1057 ng/l	Bicchi et al., 2009
NL	580-22000 ng/l	n.a.	Verliefde et al., 2007
PT	<1.10-683 ng/l	107 ng/l	Jonkers et al., 2010
SE, DK, FI, NO, Faroe Islands, Iceland	<1.00-22.3 ng/l (recipient water) <1.00-2398 ng/l (surface runoff) <1.00-10.8 ng/l (background concentrations)	8.79 ng/l 722 ng/l 6.22 ng/l	Hansen and Lassen, 2008
SE, EE, LV, LT, PL	n.a.	<14.0 ng/l	Lilja et al., 2009

A wide range of BPA concentrations were reported for surface **fresh waters** during the years 2007 and 2012 with mean BPA concentration values ranging from 9.40 ng/l in Switzerland [Jonkers et al. 2009] to 1057 ng/l in river water downstream of a waste water treatment plant in Italy [Bicchi et al. 2009]. For surface water sampled at Leipzig, Germany, Musolff et al. reported even BPA concentrations as high as 4737 ng/l [Musolff et al. 2009].

Table 42: Summary of measured levels for marine water in ng/l, if not otherwise specified (country specific)

County	Range	Mean	Author
ES	<500 ng/l	BPA not detected (consider LOD: 0.5 mg/l)	Martí et al., 2011
EU	88.0 ng/l (95th percentile)	1.60 ng/l (median)	Klecka et al., 2009
GR	26.9-55.7 ng/l	42.3 ng/l	Arditsoglou et al., 2008
GR	n.a.	15.1 ng/l	Arditsoglou et al., 2008
IT	980-25940 ng/l	8735 ng/l	Mita et al., 2011
PT	<1.10-17.0 ng/l	1.25 ng/l *detection bdl were set equal to the dl	Jonkers et al., 2010

BPA concentrations found in **marine water** ranged from values in the ng/l regime to µg/l. For Spain the value was below detection limit, whereas the high LOD of 0.5 mg/l has to be taken into account. Further, BPA concentration found in Italian marine waters sampled at the Gulf of

Neapel and the Latium coast where relatively high compared to the BPA concentrations found in the other EU Member States Greece and Portugal. For Portugal and Greece mean concentration values ranged from 1.25-42.3 ng/l. The median value in Europe indicated by Klecka et al. [2009] amounted to 1.60 ng/l.

Table 43: Summary of measured levels for ground water in ng/l, if not otherwise specified (country specific)

County	Range	Mean	Author
DE	< LOD – 57.0 ng/g*	n.a.	Wölz et al., 2011
DE	48.0-2368 ng/l (25th-75th percentile)	467 ng/l (median)	Musolff et al., 2009
DE	30.0-1250 ng/l (2003)	n.a.	Reinstorf et al., 2008
DE	<1.00-1136 ng/l	350 ng/l	Osenbrück et al., 2007
ES	n.a.	780 ng/l	Sánchez-Avila et al., 2009
EU	<1.00-2299 ng/l	79.0 ng/l	Loos et al., 2010
NL	<10.0 ng/l	n.a.	Verliefde et al., 2007

*value as elevated estrogenic activity equivalent E-EQ

Ground water sampled in Germany Spain and the Netherlands exhibited BPA concentration values ranging from <1-2368 ng/l. Values published by Wölz et al. [2011] were not taken into account since the value was indicated as elevated estrogenic activity equivalent (E-EQ). Loos et al. [2010] published values for the whole EU ranging from <1-2299 ng/l, whereas the mean BPA concentration value was 79.0 ng/l. For groundwater sampled in an industrial and urban area in Catalonia, Spain, the mean BPA concentration amounted to 780 ng/l [Sánchez-Avila et al. 2009]. Also Musolff et al. found BPA values ranging from 48.0-2368 ng/l taken from ground water observation wells in Leipzig, Germany, with a median of 467 ng/l [Musolff et al. 2009]. Osenbrück et al. investigated ground water samples from Halle, Germany, whereas the average BPA concentration value of 350 ng/l was comparably high as the value published by Musolff et al. [Osenbrück et al. 2007].

Table 44: Summary of measured levels for waste water influents and effluents in ng/l, if not otherwise specified (country specific)

County	Range		Mean		Author
	influent	effluent	influent	effluent	
BE	28.0-42.0 ng/l	n.a.	36.0 ng/l	6.00 ng/l	Loos et al., 2007
CH	226-1640 ng/l	1.30-707 ng/l	414 ng/l (median)	24.0 ng/l (median)	Jonkers et al., 2009
DE	167-6767 ng/l (25th-75th percentile)	50.0-733 ng/l (25th-75th percentile)	n.a.	467 ng/l (median)	Musolff et al., 2009
DE	-	bdl	-	-	Quednow et al., 2008
DE	-	n.a.	-	129 ng/l	Osenbrück et. al, 2007
ES	720-3400 ng/l	140-980 ng/l	1400 ng/l	380 ng/l	Gómez et al., 2007
ES	13.0-1253 ↔g/l	n.a.	n.a.	n.a.	Latorre et al., 2007

County	Range		Mean		Author
	influent	effluent	influent	effluent	
ES	-	<500 ↔g/l	-	BPA not detected (consider LOD: 0.5 mg/l)	Martí et al., 2011
ES	-	-	2400 ng/l	620 ng/l	Sánchez-Avila et al., 2009
former Yugoslavia	-	<13.0-2060 ng/l	-	510 ng/l	Terzić et al., 200
GR	128-830 ng/l	33.0-1000 ng/l	n.a.	n.a.	Pothitou et al., 2008
GR	n.a.	419-850 ng/l	n.a.	635 ng/l	Arditsoglou et al., 2008
GR	-	14.0-2358 ng/l	-	n.a.	Arditsoglou et al., 2010
GR	-	151-790 ng/l	-	292 ng/l	Stasinakis et al., 2011
IT	36.0-55.0 ng/l	n.a.	48.6 ng/l	5.00 ng/l	Loos et al., 2007
IT	-	6.00-993 ng/l	-	224 ng/l	Bicchi et al., 2009
PT	-	120-461 ng/l	-	216 ng/l	Jonkers et al., 2010
SE, DK, FI, NO, Faroe Islands, Iceland	204-9828 ng/l	<1.00-561 ng/l	3167 ng/l	288 ng/l	Hansen and Lassen, 2008
UK	298-1010 ng/l	23.0-54.0 ng/l	542 ng/l	35.0 ng/l	Zhang et al., 2008

Regarding the mean BPA concentration values for influent and effluent waters indicated above, it can be generally concluded that BPA contamination of effluent waters were lower than the influent waters. Mean effluent BPA concentrations ranged from 5.00-635 ng/l. The highest average value were found in Greece with 635 ng/l in a canal receiving effluent wastewater as well as surface runoff [Arditsoglou et al. 2008], followed by Spain with 620 ng/l in the industrial area of Catalonia [Sánchez-Avila et al. 2009]. Loos et al. investigated effluents from a textile plant in the industry region south of Como and Milan, Italy, and detected BPA in a concentration of 5 ng/l [Loos et al. 2007].

Table 45: Summary of measured levels for biota in ng/g; ww: wet weight, fw: fresh weight, dw: dry weight (country specific)

County	Range	Mean	Author
GR	mussels: <115-626 ng/g dw	404 ng/g dw	Gatidou et al., 2010
IT	fish muscle: 0.30-5.00 ng/g ww fish liver: 0.80-6.00 ng/g ww	1.50 ng/g ww 2.17 ng/g ww	Mita et al., 2011
SE	fish bile: <30-7700 ng/g	n.a.	Pettersson et al., 2007
SE	fish muscle: <0.24-4.74 ng/g fw fish liver: <0.24-39.0 ng/g fw	1.94 ng/g fw 8.49 ng/g fw	Sternbeck et al. 2007
SE, DK, FI, NO, Faroe Islands, Iceland	fish fresh water: <1.00-56.8 ng/g ww fish marine water: <10.0 ng/g ww mussels: <1.00-3.30 ng/g ww bird eggs: 6.00-9.00 ng/g ww	n.a. <10.0 ng/g ww n.a. 7.50 ng/g ww	Hansen and Lassen, 2008
SE, EE, LV, LT, PL	fish muscle: <0.60-3.90 ng/g fw	n.a.	Lilja et al., 2009

County	Range	Mean	Author
UK	insect larvae – STW sites: n.a. insect larvae – background: n.a.	8.89 ng/g 4.22 ng/g	Park et al., 2009

Different biota types were investigated in the identified scientific publications. For mussels sampled in Greece, BPA concentrations ranging from <115-626 ng/g dry weight were detected [Gatidou et al. 2010]. Concentrations reported by Hansen and Lassen ranged from <1-3.30 ng/g fresh weight and were considerably lower as the values reported by Gatidou et al. [Hansen and Lassen 2008]. The detected values in fish muscle and liver in Italy and Sweden were in a comparable range (1.5 ng/g wet weight and 1.94 ng/g fresh weight in Italy and Sweden, respectively for fish muscle; 2.17 ng/g wet weight and 8.49 ng/g fresh weight in Italy and Sweden, respectively for fish liver) [Mita et al., 2011] [Sternbeck et al. 2007]. BPA concentrations measured in liver were for both studies higher than in muscle tissue. Also Lilja et al. reported on BPA concentrations in fish muscle in the range of <0.60-3.90 ng/g fresh weight [Lilja et al. 2009]. BPA concentrations in fish bile caught in Sweden were reported to range from <30.0-7700 ng/g, which is the highest value found for BPA concentrations in fish [Petterson et al. 2007]. Park et al. investigated insect larvae in UK, on the one hand side sampled at a sewage treatment plant site, on the other hand side at a background reference site [Park et al. 2009]. A higher mean BPA concentration was reported for the larvae sampled at STW sites.

Table 46: Summary of measured levels for soil in ng/g; dw: dry weight (country specific)

County	Range	Mean	Author
DE	bld	n.a.	Wölz et al., 2011
ES	agricultural soil: 0.7-4.6 ng/g industrial soil: 0.2-44.5 ng/g	2.42 ng/g 11.28 ng/g	Sánchez-Brunete et al., 2009
SE, DK, FI, NO, Faroe Islands, Iceland	landfill soil: <0.1-2.8 ng/g dw	n.a.	Hansen and Lassen, 2008

Only little information was available for soil. Sánchez-Brunete et al. compared BPA concentrations found in agricultural soil and industrial soil in Spain [Sánchez-Brunete et al. 2009]. They reported that contamination of industrial soil was higher than for agricultural soil with a mean concentration value of 2.42 ng/g and 11.28 ng/g for agricultural and industrial soil, respectively. BPA concentrations for landfill soil investigated by Hansen and Lassen ranged from <0.1-2.8 ng/g dw [Hansen and Lassen 2008].

Table 47: Summary of measured levels for sediment in ng/g; dw: dry weight (country specific)

County	Range	Mean	Author
IT	fresh water: 3.80-32.5 ng/g	12.6 ng/g	Viganò et al., 2008
EU	fresh water: 256 ng/g dw (95th percentile) marine: 566 ng/g dw (95th percentile)	16.0 ng/g dw (median) 8.50 ng/g dw (median)	Klecka et al., 2009
FR	freshwater: 1.24-47.28 ng/g dw	14.1 ng/g dw	Kinani et al., 2010
GR	marine: n.a.	17.0 ng/g	Arditsoglou et al., 2008
ES	marine: <0.92-43.0 ng/g	5.69 ng/g *detection bdl were set equal to the dl	Puy-Azurmendi et al., 2010
SE, DK, FI, NO, Faroe Islands, Iceland	marine: <0.1-74 ng/g dw freshwater: <0.1-40 ng/g dw	19.7 ng/g dw 10.43 ng/g dw	Hansen and Lassen, 2008

BPA mean (median) concentration values for marine and fresh water sediment were generally in the same concentration range (5.69-19.7 ng/g). Values for BPA in fresh water sediments investigated in Italy (12.6 ng/g) [Viganò et al. 2008], France (14.1 ng/g) [Kinani et al. 2010] and the Scandinavian area (10.43 ng/g) [Hansen and Lassen, 2008] and marine sediment sampled in Greece (17.0 ng/g) [Arditsoglou et al. 2008], Spain (5.69 ng/g) [Puy-Azurmendi et al., 2010] and the Scandinavian area (19.7 ng/g) [Hansen and Lassen 2008] were quite in accordance with each other and with BPA levels reported for the EU by Klecka et al. [Klecka et al. 2009].

Table 48: Summary of measured levels for sewage sludge in ng/g; dw: dry weight (country specific)

County	Range	Mean	Author
GR	n.a.	29.9 ng/g	Pothitou et al., 2008
SE, DK, FI, NO, Faroe Islands, Iceland	<0.4-1914 ng/g dw	482.8 ng/g dw	Hansen and Lassen, 2008

Only scarce data were obtained for sewage sludge. For sewage sludge investigated at a sewage treatment plant in Greece a mean BPA value of 29.9 ng/g (± 10.6 ng/g) was reported by

Pothitou et al. [Pothitou et al. 2008]. In the Scandinavian area BPA concentrations measured ranged from <0.4-1914 ng/g dry weight with the highest value (1914 ng/g) detected in Finland [Hansen and Lassen 2008]. The mean concentration of BPA was ~482.8 ng/g not taking into account the value measured in Finland.

Table 49: Summary of measured levels for dust / air / PM10 (country specific)

County	Range	Mean	Author
BE (dust)	domestic: 535-9729 ng/g office: 4685-8380 ng/g	2001 ng/g 6532.5 ng/g	Geens et al., 2009
EU (North Atlantic; total suspended particulate)	4-6 pg/m^3	5 pg/m^3	Fu et al., 2010
GR (particulate matter)	urban: 0.06-18.6 ng/m^3 industrial: bdl-47.3 ng/m^3	urban: 6.78 ng/m^3 industrial: 13.2 ng/m^3	Salapasidou et al., 2011

Geens et al. investigated dust samples in Belgium from a domestic site as well as at an office site [Geens et al. 2009]. They reported that BPA values were found in all samples, whereas the mean BPA concentration derived from office dust was three times higher than the mean value derived from domestic dust. Further investigations were made by Salapasidou et al., who measured and compared particulate matter (PM) from an urban traffic site with PM received from an industrial site in Thessaloniki, Greece [Salapasidou et al. 2011]. They reported that mean BPA concentration values were two times higher for PM sampled from the industrial site. Fu et al. investigated total suspended particulates sampled in the North Atlantic during research cruises [Fu et al. 2010]. Even in the remote area of the North Atlantic BPA could be detected in low concentrations.

Table 50: Summary of measured levels for (industrial) waste leachate/waste dumps in µg/l (country specific)

County	Range	Mean	Author
IT	33500 ↔g/l	n.a.	Baderna et al., 2011
SE, DK, FI, NO, Faroe Islands, Iceland	0.71-5.91 ↔g/l	3.31 ↔g/l	Hansen and Lassen, 2008

Some authors [Baderna et al. 2011] [Hansen and Lassen 2008] reported on BPA concentrations detected in waste leachates, although considerable differences can be seen if BPA concentration values are compared. Baderna et al. detected BPA in waste leachate of an Italian industrial waste landfill site in a concentration as high as 33,500 µg/l [Baderna et al. 2011]. Hansen and Lassen reported BPA concentrations of 0.71 µg/l and 5.91 µg/l in waste dump leachates detected in Faroe Islands and Iceland, respectively [Hansen and Lassen 2008].

4.2.4 Conclusion

Information on BPA concentrations are available in the risk assessment report [EU RAR 2008], but only deliver information on BPA concentrations in freshwater, freshwater sediment, marine water and marine sediment prior to the year 2007 based on a review by the industry [Plastics Europe, 2007]. No information on BPA concentrations in environmental matrices is available in the registration dossiers.

Within this project, only 15 programmes were identified on the basis of a thourough web research, which deliver BPA concentrations in environmental matrices. Thereof, eleven programmes were conducted on a federal state level in Germany; two programmes were implemented at national level and another two on an EU wide/international level. However, these identified programmes do not measure BPA concentrations on a regular basis, but rather represent projects and studies, which investigated present BPA concentrations in the environment on a screening basis or in the frame of special investigations. Only four of these programmes deliver BPA data after 2007. These are the FATE database [FATE 2012] and four German programmes conducted at federal state level in Hesse (Pflanzenschutzmittel-Gewässermessstellen-Monitoring, 2007-2010, see Table 36), Rhineland-Palatinate (Rheinwasser-Untersuchungsstation Mainz-Wiesbaden Betriebsergebnisse 2008-2009) and Saxony (Gewässergütemessstationen Schmilka, Zehren, Dommitzsch, Bad Düben, Görlitz und Böhlen in Sachsen, 2010, see Table 37; Potentielle prioritäre Stoffe in Fließgewässern und kommunalen Abwassereinleitungen in Sachsen, 2001-2007). For results see subchapter 4.2.3.1.

In contrast, a huge number of data on BPA concentrations in different environmental matrices in nearly all EU Member States was available in scientific publications published between 2007 and 2012. A summary of BPA concentrations by matrices and countries is available in subchapter 4.2.3.2 (Table 42 - Table 51). The main results of the literature review are highlighted in the following .

BPA concentrations in surface **fresh water** ranged from 9.40 ng/l in Switzerland [Jonkers et al. 2009] to 1,057 ng/l in river water downstream of a waste water treatment plant in Italy [Bicchi et al. 2009].

BPA mean concentrations found in **marine water** ranged from 1.25-42.3 ng/l (PT and IT, respectively). The median value in Europe indicated by Klecka et al. amounted to 1.60 ng/l [Klecka et al. 2009].

Loos et al. published BPA values in **groundwater** for the whole EU ranging from 1 ng/l to 2,299 ng/l (LOD: 1 ng/l) [Loos et al. 2010], whereas the mean BPA concentration value was 79.0 ng/l. For groundwater sampled in an industrial and urban area in Catalonia, Spain, the mean BPA concentration amounted to 780 ng/l [Sánchez-Avila et al. 2009]. In ground water samples taken at German cities as Leipzig [Musolff et al. 2009] and Halle [Osenbrück et al. 2007 mean BPA values amounted to 467 ng/l and 350 ng/l, respectively.

Regarding the mean BPA concentration values for **influent and effluent waters**, it can be generally concluded that BPA contamination of effluent waters was lower than of the influent waters. Mean effluent BPA concentrations indicated in the publications ranged from 5.00-635 ng/l. The highest average values were found in Greece (635 ng/l) in a canal receiving effluent wastewater [Arditsoglou et al., 2008] and Spain (620 ng/l) in an industrial area of Catalonia [Sánchez-Avila et al. 2009]. However, also low BPA concentration values were indicated for effluents from a textile plant in the industry region south of Como and Milan, Italy (5 ng/l) [Loos et al. 2007].

Regarding data on **biota**, mussels sampled in Greece exhibited BPA values ranging from <115-626 ng/g dry weight [Gatidou et al. 2010], while concentrations reported elsewhere for mussels from the Baltic Sea were considerably lower (<1-3.30 ng/g fw) [Hansen and Lassen 2008]. BPA concentrations found in fish muscle ranged between <0.60-3.90 ng/g [Lilja et al. 2009] [Mita et al. 2011] [Sternbeck et al. 2007]. In fish liver higher BPA concentrations were detected than in muscle samples (2.17-8.49 ng/g) [Mita et al., 2011] [Sternbeck et al. 2007]. BPA concentrations in fish bile caught in Sweden were reported to range from <30.0-7,700 ng/g, which is the highest value found for BPA concentrations in fish during the review [Petterson et al. 2007]. Park et al. reported higher BPA concentrations found in insect larvae from sewage treatment plant sites (8.89 ng/g) than for insects from background reference sites (4.22 ng/g) [Park et al. 2009].

Sánchez-Brunete et al. compared BPA concentrations found in **agricultural soil and industrial soil** in Spain and reported that contamination of soil sampled at industrial areas (mean: 11.28 ng/g) was higher than for agricultural soil (mean: 2.42 ng/g) [Sánchez-Brunete et al. 2009].

BPA mean (median) concentration values found for **marine and fresh water sediment** were generally in the same concentration range (fresh water sediment: 10.43-14.1 ng/g [Hansen and Lassen 2008] [Kinani et al. 2010]; marine sediments: 5.69-19.7 ng/g [Puy-Azurmendi et al. 2010] [Hansen and Lassen 2008]) and were quite in accordance with BPA levels reported for the EU [Klecka et al. 2009].

Only scarce data were obtained for sewage sludge. For **sewage sludge** investigated at a sewage treatment plant in Greece a mean BPA value of 29.9 ng/g (± 10.6 ng/g) was reported by Pothitou et al. [Pothitou et al. 2008]. In the Scandinavian area BPA concentrations measured ranged from <0.4-1,914 ng/g dry weight with the highest value (1,914 ng/g) detected in Finland [Hansen and Lassen 2008].

Geens et al. investigated **dust samples** in Belgium from a domestic site as well as at an office site [Geens et al. 2009]. BPA values were found in all samples, whereas the mean BPA concentration derived from office dust was three times higher than the mean value derived from domestic dust. Salapasidou et al. measured and compared particulate matter (PM) from an urban traffic site with PM received from an industrial site in Thessaloniki, Greece [Salapasidou et al. 2011] with mean values being two times higher for industrial PM. Even in the remote area of the North Atlantic BPA could be detected in low concentrations [Fu et al. 2010].

Some authors [Baderna et al. 2011] [Hansen and Lassen 2008] reported on BPA concentrations detected in waste leachates, although considerable differences can be seen, if BPA concentration values are compared. Baderna et al. detected BPA in waste leachate of an Italian industrial waste landfill site in a concentration as high as 33,500 µg/l [Baderna et al. 2011].

Hansen and Lassen reported BPA concentrations of 0.71 µg/l and 5.91 µg/l in waste dump leachates detected on the Faroe Islands and Iceland, respectively [Hansen and Lassen, 2008].

To conclude, the dominating matrices for which BPA concentration values are reported were surface fresh water and waste water effluents, surface fresh water mostly in the context of legislative obligations set by the Water Framework Directive 2000/60/EC.

Fig. 11 and Fig. 12 give a geographical overview of sampling locations in Europe for water samples including surface fresh water, ground water, waste water and marine water as well as biota, soil, sludge and sediment and air/dust samples, respectively, based on the review of scientific journals, data available in the FATE database [FATE 2012] as well as actual data available for the federal states Hesse, Rhineland-Palatinate and Saxony.

Fig. 9: **Overview on water sampling locations (blue) in the EU including surface fresh water, ground water, waste water and marine water based on the review of scientific journals, the FATE database [FATE 2012] and data from 2007 to 2012 for the federal states Hesse, Rhineland-Palatinate and Saxony.**

Fig. 10: Overview on sampling locations for biota (green), soil, sludge and sediment (yellow) and air/dust samples (white) available in the EU based on the review of scientific journals

4.3 Comparison of PEC values with environmental monitoring data

4.3.1 Mean environmental concentrations compared to PECs

The content of this chapter is considered confidential.

4.3.2 Conclusion

The content of this chapter is considered confidential.

5 Conclusions and discussion of results

5.1 Status of REACH registration

The content of this chapter is considered confidential.

5.2 Information on production and use

Literature information and data from industry was collected to identify uses and life cycle steps not included in the CSR and to evaluate whether these uses result in relevant emissions of BPA to the environment. The mass flow of BPA is very complex due to the high amounts produced and used within the EU (more than 1,150,000 tonnes per year) and the variety of different applications. As a first result of the literature screening an overview on uses of BPA was provided. Numerous articles of daily life are made from materials produced from BPA and chemicals and mixtures produced from BPA are used in different industrial, professional and consumer applications. Following the EU RAR [EU RAR 2003 and 2008], uses of BPA were grouped in different categories of main uses. Comparison of the collected uses and life cycle steps of BPA with the data provided in the CSR showed that the most important uses based on volumes (manufacturing of BPA, PC production, production of expoy resin) are covered by the CSR. Nevertheless it became obvious that some life cycle steps and the waste stage of some applications of BPA and products produced from BPA are not within the scope of the CSR for BPA. Use of PC, use of epoxy resins, use of polymers made from BPA, use of coating materials, and the related waste stages have not been taken into account because these processes are not considerd to be life-cycle steps of BPA from a REACH point of view. Taking into account the great volume of BPA used for these applications, emissions from residual monomer in the polymer or degradation of the polymer could be a source of emission to the environment. Furthermore, the service life and waste stage of thermal paper and PVC articles have not been assessed despite the fact that BPA is available as monomer in these articles. The evaluation of literature data and information from data bases showed that there are a lot of different applications for materials made from BPA. However, unknown uses which have neither been reported in the EU RAR [EU RAR 2003 and 2008] nor in the CSR have not been identified.

Against the background that data on emissions of BPA to the environment provided in the EU RAR [EU RAR 2003 and 2008] is based on information collected some years ago and seems to be incomplete, literature data was used to elaborate a more detailed mass flow of BPA to get a better overview on emission sources. The annual production volume of BPA reported fits well with the sum of tonnages provided by REACH registrants in their individual dossiers for production of BPA and it seems that production of BPA remained at the level of 2006.. It can be expected that for example production and use of PC is increasing due to its uses in construction and the automotive industry (weight reduction). Production and use of thermal paper is also increasing as new cash desk systems use thermal printers and the field of applications of thermal printers gets wider (e.g. park tickets, boarding passes, lottery tickets). This would also result in increased emissions. As there is only very limited up-to-date information on volumes of BPA used for single applications publicly available, it was not possible to judge whether the data on volumes provided by registrants, which are an important factor during estimation of emissions, are reliable.

5.3 Mass flow

The content of this chapter is considered confidential.

5.4 Conclusions on life cycle steps

5.4.1 Production of BPA

Production of BPA is the first step in the life cycle of BPA which is followed by several use paths. Against the background that there is only a limited number of manufacturers and production and use of BPA has been reported to increase mainly in Asia, it is possible that production volumes have not been expanded in Europe since 2006. Estimated emissions to air and surface water reported by the EU RAR [EU RAR 2003] are considered to be realistic as there is no other information available from literature or different sources. Exposure of soil and groundwater may occur via atmospheric deposition or application of sewage sludge to non-controlled sites (e.g. cropland). BPA can regularly be found in sewage sludge from public WWTPs and it is more likely that emissions to soil result from application of biological sludge from these plants to agricultural soils. As reported by the EU RAR [EU RAR 2003 and 2008], production of BPA is identified to be one of the most important sources (after production of epoxy resins and PVC applications) for emissions of BPA to the environment.

5.4.2 Repackaging of BPA

The content of this chapter is considered confidential.

5.4.3 Production of PC

According to the EU RAR [EU RAR 2008], approximately 865,000 tonnes of BPA are used for PC production in Europe per year which is the most important use with respect to BPA consumption. Production of PC has been reported to take place only at 5 BPA production sites and no other information is available at moment. The EU RAR [EU RAR 2003] (based on industry information)confirms that PC is only produced at BPA production sites. Assuming that the production of PC always takes place at production sites where BPA is produced, measured emissions reported by operators of these sites already include emissions from BPA production and emissions from PC production as for example waste water from both processes is collected in on one-site WWTP. Consequently, estimated local concentrations for manufacture of BPA already take into account aggregated emissions.

5.4.4 Processing of PC

Processing of PC has not been reported in the CSR. The EU RAR [EU RAR 2003] mentions processing of PC but does not include calculated emissions the environment. Based on literature data emissions of BPA during manufacture of articles made from PC have been estimated. The results showed that processing of PC is not likely to be a source for relevant emissions to the environment compared to other uses.

5.4.5 Use of articles made from PC

Use of articles made from PC has not been reported in the CSR and was discussed in the EU RAR [EU RAR 2003] only in relation with use of bottles made from PC (bottle washing). The evaluation of literature information on different applications of PC and articles made from PC demonstrated that there are a huge number of different articles produced from PC or including PC parts. These articles are used in indoor and outdoor applications and depending from the application area there may be a potential for releases of BPA to the environment due to leaching of residual monomers or release of BPA due to weathering. Some information on migration of BPA from PC was available. It is however unclear which amount of PC is used for production of individual types of articles as only very general information about industrial sectors where articles made from PC are used could be identified. Based on this data basis it is not possible to calculate total release of BPA during the life cycle of articles made from PC. Information on amounts used for production of single types of article (e.g. sheets for roofing) as well as migration rates under environmental conditions would be required to calculate estimated emissions. Taking into account the high number of different applications it seems to be questionable whether it will be possible to calculate aggregated emissions for use of articles made from PC. Nevertheless, the available information has been used to provide a rough estimation for release of BPA from articles made from BPA. These figures indicate that especially outdoor use of articles made from PC may cause release of BPA in low concentrations which might sum up in relevant total releases. Nevertheless, local concentrations resulting from this use are not high enough to be considered as relevant.

5.4.6 Waste stage of articles made from PC

The waste stage has neither been addressed in detail in the EU RAR [EU RAR 2003 and 2008] nor in the CSR. Data from literature and environmental monitoring data however indicate that release of BPA from waste deposited at landfills is likely to occur. BPA has been detected in landfill leachates and influents/effluents from on-site WWTPs. As degradation of plastic materials in landfills will continue for long time periods, leaching from landfills is assumed to be a relevant source for emissions of BPA to WWTPs and in case WWTPs have low efficiency also to surface water. Due to the different conditions in landfills which influence stability of polymers, missing information on volumes of PC landfilled in the past and the different efficiency of WWTPs, it will not be possible to calculate releases from landfills resulting from PC. Monitoring data of effluents from landfill WWTPs might provide information on which basis total releases of BPA can be estimated. However, this information is not available at moment and although it is not possible to calculate aggregated emissions from waste including materials made from BPA waste has to be considered as potential source for release of BPA to the environment.

5.4.7 Production of epoxy resins

Epoxy resin production is the second largest use of BPA in the EU. According to information from the EU RAR [EU RAR 2008], approximately 195,000 tonnes/year of BPA is used in the production of epoxy resins per year. The estimated emissions reported by registrants and in the EU RAR [EU RAR 2003] are considered to be plausible and production of epoxy resins has been identified as important source for emissions of BPA to surface waters.

5.4.8 Use of epoxy resins

Use of epoxy resins has not been discussed in the CSR and in the EU RAR [EU RAR 2003 and 2008]. The evaluation of literature information on applications of epoxy resins and articles including epoxy resins demonstrated that there are a huge number of different applications for epoxy resins. Epoxy resins are used in indoor and outdoor applications and depending from the application area there may be a potential for releases of BPA to the environment due to leaching of residual monomers or release of BPA due to depolymerisation. It is unclear which amount of epoxy resin is used for production of individual types of articles as only very general information about industrial sectors where epoxy resins are used could be identified. Against the background that registrants do not have to report tonnages for import of epoxy resins but only total volumes of imported BPA (combining import as such, import in mixtures and import of polymers)it is not clear from dossier data which amount of epoxy resins is used in the EU. It can be assumed that in addition to the amount of epoxy resin produced, import of epoxy resins also has to be taken into account. Emissions during use of epoxy resins have been discussed in the EU RAR [EU RAR 2003] only in relation to migration from coated cans to food. Some information on migration of BPA from epoxy resins was available from literature. Expected emission from use of epoxy resins for lining of water pipes has been discussed and estimation for release from this use has been provided. The most important application of epoxy resins according to literature data is use in paints and lacquers. Emissions from use of epoxy resins in marine and protective coatings have been calculated based on literature information as far as possible. Epoxy resins are also used for other coating applications, which is a separate life cycle step in the CSR. Based on the available data it was not possible to calculate the total release of BPA during the life cycle of epoxy resins. Information on amounts used for single applications as well as migration rates under environmental conditions would be required to calculate estimated emissions but taking into account the high number of different applications it seems to be questionable whether it will be possible to calculate aggregated emissions for use of epoxy resins.

5.4.9 Production of epoxy resin hardeners

5.4.10 The content of this chapter is considered confidential.Use of epoxy resin hardeners

Industrial and professional use of epoxy resin hardeners is covered by the CSR. Worst case calculations show that there might be relevant emissions of BPA resulting from releases of monomeric BPA from epoxy resins used in protective coatings or due to weathering of epoxy rsins in outdoor applications. Consumer use of epoxy resin hardeners which has not been addressed in the CSR is also expected to happen. Although the amount of epoxy resins used in consumer applications can be assumed to be low, it can be expected that no RMMs preventing release to the environment are implemented, which might result in emissions to the environment.

5.4.11 Waste stage of epoxy resins and epoxy resin hardeners

The waste stage has neither been addressed in detail in the EU RAR [EU RAR 2003 and 2008] nor in the CSR. Data from literature and environmental monitoring data however indicate that release of BPA from waste deposited at landfills is likely to occur. For further information refer to “Waste stage of articles made from PC”.

5.4.12 Production of coating materials

Based on the available information it was not possible to calculate emissions to the environment resulting from manufacture of coating materials to check whether the assumption that no emissions occur is realistic. More detailed information about conditions of use and amounts used per site or results of environmental measurements near the production sites would be required.

5.4.13 Use of coating materials

Use of coating materials, use of articles and the waste stage are not covered by the CSR, may however also result in emissions to the environment. Emissions from can coating materials has been discussed in the EU RAR [EU RAR 2003] in relation to human exposure but the potential for emissions to the environment have not been discussed.

5.4.14 Manufacturing of polymers

Due to missing publicly available information on tonnages of single polymers produced as well as on manufacturing conditions, it was not possible to calculate estimated emissions. Nevertheless, it seems to be plausible that only closed processes are used to produce the indicated polymers and therefore emissions to the environment are expected to be very low. Against this background, it is unlikely that manufacturing of polymers results in relevant emissions to the environment.

5.4.15 Use of polymers and waste stage

Use of polymers, use of articles made from polymers and the waste stage are not covered by the CSR, may however also result in emissions to the environment. Based on the available information it was not possible to calculate expected emissions during use of polymers (missing tonnages, missing information on migration/release of BPA). Against this background, that the discussed polymers are mainly used in special applications which are not assumed to have a potential for release of BPA (see chapter 3.2), is unlikely that use of polymers results in relevant emissions to the environment. Regarding emissions from waste please refer to the section addressing PC waste.

5.4.16 Production of chemicals

The EU RAR [EU RAR 2003] concluded that no significant amounts of waste water or waste air occur during manufacturing of chemicals. There is no contrary information available and du to use of BPA in closed systems only, manufacturing of chemicals is not considered to result in relevant emissions to the environment.

5.4.17 Use of chemicals and waste stage

Manufacturing of chemicals is the only use of this mass flow path addressed in the CSR. It is not clear whether this IU only addresses use of BPA as intermediate for the production of other substances or whether also use of BPA for the manufacturing of mixtures like brake fluids is included. In case production of mixtures is included, use of mixtures and the waste stage are completely missing in the CSR. These life cycle steps may however also result in emissions to the environment.

5.4.18 Manufacture of thermal paper

Manufacture of thermal paper is covered by the CSR and has been discussed in the EU RAR [EU RAR 2003 and 2008]. All manufacturing plants assessed in the EU RAR [EU RAR 2008] transferred waste water to sewage treatment plants. Based on information from manufacturers and the EU RAR [EU RAR 2003 and 2008] paper waste which occurs during manufacture has been reported to be recycled. During recycling of the so called paper broke, emissions to water are likely to occur. Releases to WWTPs, fresh water and fresh water sediments have been reported in the EU RAR [EU RAR 2008]. The production of thermal paper has increased during the last years. Data used for exposure estimation in the EU RAR [EU RAR 2008] is therefore not up-to-date. Against this background, emissions from production of thermal paper have been calculated based on new information collected from literature and companies. It has been shown that today emissions from manufacture of thermal paper are expected to be higher than indicated in the EU RAR [EU RAR 2008]. Manufacture of thermal paper is considered to be a relevant source for emissions of BPA to the environment.

5.4.19 Use of thermal paper

Use of thermal paper is assumed not to result in emissions of BPA to the environment.

5.4.20 Waste stage of thermal paper

The waste stage of thermal paper is not addressed in the CSR but has been discussed in detail in the EU RAR [EU RAR 2003 and 2008]. According to the EU RAR [EU RAR 2008] and information collected from industry, the waste stage of thermal paper and especially recycling of thermal paper are considered to be important sources for emissions of BPA to the environment. A recalculation of estimated emissions has been performed based on new information and it can be concluded from this re-evaluation that there is a high potential for release of BPA to surface water and to soil during recycling of thermal paper and use of recycled paper containing residual BPA. The elaborated mass flow for BPA used to produce thermal paper (see chapter 3.3.8) shows that emissions to the environment occur during paper recycling and the waste stage of thermal paper, which are part of the life cycle of BPA.

5.4.21 Use of BPA as antioxidant in PVC processing

In the EU RAR [EU RAR 2008] emissions during the use of BPA as anti-oxidant during the processing of PVC, the use for incorporation into an additive package for processing of PVC and the use as an anti-oxidant in the production of plasticisers used in PVC processing are reported separately. Against the background that no other publicly available information has been found, it can be assumed that estimated emissions provided in the EU RAR [EU RAR 2008] are reliable. Use of BPA as antioxidant in the processing of PVC may therefore be an important source for emissions of BPA to waste water and surface water.

5.4.22 Use of BPA in articles made from PVC

High releases of BPA from articles made of PVC have been reported in the EU RAR [EU RAR 2008].As there was no other data available, based on data in the EU RAR [EU RAR 2008], losses from PVC articles in use have to be considered as relevant source for emissions of BPA to air and surface water. It was not possible to check whether the emissions calculated in the EU RAR [EU RAR 2008] are realistic or overestimate release of BPA as up-to-date information is not publicly available. Industry information on migration rates, tonnages used for the different application and conditions of use would be required to recalculate total emissions of BPA during service life of articles made from PVC.

5.4.23 Waste stage of articles made from PVC

The waste stage of articles made from PVC containing BPA has not been addressed in the CSR and the EU RAR [EU RAR 2003 and 2008]. Based on the information publicly available it was not possible to calculate estimated emissions of BPA from this type of waste to the environment. Waste and landfills as potential source for emissions of BPA to the environment has been discussed above (waste stage for PC).

5.5 Environmental concentrations

Information on BPA concentrations in the environment are available in the EU RAR [EU RAR 2008], but only deliver information on BPA concentrations in freshwater, freshwater sediment, marine water and marine sediment prior to the year 2007 based on a review by the industry. Against this background and as no information on BPA concentrations in environmental matrices is available in REACH registration dossiers a literature research on publications addressing environmental BPA concentrations has been performed. The evaluation of up to date data on environmental concentrations of BPA in different environmental compartments showed that BPA can be found in all environmental compartments in the whole EU in levels up to 1 µg/L in fresh water, 20 ng/g in sediments and 2.5 ng/g in agricultural soils. Concentrations found in rivers, lakes and in coast areas demonstrate the wide distribution of emission sources. The data collected shows that BPA can be assumed not only to be released at point sources like production plants or industrial sites where products made from BPA are processed. Against this background, emissions from processes which are widely distributed over Europe like paper recycling or landfills and consumer uses like use of recycling toilet paper or thermal paper might also play an important role. In these areas there is a need for further research and more data has to be collected to get a clearer picture about trends and local concentration of emissions. Based on data available so far, it is not possible to correlate detected environmental concentrations to single uses of BPA. Local measurements near production and use sites, like industry reports used to calculate emissions in the EU RAR [EU RAR 2003], would be required to check whether calculated PEC values fit with environmental concentrations.

5.6 Comparison of PECs and environmental monitoring data

The content of this chapter is considered confidential.

5.7 Final conclusion

Information provided by REACH registrants in their registration dossiers and in the joint CSR has not significantly improved the knowledge about use of BPA and the related emissions to the environment. Publicly available information was not suitable to fill all remaining data gaps. For some uses it was possible to provide estimations for emissions based on calculations. Based on scientific literature it can be concluded that the uses with the highest emissions to the environment are production of BPA, production of epoxy resins, production and recycling of thermal paper and use of PVC articles including BPA. In all cases emissions to receiving waters occur, which is the most important environmental compartment. Consequently also emissions to sediments occur, which has been demonstrated by detections of BPA in freshwater and marine sediment samples. Local concentrations at production and use sites have been shown to be higher compared to areas where BPA is not used. It is assumed that the reason therefore is that BPA has comparable short half-lives in the environment and is therefore rapidly degraded.

There exist nevertheless emission sources (see above) which contribute to releases resulting in high local environmental concentrations. Furthermore, wide dispersive outdoor use of articles containing materials made from BPA are assumed to result in emissions to the environment which is supported by the fact that BPA can be found in nearly all compartments across Europe. Up-to-date information on conditions of use and releases would be required to allow a final evaluation and conclusion on relevance of the emissions with respect to environmental health.

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7 Appendix

7.1 Information sources for identification of BPA uses

Table 51: Information sources for identification of BPA uses

Name	Source
TEDX	http://www.endocrinedisruption.com/endocrine.bisphenol.overview.php
US-American product database	http://householdproducts.nlm.nih.gov/
CMR database of the INRS	http://chat.inrs.fr/cmr/publigen_cmr_v2.nsf/FrontOffice?OpenFrameset&Start=D:CAS_80-05-7
OEKOpro	http://129.217.201.70/index.php?s=1005&view_html=80-05-7
GESTIS database	http://gestis.itrust.de/nxt/gateway.dll/gestis_de/000000.xml?f=templates$fn=default.htm$3.0
Environment Canada	http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=79A93C66-1&offset=4
Bisphenol A	http://www.bisphenol-a.org/about/faq.html#b
Plastics Europe	http://www.plasticseurope.org/
SPIN - Database	http://188.183.47.4/DotNetNuke/default.aspx
Bisphenol A Europe	http://www.bisphenol-a-europe.org/

7.2 List of screened scientific journals for the review of scientific publications on BPA concentrations in the environment

- Advances in Environmental Monitoring and Modelling
- Atmospheric Environment
- Advances in Environmental Research
- Advances in Environmental Sciences
- Agriculture and Environment
- Agriculture, Ecosystems & Environment
- Air and Water Components of the Environment Conference
- AMBIO: A Journal of the Human Environment
- Annals of Environmental Science
- Annual Report of the European Environment Agency (EEA)
- Applied and Environmental Soil Science
- Archives of Environmental Contamination and Toxicology
- Atmospheric Environment
- Baltic Sea Environment Proceedings (BSEP)
- BioScience: Organisms from Molecules to the Environment
- British Journal of Environment and Climate Change
- Building and Environment

- Biomedical and Environmental Sciences
- Built Environment
- Bulletin of Environmental Contamination and Toxicology
- Developments in Environmental Science
- Energy & Environment
- Energy & Environmental Science
- Environment, Development and Sustainability
- Environment Bulletin
- Environment and Urbanization
- Environmental Annual Report
- Environmental Bioindicators
- Environmental Chemistry
- Environmental Research
- Geochemistry: Exploration, Environment, Analysis
- Global Environmental Change Part B: Environmental Hazards
- Marine Environmental Research
- OECD Environmental Data
- The Open Environmental & Biological Monitoring Journal
- The Open Environmental Pollution & Toxicology Journal
- Scandinavian Journal of Work, Environment & Health
- The Science of the Total Environment
- Plant, Cell and Environment
- Remote Sensing of Environment
- Regional Environmental Change
- Research Journal of Environmental and Earth Sciences
- Research Journal of Environmental Sciences
- Report of the Royal Commission on Environmental Pollution
- Studies on Neotropical Fauna and Environment
- Trace Metals and other Contaminants in the Environment
- Studies in Environmental Science
- Water and Environment Journal
- Water Environment Research
- Wuppertal Report of the Wuppertal Institute for Climate, Environment and Energy

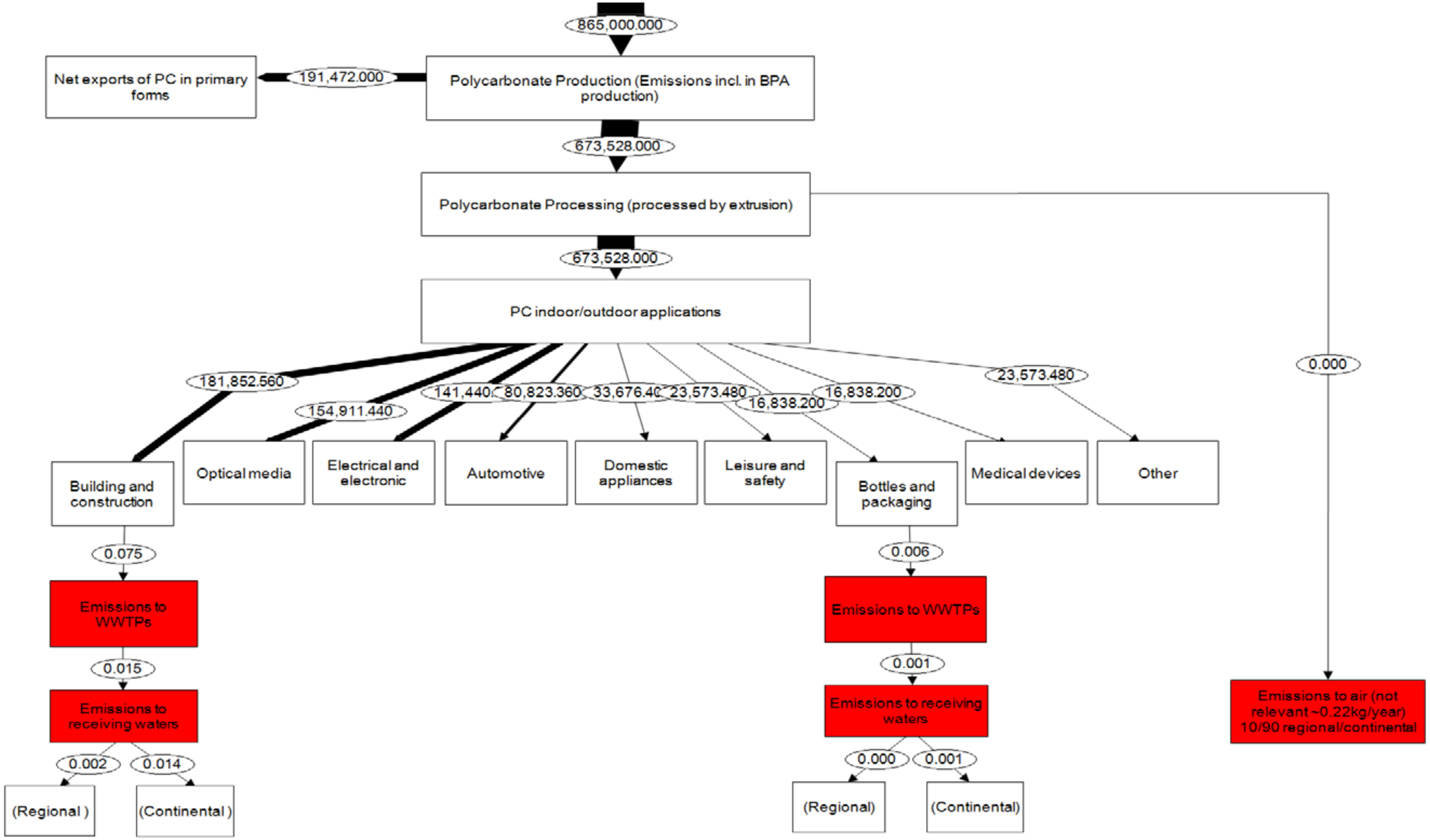
- Water, Air, and Soil Pollution
- Air Pollution Studies (by the UNECE)
- Continental Journal of Water, Air and Soil Pollution (CJWASP)
- Environmental Pollution
- Environmental Science and Pollution Research (ESPR)
- International Journal of Environment and Pollution (IJEP)
- Marine Pollution Bulletin
- Oil and Chemical Pollution
- Environmental Monitoring and Assessment
- Ground Water Monitoring and Remediation
- Journal of Environmental Monitoring (JEM)
- The Open Environmental & Biological Monitoring Journal
- Global Monitoring Report
- Monitoringbericht by the Bundesnetzagentur
- Chemosphere
- Environment Science Technology
- Journal of Environmental Science and Health Part A

7.3 Data reported in REACH dossiers

The content of this chapter is considered confidential.

7.4 Mass flows

Fig. 113: Mass flow PC based on literature information



7.5 Detailed overview on reviewed scientific publications

Table 52: Scientific literature for environmental monitoring

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
IT	Baggiani et al., 2010, Anal Bioanal Chem 397, 815–822	March 2008	Surface river water of the river Po in Torino, single sampling	5	10 ng/l	5/5 (100%)	range: 10-100 ng/l mean: (10, 12, 20, 40, 95 ng/l)
GR	Salapasidou et al., 2011, Atmospheric Environment 45, 3720-3729	January-February 2007	Dust/air sampling (PM10) was conducted at two sites within the urban area of Thessaloniki, an urban-traffic site (AS) and an urban-industrial site (EK). 24-h PM10 samples were collected according to EN-12341.	10 (urban traffic site) 10 (urban industrial site)	Concentration values below detection limits were considered as half of the detection limit; dl: n.a.	100% (urban traffic site) 90% (urban industrial site)	The concentrations of BPA in PM10 ranged from 0.03 to 47.3 ng m3 urban traffic site: 6.78✣6.45 (mean ✣ sd), 6.27 (median), 0.06-18.6 (range) urban industrial site: 13.2✣18.0 (mean ✣ sd), 2.73 (median), bdl-47.3 (range)
DE	Weschler et al., 2008, Atmospheric Environment 42, 9018–9040	-	Typical reported concentrations in indoor environments (air and dust) Data prior to 2007, available in primary literature. Please refer to Morgan et al., 2004; Rudel et al., 2003. Not included in this table.	-	-	-	air: 0.5–5 ng/m3 (Morgan et al., 2004) dust: 0.2–2 ↔g/g (Rudel et al., 2003)
AT	Clara et al., 2012, Chemosphere xxx, xxx–xxx_article in press	September 2010	Influent and effluent samples from 15 waste water treatment plants (WWTP) were taken over a sampling period of 11d (on a screening base). Bisphenol A was present, but was not further monitored since the concentration was below EQS/2. Only substances with concentratiosn > EQS/2 were monitored for a period of 1 year with samples taken every 2 month.	Screening: 30 (2x15)	n.a. (Supplementary Material)	n.a.	BPA concentration was < EQS/2; Please refer to the Supplementary Material available for purchase online
ES	Gómez et al., 2007, Chemosphere 66, 993–1002	2003/2004	Wastewater samples were collected from a municipal sewage treatment plant (STP) located in the southeast of Spain (Almeria) for a duration of 1 year every month.	n.a.	7 ng/l	n.a.	influent (range): 0.72-3.4 ↔g/l; mean: 1.4 ↔g/l effluent –range: 0.14-0.98 ↔g/l; mean: 0.38

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
							↔g/l
BE	Geens et al., 2009, Chemosphere 76, 755–760	Spring 2008	Dust samples (n = 20; each sample analysed 6 times for verification of repeatability, standard deviation for BPA: 6%) were collected in the spring of 2008 from 18 houses (domestic) and 2 offices, randomly selected in Flanders, Belgium, using a vacuum cleaner.	20	LOQ: 0.5 ng/g	100%	domestic dust – range: 535-9729 ng/g; 95th percentile: 4873 ng/g; mean: 2001 ng/g; median: 1461 ng/g; standard deviation: 2102 ng/g office dust: 4685 and 8380 ng/g
BE, IT	Loos et al., 2007, Chemosphere 66, 690–699	17-18 June 2003 (BE), 19 November 2003 (IT)	Textile industry discharges, the corresponding wastewater treatment plant (WWTP) effluents and the receiving rivers (surface water) in Belgium and Italy were analysed. Water sampling in Belgium was performed in the textile industry region south of Ghent. Effluent samples (EF) were taken sequentially at 3 different times at 3 textile companies (1, 2, 3) or the corresponding WWTPs (WWTP), and the receiving waters (RW: River Schelde, Creek Molenbeek and Creek Gaverbeek) before (up) as well as after (down) the waste water treatment. The Italian sampling campaign was performed in the textile industry region south of the city Como and in Milan (1: Fino Mornasco; 2: Bulgarograsso). (TP: textile plant)	38	2 ng/l	33/38 (87%)	Values in ↔g/l: Belgium: EF1 (STP): - EF1 (WWTP): - RW1 (up): 0.038✣0.006 RW1 (down): 0.055✣0.029 EF2 (TP): 0.006 RW2 (up): 0.042✣0.024 RW2 (down): 0.016✣0.005 EF3 (WWTP): - RW3 (up): 0.028✣0.01 RW3 (down): 0.003 Italy: EF1 (WWTP): 0.005 RW1 (up): 0.036 RW1 (down): - RW1: 0.175 EF2 (WWTP): - RW2 (up): 0.055 RW2 (down): 0.050 RW2: 0.074
IT	Mita et al., 2011, Chemosphere 82,	n.a.	BPA concentration was measured in biota, i.e. the muscle and liver of five edible fish (grey mullet,	No. of fish (Naples/Lati	n.a.	Naples/Latium coast:	fish (Naples: muscle/liver, Latium

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
	405–410		salpa, white bream, bass, ombrine), caught in two different sites of the Tyrrhenian Sea such as the Gulf of Neapel (high population, industry, river Sarno, low diffusion rate) and the Latium coasts (high diffusion rate). Mullet, Salpa, and Bass were caught just along the coast near the mouth of the Sarno and Tiber rivers at a depth between 2 and 12 m, while White Bream and Ombrine were caught about 1 mile from the coast at a depth of about 60 m. Further measurements were performed for sea water samples from 4 sites (site 1-2: Gulf of Neapel; site 3-4: Latium coast) taken during a 6 month period in a 3 month interval (3 samples per site; total: 27).	um coast): salpa: 21/21, mullet: 21/21; bream: 18/18; ombrine: 12/12; brass: 15/15 No. of fish samples: sea water: 27		salpa: 90/90, mullet: 76/67; bream: 78/78; ombrine: 83/58; brass: 73/60 sea water: n.a.	coast: muscle/liver; in pg/g tissue, wet weight; values are ca. values derived from graph): salpa: 5000/6000, 2000/1950, mullet: 3900/3800, 600/1250; bream: 700/1800, 650/1400; ombrine: 700/2000, 500/1000; brass: 650/1700, 300/800 sea water: site 1: 4.05 ✥ 0.37 ppm, site 2: 3.97 ✥ 0.40 ppm, site 3: 25.94 ✥ 3.11 ppm, site 4: 0.98 ✥ 0.07 ppm
UK	Park et al., 2009, Chemosphere 77, 1459–1464	2003, 2005 and 2006	Determination of concentration levels in biota, i.e. invertebrate aerial insects whose larval stages develop on percolating filter beds at 4 sewage treatment works (Linlithgow, Bathgate, Fallin, Doune) as well as comparison with concentration levels found at 2 rural non-sewage treatment sites (Ashfield, Stirling University; > 2km from nearest STW) in Central Scotland. Sampling dates were randomised with respect to site. Between two and four samples were collected at each site.	at STW: 12 at non-STW: 4	LOQ: between 0.14-1.9 ng/g; no exact indication for BPA	no exact indication for BPA; BPA found in atleast one of the 12 STW samples and atleast in one of the 4 non-STW samples	(values are ca. values derived from graph, values in ng/g) STW site – mean: 8.89; median: 4.44; 25th percentile: 1.11; 75th percentile: 10.0 non STW site – mean: 4.22; median: 4.0; 25th percentile: 3.78; 75th percentile: 6.44

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
GR	Pothitou et al., 2008, Chemosphere 73, 1716–1723	2007	The occurrence and fate of BPA in a sewage treatment plant (STP) and two industrial wastewater treatment plants (textile and tannery) were investigated. BPA was determined in waste water (WW), total suspended solids/particles (P) and sewage sludge (SS) for the STP (5 sampling campaigns; April to June 2007) at all stages of the treatment and post-treatment (influent-raw wastewater (IN), aeration (AE), secondary sedimentation (SE), final effluent (EF) and sewage sludge (SS)). For the WWTP of the industry sampling has been conducted twice, with 8 samples for each branch.	STP: 45 Textile: 8 Tannery: 8	n.a.	100 for all	STP: WW (ng/l): IN: 676 ✥ 151; AE: 42 ✥ 25; SE: 69 ✥ 51, EF: 33 ✥ 11, P (ng/mg): IN: 0.48 ✥ 0.71, AE: 0.082 ✥ 0.097, SE: 0.015 ✥ 0.010, EF: 0.40 ✥ 0.62 SS: 29.9 ✥ 10.6 ng/g Textile: WW (↔g/l): IN: 0.128; EF: 0.035; P (ng/mg): IN: 0.047; EF: 0.005 Tannery: WW (↔g/l): IN: 0.83; EF: 1.0; P (ng/mg): IN: 0.069; EF: 0.154
IT	Urbatzka et al., 2007, Chemosphere 67, 1080–1087	n.a.	Screening of BPA in water and sediment samples from the river Lambro, Italy (industrial sites). The water and sediment samples were derived from original volume 10 l water and 5 g sediment (just before its confluence with the river Po).	surface water: 1 sediment: 1	n.a.	n.a.	values mostly available as androgenic activity equivalents; some values for BPA are available for surface water: 76.1 ng/l (water fraction 6), 207.1 ng/l (total water fraction)
IT	Viganò et al., 2008, Chemosphere 73, 1078–1089	summer/winter 2005	Sediment samples (whole samples collected in summer 2005, bed sediment samples for fractioning collected in winter 2005) collected from other tributaries and potentially critical sites of the River Po, Italy, were analysed (total 7 sites at the rivers Po, Ticino, Olona, Lambro).	14; composite samples with several sub-samples (5–10)	LOD: 0.5 ng/g	n.a.	(values are ca. values derived from graph, values in ng/g) ELISA method: Turin: 13.0, Ticino: 11.0, Olona: 11.0, Gabbiane: 8.0, Lambro: 32.5, Somaglia: 21.5, Piacenza: 11.5 LC-MS/MS: Turin: 9.24, Ticino: 5.33,

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
							Olona: 10.0, Gabbiane: 3.8, Lambro: 19.46, Somaglia: 13.04, Piacenza: 7.07
DE	Wölz et al., 2011, Chemosphere 85, 717–723	Groundwater: June 2006 to January 2008 SPM and soil: August 2007	Groundwater was sampled 12 times at 3 public wells over 2 years at a non-inundated site with increasing distance to the river Rhine near Karlsruhe, Germany. Flood suspended matter (SPM, 2 sites) and floodplain soil (1 site) was sampled at the river Rhine barrage of Iffezheim, Germany, which is close to the groundwater sampling sites.They were fractionated and analyzed for estrogenic activity in parallel as consequence of floods.	Groundwater: 28 SPM 1: 4 SPM 2: 4 Soil: 4	Groundwater: n.a. LOD SPM: 1.7 ng/g LOD soil:0.8 ng/g	Groundwater: n.a. SPM 1: < LOD (0%) SPM 2: 25% (1/4) Soil: < LOD (0%)	Groundwater: n.a. (only as elevated estrogenic activity equivalent E-EQ) SPM 1: < LOD SPM 2: 57 ng/g Soil: < LOD
UK	Zhang et al., 2008, Chemosphere 73, 848–853	2004-2005	Wastewater samples were collected from Horsham STP, West Sussex, UK, on the following dates: 08/09/04 (a), 01/12/04 (b), and 10/05/05 (c). Samples were taken to cover the whole treatment processes including influent (site 1), post sedimentation (site 2), post biological filter (site 3), and the final effluent (site 4).	✣ 12	n.a. (LOD for EDCs have been reported by Liu et al. (2004))	100%	Site x: (a, b, c) in ng/l: Site 1: 298, 318, 1010; Site 2: 232, 236, 648; Site 3:64, 110, 113; Site 4: 28, 23, 54 (values are ca. values derived from graph)
EU and North America	Klecka et al., 2009, Environ. Sci. Technol. 43, 6145-6150	n.a. (prior to 2007)	Summary paper (meta-data) on BPA studies conducted in North America and Europe published between the years 1991 and 2007 for surface water (fresh and marine water) and sediment (89 papers in total, 58 for Europe).	No. of observations (no. < DL): Fresh water: 848 (415) Marine water: 115 (58) Fresh water sediment: 249 (75) Marine water sediment: 67	DL are different for different studies	Fresh water: 49% Marine water: 50% Fresh water sediment: 30% Marine water sedment: 66%	Fresh water (↔g/l): median: 0.01; 95th percentile: 0.35; Marine water (↔g/l): median: 0.0016; 95th perc.: 0.088; Fresh water sediment (ng/g dw): median: 16; 90th percentile: 162; 95th percentile: 256; Marine water sediment (ng/g dw): median: 8.5;

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
				(44)			90th percentile: 207; 95th percentile: 566
GR	Arditsoglou et al., 2008, Environmental Pollution 156, 316-324	n.a.	Investigation of sampling efficiency of passive samplers (Polar organic chemical integrative samplers - POCIS) in the laboratory as well as in the environment (surface water, waste water) at 4 sites in Greece for 7 days: Axios River (receives various domestic and industrial wastewaters as well as agriculture runoff (site AR)), Thermaikos Gulf (1.5 km away from the estuaries of Axios River and close to a mussel cultivation area (site MC)), harbor of Thessaloniki (commercial and touristic activity (site HA)), and a wastewater canal (receives surface runoff and wastewater of diverse origin (site WC)). Grab water samples were also collected from each site (2 samples per site) on the first and the last day of the POCISs exposure period.	4 for Pest-POCIS, 4 for Pharm-POCIS and 8 grab water samples (2 per site)	n.a.	100%	POCIS (Pest-POCIS; Pharm-POCIS; in ng/POCIS): AR: 28.2; 26.1 HA: 35.6; 25.5 MC: 22.2; 13.6 WC: 378; 557 Grab water (sample A; sample B; in ng/l): AR: 58.8; 25.0 HA: 55.7; 26.9 MC: 36.3; 50.4 WC: 850; 419
India, China, Japan, New Zealand, USA, North Pacific, North Atlantic, Indian Ocean, China Sea, Japan Sea, (Ant-)Arctic	Fu et al., 2010, Environmental Pollution 158, 3138-3143	1989-2009; many samples after 2000	More than 260 atmospheric aerosol samples were collected from various cities in Japan, China, India and New Zealand, as well as remote sites including the Pacific, Indian and Atlantic Oceans and the Polar Regions. The marine aerosols were collected during a round-the-world cruise.	314	0.3 pg/↔L (LOD for BPA in extracts)	100% (2/2)	North Atlantic Ocean, range: 4-6 pg/m3 average: 5 pg/m3
CH	Jonkers et al., 2009, Environmental Pollution 157, 714–723	September 16 to 29, 2006 (River and wastewater effluents: 14 days; WWTP	24h composite-samples of influents and effluents of wastewater treatment plants (WWTPs; 7 sites) discharging into the Glatt River (Switzerland) as well as to river water samples (at 3 sites) were collected.	River water: 42 WW IN: 49 WW EF: 98	LOD: 1.1 ng/l	100%	Values in ng/l River water: Range: 2.0-46 Median: 9.4 WW IN:

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
		influents: day 1 to 7)					Range: 226-1640 Median: 414 WW EF: Range: 1.3-707 Median: 24
FR	Kinani et al., 2010, Environmental Pollution 158, 74–83	July 2004	Sediment samples from 2 reference and 3 impacted small rivers in North of France (Aisne (Ais), Vallon du Vivier (VdV), Rhonelle (Rho), Réveillon (Rev), Lézarde (Lez)). At each site at least five grab sediment samples were taken alongside the river section and were pooled to obtain an average sediment sample.	5	LOQ: 0.01 ng/g	100%	Values in ng/g dw Ais: 2.29 VdV: 11.67 Rho: 7.92 Rev: 47.28 Lez: 1.24
UK, EU, USA	Lapworth et al., 2012, Environmental Pollution 163, 287-303	n.a.	Review of existing data in groundwater for a range of substances including pharmaceutical, personal care, 'life-style' and selected industrial compounds (BPA: 9 studies, thereof 2 relevant studies conducted in UK (Stuart et al. 2012, included in this table) and in the EU (Loos et al. 2010, included in this table); average max. conc. 2.5 x 103 ng/l; data available for UK, EU and USA.)	9 (number of studies) UK: 2644 samples EU: 164 samples	UK: n.a. EU: 0.1 ↔g/l	UK: 7.9% EU: 39.6%	UK – max. conc.: 9300 ng/l EU – max. conc.: 2299 ng/l Total: Range: 470-9300 ng/l Average: 2527 ng/l
ES	Latorre et al., 2007, Environmental Pollution 147, 648-655	n.a.	Identification of BPA in two types of pulp and paper mill whitewaters. Samples were collected in two recycled based packaging board mills (mill A and B), operating with a closed water system. Each type of water (untreated water - U) underwent different treatments and was sampled at the specific treatment steps. In the case of mill A, anaerobic (An) and anaerobic with aerobic (An/A) followed by ozonation step as post-treatments (An/A/O3), were evaluated. For mill B, aerobic (A), anaerobic (An) and anaerobic followed by aerobic treatments (An/A) were tested.	Mill A: 4 Mill B: 4	n.a.	n.a.	Values of untreated waste water in ↔g/l: Mill A: Range: 13-1253 Mill B: Range: 101-429
EU	Loos et al., 2009, Environmental Pollution 157, 561–568	< 2007 (expected; it is suspected that	122 individual surface water samples from over 100 European rivers (122 sampling stations) from 27 European Countries were analysed for 35 selected	122	5 ng/l	34%	max: 323 ng/l average: 25 ng/l median: 0 ng/l

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
		the samples are identic to the samples available for surface water made available by the JRC via the database FATE; see FATE)	compounds. Water sampling was performed by the participating laboratories from the EU Member States (research, public, as well as state-run laboratories) and analysed by the JRC, Ispra, Italy.				percentile 90%: 64 ng/l
DE	Musolff et al., 2009, Environmental Pollution 157, 3069–3077	April 2007 to April 2008	Sampling was performed within a fixed-period covering the different seasons as well as different flow conditions in the surface water at a WWTP, 6 surface water sampling sites, and 22 groundwater observation wells in Leipzig, Germany. Five main sampling campaigns were conducted (April 3–11 2007, July 9–12 2007, October 8–11 2007, January 14–16 2008, April 7–9 2008). Further monthly sampling at selected critical points (WWTP influent and effluent; observation wells; one surface water sampling site) was conducted.	untreated WW: 12 treated WW: 12 surface water: 29 groundwater: 57	LOD surface water: 10 ng/l LOD groundwater: 1 ng/l	100%	Values (25th percentile, median, 75th percentile) in ng/l: untreated WW: 167, -, 6767 treated WW: 50, 467, 733 surface water: 333, 2368, 4737 groundwater: 48, 467, 2368 (values are ca. values derived from graph)
DE	Quednow et al., 2008, Environmental Pollution 152, 476-483	September 2003 to September 2005	BPA was detected in small river freshwater streams (Schwarzbach, Modau, Winkelbach and Weschnitz; tributaries to the Rhine) in Hessisches Ried at 26 sampling sites (south of Frankfurt am Main, Germany) from September 2003 to September 2005. Sampling was carried out at intervals of 2-4 months. During summer 2005 STP effluents were included in the sampling (Darmstadt, Weinheim, Da/Eberstadt, Pfungstadt).	227 for surface water 8 for STP effluents	20 ng/l	13% (30/227) for surface water 0% (0/8) for STP effluents	Values in ng/l: Range: <20-1924 Std. Deviation: 259 Mean: 57 Median: < DL STP effluents: < DL
IT	Pistocchi et al., 2012, Environmental Pollution 162, 159-167	-	Values for calculation of emissions were derived from values published by Loos et al. 2009. Please refer to Loos et al. 2009. Included in this table.	-	-	-	-

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
DE	Reinstorf et al., 2008, Environmental Pollution 152 452-460	2002-2005	The water sampling at the river Saale was carried out at a total of 8 sites (HS1-HS8) along the river. Sampling was performed on 6 days between the years 2002 and 2005 (dates: 14/2/02, 16/7/02, 25/3/03, 8/9/03, 15/7/04, 22/2/05) for surface river water. The groundwater sampling was carried out at 8 monitoring points (HG1-HG8).	n.a. (suspected: surface river water: 8; groundwater: 8)	LOD: 0.05 ng/L	100%	Mean values 2003-2005 in ng/l: HS1: 209.7 HS2: 223.6 HS8: 192.4 HS7: 214.8 Values 2003: HS2: 250 HS3: 580* HS4: 420* HS7: 620* HG2: 30* HG3: 1250* HG4: 1100* (*values are ca. values derived from graph)
NL, Flanders, EU	Verliefde et al., 2007, Environmental Pollution 146, 281-289	-	Paper offers an overview of priority organic micropollutants, among them BPA, and their occurrence in Flemish and Dutch water sources, i.e. groundwater and surface waters.	n.a.	n.a.	n.a.	Flanders: Surface water: 580 ng/l Netherlands: Surface water: 22000 ng/l Drinking water: <10 ng/l EU: 22000 ng/l
IT	Baderna et al., 2011, Environmental Research 111, 603–613	n.a.	Industrial waste landfill leachate: an industrial waste landfill in northern Italy for which data on the presence of leachate contaminants are available from the last 11years was investigated. Frequency of identification of BPA in 55 sampling campaigns conducted in 11 years amounted to 90.9%. Five campaigns were done yearly, one every 2 months exluding July and August.	n.a.	n.a.	90.9%	Bisphenol A was present at the concentration of 33.5mg/l
DE	Oehlmann et al., 2008, Environmental	-	A review and critical evaluation of the environmental risk assessment for plasticizers in	-	-	-	River Elbe: 9 - 776 ng/L in water,66 - 343 ↔g/kg

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
	Research 108, 140–149		the freshwater environment in Europe, with special emphasis on bisphenol A and endocrine disruption. Data prior to 2007, available in primary literature; please refer to publications Heemken et al., 2001; Stachel et al., 2003, Bolz et al., 2001. Not included in this table.				in sediments (Heemken et al., 2001). 3 years later: 4–92 ng/L in water, sediment 10–380 ↔g/kg (Stachel et al., 2003). In 5 other German streams: 272 ng/L (Bolz et al., 2001).
GR	Arditsoglou et al., 2008, Env. Sci. Pollut. Res. 15, 228-236	n.a.	Besides analytical studies field sampling in order to prove developed analytic methods was conducted for inland and marine waters in the area of Thessaloniki, Northern Greece. (seawater, river water, wastewater, total suspended solids (TSS) and marine sediments). Samples were collected from Thermaikos Gulf (seawater, TSS, sediments), Loudias River (water, TSS) and from a canal (water, TSS).	7	Water: DL=2.30 ng/l LOQ: 7.2 ng/l Sediment: DL=4.93 ng/g LOQ: 15.7 ng/g	100%	Thermaikos Gulf: Seawater: 15.1 ng/l TSS: 33.1 ng/g Sediment: 17.0 ng/g Loudias river: Water: 138 ng/l TSS: 56 ng/g Canal: Water: 380 ng/l TSS: 1450 ng/g
GR	Arditsoglou et al., 2010, Env. Sci. Pollut. Res. 17, 529-538	September 2005, March 2006	Investigation of the occurrence and distribution of BPA in inland waters (rivers and streams) and wastewaters (domestic and industrial) discharging in the area of Thermaikos Gulf, Thessaloniki, Northern Greece. Further, BPA was determined in water and total suspended solids (TSS). Samples were collected from various inland water types: the rivers Aliakmon (R1), Axios (R2) and Loudias (R3), 4 streams/canals (S1 and S2 located at the west and S3 and S4 at the east area of Thessaloniki), and 4 industrial and municipal wastewaters (W1: treated sewage effluents, W2: treated industrial effluents, W3: domestic effluents, and W4: tannery wastewaters) during two sampling campaigns (September 2005/March 2006).	24	n.a.	100%	Rivers (R1-R3): Water: 15-138 ng/l Particulate: 23-1784 ng/g dw Streams/canals (S1-S4): Water: 49-460 ng/l Particulate: 77-12243 ng/g dw Waste water (W1-W4): Water: 14-2358 ng/l Particulate: 14-429 ng/g dw
PT	Jonkers et al., 2010,	August 2006	An extensive sampling campaign was performed,	109 (total);	LOQ: 1 ng/l	n.a.	Values in ng/l

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
	Env. Sci. Pollut. Res. 17, 834-843		with marine surface water and wastewater grab samples taken at over 50 locations, in duplicate (one week difference) in Ria de Aveiro, which is a shallow coastal lagoon at the city Aveiro, Portugal. Samples included: — The submarine wastewater outfall: Marine water samples were taken near the outfall as well as near the inlet of the lagoon where part of the wastewater possibly reenters the lagoon; — The city of Aveiro: Samples were taken in five of the city's channels and the main entrance canal into the city. — The large harbours in the vicinity of Aveiro: Two fishing ports, the commercial and the chemical ports were sampled. — The rivers discharging into the lagoon: The 6 sources of freshwater into the lagoon were sampled, from north to south: Rio Caster, Rio Antuã, Rio Águeda (which flows into Rio Vouga), Rio Vouga, Rio Boco and the far end of the Mira channel. In addition, duplicate 24-h wastewater effluent samples were taken from the three wastewater treatment plants (WWTPs) in the study area: WWTP Cacia (ETAR Norte), WWTP Gafanha (ETAR Sul) and wastewater from a large pulp mill.	Lagoon: 28 Harbour: 10 Sea: 12 Sea near outfall: 20 City: 14 Rivers Agueda/Vouga: 12 Rivers Caster/Antua: 5 WWTP EF: 8			(range, median, average): Lagoon: <1.1-17, <1.1, 0.7 Harbour: <1.1, <1.1, <1.1 Sea: <1.1, <1.1, <1.1 Sea near outfall: <1.1-13.1, 0.7, 2.1 City: <1.1-18, 5.2, 6.5 Rivers Agueda/Vouga: <1.1-5.4, 0.4, 1.4 Rivers Caster/Antua: 23-683, 141, 212 WWTP EF: 120-461, 180, 216
GR	Stasinakis et al., 2011, Env. Sci. Pollut. Res. XX, XXX-XXX	May and June 2008	BPA levels were investigated in surface water samples taken at 4 sampling sites along the Greek river Aisonas (A-D), receiving municipal and industrial wastewater, and from the outlet (EF) of a STP (E), during 6 sampling campaigns.	River water: 24 (6 per site) EF: 6	LOD: 14 ng/l	100%	Values in ng/l: A (mean✣SD, range): 96✣18; 80-122 B: 82✣28, 55-114 C: 122✣29, 80-162 D: 94✣30, 61-135 E: 292✣279, 151-790
EU	EEA_Technical-	-	Please refer to Loos et al. 2009 and Loos et al.	-	-	-	-

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
	Report_Hazardous_substances_Europe_2011		2010. Both are included in this table.				
ES	Sánchez-Brunete et al., 2009, Journal of Chromatography A, 1216, 5497–5503	n.a.	Development of a analytical method to analyse BPA in soil samples collected from different locations in Spain. BPA was detected in all samples at concentrations from 0.7-4.6 ng/g in agricultural soils and from 1.1-44.5 ng/g in industrial soils. Surface soil (0–10 cm) was sampled from agricultural fields (horticultural and forested) located in different Spanish regions and from industrial soils in the area of Bilbao, an important industrial region.	Agricultural soils: 5 Industrial soils: 6	LOD: 0.03 ng/g LOQ: 0.12 ng/g	100%	Values in ng/g: Agricultural soils (horticultural and forest fields): 4.6✥0.32, 3.0✥0.07, 0.7✥0.06, 0.8✥0.06, 3.0✥0.22; Industrial soils (area of Bilbao): 10.2✥1.2, 1.6✥0.12, 0.2✥0.02, 1.1✥0.3, 44.5✥3.0, 10.1✥1.5
PT, DE, world wide	Sharma et al., 2009, Journal of Environmental Science and Health Part A 44, 423–442	n.a.	The paper reviews the occurrence, biodegradation, and photooxidation of bisphenol-A (BPA) in aquatic environment. Generally, the concentrations determined were 0.0005–4.0 ↔g/l in river waters worldwide. Data prior to 2007, available in primary literature; please refer to publications Azevedo et al. 2001, Kuch et al. 2001, Bolz et al. 2001, Stachel et al. 2003. Not included in this table.	-	-	-	River water: PT: 0.07-4.0 ↔g/l (Azevedo et al. 2001); DE: 0.0005-0.014 (Kuch et al. 2001); <0.05-0.272 (Bolz et al. 2001); 0.0038-0.030 (Stachel et al. 2003)
UK	García-Alonso et al., 2011, Marine Environmental Research 71, 295-303	May 2007	Biota, i.e. ragworms (Hediste diversicolor) and sediments were collected along the Humber Estuary, England, at 12 sampling sites covering 4 different zones (Kilnsea, close to estuary mouth: 1-3, Paull, urban/industrial zone: 4-6, Hessle, urban/industrial zone: 7-9, Blacktoft, at the confluence of River Ouse with the Humber: 10-12) and inorganic and organic contaminants were quantified. Samples were taken during the low tide in the upper intertidal zone during May 2007	24	n.a.	n.a.	BPA was detected at lower concentrations (highest value was 0.038 mg/g) and close or below the limit of detection in the other sampling locations. Please refer to the Supplementary Data available for purchase online at doi:10.1016/j.marenvres.2011.02.004.

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
ES	Puy-Azurmendi et al., 2010, Marine Environmental Research 69, 63–66	April 2007, October 2007, April 2008	Integrated study of endocrine disruptors in surface sediments and reproduction-related parameters in mussels/bivalve molluscs from the Biosphere's Reserve of Urdaibai (Bay of Biscay). Samples were collected at five localities (Mundaka, Txatxarramendi, Murueta, Arteaga, Laida) in April 2007, October 2007 and April 2008. Mussels were collected at the outer points of the estuary (Mundaka, Laida, Txatxarramendi), oysters were collected in Txatxarramendi and at the inner localities of Murueta and Arteaga when mussels were not found.	Sediment: 15 Mussels: at each site 30 mussels or oysters were collected	Sediment DL: 0.92 ng/g	Sediment: 67% (10/15)	Values in ng/g: Sediment: Mundaka (4/07, 10/07, 4/08): 43.0, bdl, bdl Txatxarramendi: 0.01, 0.03, 37.62 Murueta: 0.01, 0.02, bdl Arteaga: 0.01, 0.01, bdl Laida: 0.00, 0.01, bdl Concentrations not determined for mussels.
GR	Gatidou et al., 2010, Marine Pollution Bulletin 60, 2111–2116	September 2006	Biota samples from 3 different bivalve species (Modiola barbatus L. (bearded horse mussel), Mytilus galloprovincialis (Mediterranean mussel) and Venus gallina (stripped venus)) were collected. Sampling was performed during September, 2006 at Thermaikos Gulf and Lesvos Island (Greece).	18 (Mediterranean mussel: 7, Stripped venus: 4, Bearded horse mussel: 7):	LOD tissue: 115 ng/g dw	94% (17/18)	Values in ng/g dw: Mediterranean mussel: 611.9, 542.1, 527.6, 396.7, 387.2, 366.8, 342.8 Stripped venus: 626.3, 398.7, 298.1, <LOD Bearded horse mussel: 515.2, 506.3, 480.0, 441.2, 355.2, 212.6, 209.2 Average conc.: 404
ES	Martí et al., 2011, Marine Pollution Bulletin 62, 615–625	July 2008 to May 2009	Coastal waters and WWTP effluents (28 WWTPs) along the Comunidad Valenciana coastal waters (Spain) were investigated at 24 sampling sites representing different coastal zones (19: coastal water zones, 5: heavily modified coastal water zones, i.e. ports of Castellón, Sagunto, Valencia, Gandia, Denia, Alicante) with samples taken during 4 sampling campaigns (July 2008, November 2008, February 2009, May 2009).	Surface (coastal) water: 160 WWTP EF: 84	LOD: 0.5 mg/l	0%	BPA not detected
SE	Pettersson et al., 2007, Marine Pollution Bulletin 54,	October-November 2003	Investigation of Swedish coastal waters close to STP and pulp mill effluent discharge points along the Swedish Baltic Sea coast by the analysis of	19 (male: 6; female: 13)	LOQ: 0.03 ↔g/g bile	84% (16/19)	(valuesare ca. values derived from graph) average values in ↔g/g

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
	1868–1880		biota, i.e. bile fluid from perch (19 sites). BPA was detected in perch from both reference sites (8) and exposed sites (pulp mills: 7, STPs: 4), though not at every site perch could be collected (8). The sampling of bile fluid from perch were performed in two ways; either the fish were kept alive in tanks with recipient water for two days prior to sampling (A) or the fish were frozen directly after catch (B). BPA was detected in perch from all sites, even reference sites, except for one reference site, Skutskär SKUr, and one pulp mill recipient site, Skutskär SKU2.				from pooled samples (n=1-2): Range (male, A): 0.64-6.38 (4 values) Range (female, A): 0.38-3.8 (4 values) Range (male, B): 2.3-3.2 (2 values) Range (female, B): <LOQ-7.7 (9 values, 3<LOQ)
IT	Bicchi et al., 2009, Science of the Total Environment 407, 1842-1851	January-May 2007	Composite samples of the effluent (OUT) of a WWTP over 24 h were taken on 6 samplings (1-6) between January and May 2007 (16/01; 20/02; 06/03; 20/03; 11/04; 12/05). On the same dates, two grab samples of water were collected from the recipient river, 2 km upstream (US) and 2 km downstream (DS) of the WWTP.	18	n.a.	100%	Values in ng/l: 1 (US, OUT, DS): 88.0, 992.8, 26.8 2: 72.1, 71.2, 48.9 3: 22.5, 30.3, 21.2 4: 42.0, 6.2, 2.6 5: 3.7, 40.3, 6056.5 6: 3.6, 201.1, 186.0
ES	Calderón-Preciado et al., 2011, Science of the Total Environment 412-413, 14–19	Summer 2008 and summer 2009 (during the highest pollution impact)	Occurrence and potential crop uptake of emerging contaminants and related compounds in an agricultural irrigation network, 4 sampling points (P1-P4). This survey was carried out in the agricultural irrigation network of the municipalities of Sant Vicenç dels Horts, Santa Coloma de Cervelló, Sant Boi de Llobregat, El Prat de Llobregat, and Sant Joan Despí in the province of Barcelona in northeastern Spain. Field irrigation in this region is carried out through a series of interconnected open-air concrete distribution channels in which the water is supplied by surface waters (i.e. Llobregat River, Anoia River, and Rubí Creek). Llobregat River supplies the Santa Coloma channel (P2), the Upper channel (P1) and the Cal	8	LOD and LOQ ranged from 0.002 to 0.28 and from 0.003 to 0.47 ↔g/l, respectively (please refer to Calderón-Preciado et al. 2011)	50% (4/8)	Values indicate the mean and standard deviation concentrations in ↔g/l: P1: 0.024✣0.023 P2: 0.025✣0.029 P3: 0.042✣0.054 P4: 0.055✣0.073

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			Roc channel (P4), while Rubí Creek, which basically consists of treated wastewater, feeds the Infanta channel (P3).				
ES	Sánchez-Avila et al., 2009, Science of the Total Environment 407, 4157–4167	November 2007	The sampling network covered an industrial and urban area and wastewaters, influents and effluents of a WWTP were analyzed. Industrial (5 samplig sites), urban (2) and mixed wastewater (6) samples from the area of Maresme (Catalonia, Spain) were collected directly from sewers in 14 selected points of the sewage grid (1 groundwater sampling site; total 14 sites). For influents and effluents a total of 12 samples (each 6 samples) were taken (3 samples per day; 2 sampling days).	Influent: 6 Effluent: 6 WW: 13 Groundwater: 1	54 ng/l	100%	Values in ↔g/l: Groundwater: 0.78 Wastewater: Domestic: 5.37, 2.26 Mixed: 7.36, 3.91, 6.37, 1.32, 3.63, 4.13 Industrial: 2.29, 5.54, 11.1, 4.19, 1.92 Influent: 2.40✥0.7 Effluent: 0.62✥1.5
UK	Stuart et al., 2012, Science of the Total Environment 416, 1–21	-	This paper provides a review of the types of emerging organic groundwater contaminants (EGCs), among them BPA, which are beginning to be found in the UK. Please refer to Zhang et al. 2008, Musolff et al 2009 and Osenbrück et al. 2007. All 3 papers are included in this table.	-	-	-	Waste water (UK): please refer to Zhang et al. 2008 Groundwater: DE (Lepizig): -7000ng/l (Musolff et al. 2009) DE (Halle): range: <1-1136 ng/l (Osenbrück et al. 2007)
Bosnia and Herzegovina, Croatia, Serbia	Terzić et al., 2008, Science of the Total Environment 399, 66-77	Autumn 2004, Spring 2005	Occurrence and fate of emerging wastewater contaminants in Western Balkan Region (municipal and industrial WWs, in Bosnia and Herzegovina (6 sampling sites), Croatia (17) and Serbia (6); total: 29 sampling sites). 2 sampling campaigns in Croatia, 1 in Bosnia and Herzegovina as well as Serbia were conducted. The majority of samples from Bosnia and Serbia were untreated municipal and industrial wastewaters, while in Croatia,	40	LOD: 0.013 ↔g/l	55% (22/40)	Conc. range: <LOD-2.06 ↔g/l Mean value: 0.51 ↔g/l

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
			effluents from the existing wastewater treatment plants (WWTPs) were also collected. Only few WWTPs contained facilities for 24-hour flow-proportional composite sampling, while some other locations (Rijeka, Split, Varaždin) composite samples were prepared by mixing grab samples, taken over a diurnal cycle. For all other locations, only grab samples were available.				
DK, FI, NO, SE, Faroe Islands, Iceland	Hansen and Lassen, 2008	2006	samples were of three main types: water, solids and biota. Water samples included waste water (influents and effluents) from sewage treatment plants (STPs) and effluents from landfills; besides surface run-off and recipient water samples from both freshwater/brackish and marine environments were included. The solid samples also included several types: sewage sludge from STPs, soil from landfills and sediments from both marine and freshwater environments. Biological samples included mussels from marine environments, fish from both freshwater/brackish and marine environments, marine mammals (seal and pilot whales) and two egg samples from seabirds (black guillemots).	120	STP sludge: 0.4 ↔g/kg Landfill soil: 0.1 ↔g/kg Sediment (recipient env.): 0.1 ↔g/kg sediment (background): 0.1 ↔g/kg	n.a.	STP IN (ng/l): range: 204-9828 DK: 2138; FO: 232, (11016); FI: 9828, 7766; IS: n.a., 204; NO: 765, 1236 STP EF (ng/l): range: <1-561 DK: 8.5, 8.1, 58.8; FO: <1, 561; FI: 223, 200, 467; NO: 96.3, 96.9 Landfill EF/waste dumps (ng/l): range: 711-5910 FO: 711; FI: n.a.; IS: 5910 Recipient water (ng/l): range: <1-22.3 DK: <5, <2, 3.0; FO: <1, 22.3; FI: 10.9, 1.1, 4.0; IS: 15.4, 14.1; NO: 11.5, 3.9, 1.7 Surface runoff (ng/l): range: <1-2398 NO: <1, <1; SE: 1319, 1513, 2398, 1180, 14.5, 54.9, 17.0, 1.6, 2.4 background env. (ng/l): range: <1-10.8

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
							DK: 1.4, 4.8; NO: 8.7, <1, <1; SE: 5.4, 10.8 STP sludge (↔g/kg dw): range: <0.4-1914 DK: 271, 410; FO: <DL, 451; FI: <DL, 1914, 217; IS: n.a., 637; NO: 539, 41.3, 290, <DL; SE: 96.7, 444 Landfill soil (↔g/kg dw): range: <0.1-2.8 FO: 2.8, <DL Sediment (marine, (↔g/kg dw): range: <0.1-74 DK: <DL, 2.6; FO: <DL, <DL, 74.0; FI: 5.4, 39.7; NO: 0.3, <DL, <DL; SE: 11.8, 15.2, 11.8, 16.5 Sediment (background env./non-marine; ↔g/kg dw): range: <0.1-40 DK: 0.4; NO: 0.9, <DL; SE: 0.4, <DL, <DL fish (freshwater; ↔g/kg ww): range: <1-56.8 DK: n.a., <5; FI: n.a., n.a., 56.8, n.a., <1, <1; NO: 11, n.a. Fish (marine; ↔g/kg ww): IS: <10, n.a., n.a., n.a.; NO: n.a. mussels (↔g/kg ww): range: <1-3.3

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
							DK: <5, <5; FO: 3.3,<1, <1; NO: <5, <2.5 bird eggs (↔g/kg ww): FO: 6.0, 9.0
SE (Baltic)	Sternbeck et al. 2007, Screening of bisphenol A in fish from Swedish waters, report by WSP for Naturvårdsverket, Sweden	2000/2001, 2005	BPA was analysed in biota, i.e. fish from background lakes (perch: 4 sites), urban lakes (perch: 2 sites), marine/brackish background (herring: 2 sites; cod: 1 site), brackish coast (perch: 2 sites), urban background lakes (perch: 1 site), Lake Vänern (large lake with some industrial impact; perch: 1 site, salmon: 1 site) and the marine environment. There were no pronounced differences in concentrations between different species or when urban sites were compared to background sites.	23	0.24 ng/g fw	87% (20/23)	values in ng/g fw: background lakes: perch muscle: 2.14, 1.71, 3.01, 2.31 urban lakes: perch muscle: 1.30, 1.41 marine background: herring muscle: 3.27, 0.59 cod muscle: 2.33, 4.74, 2.20, 2.86, 1.44 cod liver: <0.24, 1.77, <0.24, 39.00, 1.20 brackish coast (Baltic coast): perch muscle: 1.51, 0.92 urban background lakes: perch muscle: 0.57 Lake Vänern (large lake with some industrial impact): perch muscle: 0.69 salmon muscle: <0.24 Ranges: range muscle: <0.24-4.74 range cod liver: <0.24-39.00
SE, EE, LV, LT, PL (Baltic)	Lilja et al., 2009, Screening of Selected Hazardous Substances in the Eastern Baltic	2008	Concentrations of BPA in surface water and biota, i.e. fish liver tissue from the eastern Baltic environment were investigated for herring, flounder and perch. Water samples from 9 sampling	Fish: 23 Herring: 10 Perch:5 Flounder: 8	LOQ 0.6 ng/g fw LOQ water: 14	Fish: 78% (18/23) Water: 0% (0/9)	Fish muscle in ng/g fw: total range: <0.6-3.9 Range - herring: <0.6-3.1; perch: <0.6-1.3; flounder:

Country	Author	Sample date(s)	Sample Description	No. of Samples	Minimum Det. Limit	Frequency Detection (%)	Summary Statistics
	Marine Environment, Report by the IVL (Swedish Environmental Research Institute) and NILU (Norwegian Institute for Air Research)		sites in Estonia, Latvia, Lithuania, Poland (p. 49) and fish samples from 11 sampling sites in Estonia, Latvia, Lithuania, Poland, Sweden (p-50) were collected (1-3 samples).	Water: 9	ng/l		<0.6-3.9 Water samples: <14 ng/l
EU	Loos et al., 2010, Water Research 44, 4115-4126	Autumn 2008	This study provides the first pan-European reconnaissance of the occurrence of polar organic persistent pollutants in European ground water. In total, 164 individual ground-water samples from 23 European Countries were collected and analysed (among others) for 59 selected organic compounds, also BPA.	164	LOD: 1 ng/l	40%	Values in ng/l: Max.: 2299 Average: 79 Median: 0 90th Perc.: 73
DE	Osenbrück et al., 2007, Water Research 41, 3259 – 3270	2002-2006	In this study, we used isotopic (d180, d2H, d34S-S04) and chemical tracers (boron) to assess the sources and transport processes of the micropollutants carbamazepine, galaxolide, and bisphenol A in groundwater underlying the city of Halle (Saale), Germany. Surface water samples for the analysis of PPCPs, EDCs, hydrochemistry, and stable isotopes were taken during 13 campaigns from 2002 to 2005 along the Saale River, from the STP outflow, and from a small brook. Additional samples for hydrochemical and isotopic analysis were taken at low flow conditions during 12 campaigns from 2005 to 2006 from the Saale sites S12 and S16 representing the in- and outflow to the urban centre of Halle (see Fig. 1). River water samples were taken as grab water samples from the middle of the river. Groundwater samples from the main aquifers were taken during two campaigns in 2004 and 2005, and more frequently at four sites (HaNeu1, HP8, Hy30, and Pb1) during 2005 and 2006	293	LOD: 0.001 ↔g/l LOQ: 0.010 ↔g/l	n.a.	Values in ↔g/l: Saale river: 0.089 STP effluent: 0.129 (samples collected 2002-2006) Main quaternary aquifer: 0.120, <0.001, 0.898, 1.136, 0.028, 1.110, 0.008, 0.003, 0.535, 0.274 Tertiary aquifer: 0.003, 0.498 Triassic and Permian aquifers: 0.037, 0.002, 0.610