SUBSPORT Specific Substances Alternatives Assessment – Bisphenol A

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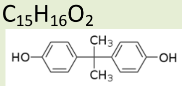
1 Profiling bisphenol A to be included in the Specific Section of the Case Story Database

Bisphenol A (BPA) is used mainly in the manufacture of plastics and paints, coatings and adhesives. BPA is today one of most common used industrial chemicals. BPA is found in most food packaging, plastic bottles, plastic containers, on receipts and in children's toys, as well as in many other everyday products. BPA pollutes our environment and almost every human is exposed to BPA, which is an endocrine disruptor and sentisizer and is suspected to be neurotoxic.

1.1 Chemical identity

BPA is manufactured from phenol and acetone in the presence of an acid catalyst such as hydrogen chloride. It belongs to the group of aromatic carbon compounds with two phenol rings. The 2-dimensional structure and other general information on BPA are shown in table 1.

Table 1: General information on BPA

Chemical name (IUPAC)	Chemical formula	Identification number	Common names	Function/ uses
4,4'-propane-2,2-diyldiphenol	$C_{15}H_{16}O_2$ 	CAS 80-05-7, EC 201-245-8	Bisphenol A, 4,4'-isopropylidenediphenol, 2,2-bis(4-hydroxyphenyl)propane, BPA, Diphenylol propane, DPP	antioxidant, plasticizer, intermediate, flame retardant, pesticide, process regulator, paints, adhesive, softener, construction material, stabilizer, lubricant, additive, surface treatment, filler, antistatic agent, viscosity adjustor, insulating material, hydraulic fluid, corrosion inhibitor, hardener, jointless floor, curing agent, casting material, brake grease, primer, stopping material, catalyst, paper additive

IUPAC: International Union of Pure and Applied Chemistry
CAS: Chemical Abstracts Service Registry Number
EC: European Commission number

1.2 Hazard characteristics

Characterising BPA based on its inherent hazards is an essential component of conducting an alternatives assessment. This approach allows the reviewer to assess whether or not an alternative is indeed preferable from an environmental, health and safety perspective. The hazard properties are intrinsic to the chemical, which means that regardless of the way that a chemical is used, these characteristics do not change. The goal of the substitution processes is to advance inherently safer chemicals and products, consistent with the principles of green chemistry.

Sources that have been checked for hazard characterisation:
1. SUBSPORT Hazardous Substance Database according to SUBSPORT Screening Criteria (SDSC) including:
- CLP Regulation (CMR 1A or 1B)
- IARC (group 1, 2A or 2B carcinogens)
- CLP Regulation (Sensitiser: H317, H334)
- EC PBT Working Group
- OSPAR List of Substances of Possible Concern (PBT)

- EC Endocrine Disruptors Database
- SIN List (endocrine disruptors)
- Vela et al. (neurotoxins, cat 2-4)

2. The ESIS (European chemical Substances Information System), http://esis.jrc.ec.europa.eu/
3. TOXNET/ HSDB (Hazardous Substances Data Bank), http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

For green house gases and ozone depleting substances:
4. Greenhouse gases- Kyoto protocol- Annex A, as presented in IPCC (intergovernmental panel on climate change)
5. Ozone Depleting Substances List (Montreal Protocol)

6. Additional sources have been checked for information, especially for endpoints where no information is available in the previous mentioned sources, and also for getting the most up-to-date information. These sources include:

- REACH registration dossiers, http://apps.echa.europa.eu/registered/registered-sub.aspx
- C&L Inventory database, http://echa.europa.eu/de/information-on-chemicals/cl-inventory-database
- Ordinary Google search
- Producer information; MSDS

Table 2: Hazard characteristics of BPA

	Properties	Source
Physical Hazards		
Explosivity	Bisphenol A dust was classified in the explosion class 3	REACH registration dossier
Flammability	No	REACH registration dossier
Oxidizing	Strong oxidizers	HSDB
Other properties of reactivity	Substance thermally stable Strong base	REACH registration dossier HSDB
Human Health Hazards		
Acute toxicity		
Highly toxic	No data	
Skin or eye corrosion / irritation	H318: Causes serious eye damage H335: May cause respiratory irritation R37: Irritating to respiratory system R41: Risk of serious damage to eyes	ESIS
Chronic toxicity		
Carcinogenicity	No data	
Mutagenicity	No data	
Reproductive toxicity (including developmental toxicity)	H361f: Suspected of damaging fertility R62: Possible risk of impaired fertility; Repr. Cat. 3	ESIS
Endocrine disruption	Endocrine disruptor Endocrine disruptor cat. 1	SIN list EC Endocrine Disruptors Database
Respiratory or skin sensitization	H317: May cause an allergic skin reaction R43: May cause sensitization by skin contact H334: May cause allergy or asthma symptoms or breathing difficulties if inhaled	ESIS CLP Regulation
Neurotoxicity	Exposure to BPA during development may affect brain organization and behavior, perhaps as a consequence of its actions as a steroid hormone agonist/antagonist and/or an epigenetic modifier	HSDB
Immune system toxicity	BPA enhances immune responsiveness of the uterus and that heightened responsiveness in females is related to increased susceptibility to pyometra	HSDB
Systemic Toxicity	Higher urinary BPA concentrations were cross-sectionally associated with heart disease, coronary artery disease	HSDB
Toxic metabolites	No data	

	Properties	Source
Environmental Hazards		
Acute/chronic aquatic toxicity	R52: Harmful to aquatic organisms	ESIS
Bioaccumulation	Short environmental half-lives in surface waters and soils	HSDB
Persistence	Microorganism can easily degrade BPA in water	EC (2010)
Greenhouse gas formation potential	Not listed	Kyoto protocol - Annex A
Ozone-depletion potential	Not listed	Montreal Protocol
Monitoring – has the substance been found in human or environmental samples?	Detected in human and animals body	HSDB

2 Identify functions and uses

2.1 BPA uses

A key first step in identifying appropriate alternatives is to determine the functions, uses and processes associated with BPA.

Following ECHA (European Chemicals Agency) BPA has been registered according to REACH, in the tonnage band more than 1,000,000 tonnes per annum. Registered uses are:

- Use as laboratory reagent
- Anti-oxidant for processing PVC
- Manufacturing epoxy resin hardeners
- Use in epoxy resin hardeners
- Manufacturing thermal paper
- Manufacturing polycarbonate
- Manufacturing epoxy resins
- Manufacturing polymers
- Manufacturing coating materials
- Manufacturing chemicals
- Use as intermediate in the manufacture of chemicals
- Use in epoxy adhesives and encapsulants

2.2 Prioritizing uses

Global production capacity for BPA was 5.2 million metric tonnes in 2008 (ICIS, 2008). According to ICIS Chemical Business the European BPA capacity amounts to 1,375,000 tons/ year in 2011 (ICIS, 2011).

Figure 1 shows major uses of BPA in 2005/ 2006 in Europe. The largest share is further processed to **polycarbonates** and amounts to 80%. Typical articles made of polycarbonates are: safety glass (glassy polymers); parts for plugs and switches; housings of electrical/ electronic devices and equipment (for example, mobile telephones, water boilers, coffee machines and computers); optical storage media, such as CDs, DVDs and Blu-ray discs; car parts (transparent plastic parts), such as reflectors; bottles and containers for food and drinks; spectacle glasses; microwave-proof crockery, plastic cutlery and cooking utensils; motorcycle helmets and shields; medical equipment. 18% of BPA is produced for the manufacture of **epoxy resins**, which are used for floorings; varnishes (as coatings for household appliances and equipment); beverage cans and food cans; printed circuit boards in electronic products; composite materials (e.g. for tennis rackets and surfboards); adhesives; inner coatings for decontamination of drinking water containers and wastewater tanks and pipes. **Other applications** (2% of BPA production) include: thermal paper; electrical and electronic products (treatment of envelopment materials or electronic components with TBBPA as flame retardant); brake fluids; rubber and PVC products, such as high-temperature cables (as a stabilizer); dental fillings and sealing materials, braces and prostheses.

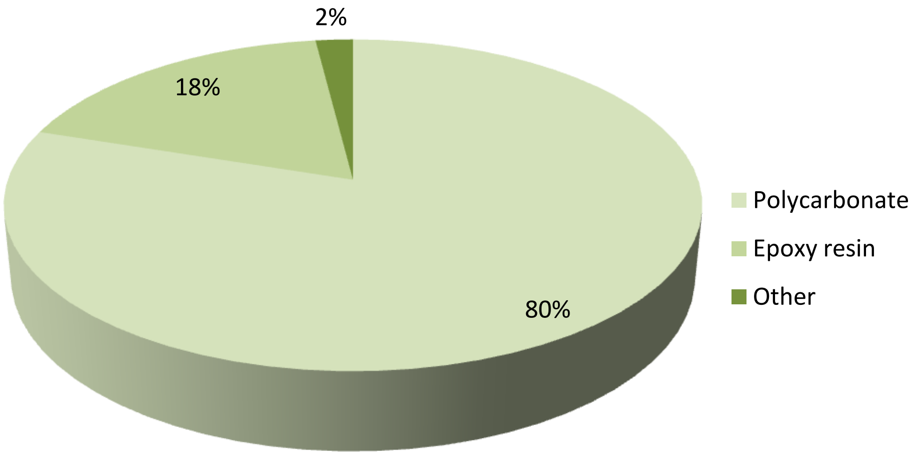


Figure 1: BPA use in Europe in 2005/ 2006 (EC, 2008a)

For this report, alternatives for the following BPA uses will be identified and screened:

- Bottles and containers for foods and drinks
- Beverage and food can liners
- Thermal paper (e.g. fax paper, cash register receipts)

The main focus will be the use of BPA containing bottles and containers for foods and drinks. There are two main reasons for this:

- Many humans are exposed to BPA from plastic products , given its widespread distribution
- Consumers who are concerned might be able to reduce their dietary exposure to BPA

2.3 Exposure to BPA

BPA is used primarily to make polymers that are subsequently used to produce industrial and consumer products. It is not distributed for consumer use.

Workplace exposure - Exposure can occur either in a BPA manufacturing facility or in various industrial and manufacturing facilities that use this chemical. Workers could potentially be exposed to BPA during maintenance, sampling, testing, transfer or other procedures. Each manufacturing, industrial, and service facility should have appropriate work processes and safety equipment policies in place to limit BPA exposure.

Consumer exposure - Human exposure occurs primarily through contaminated food and beverages but also through skin absorption, e.g. by contact with sales slips of thermal paper. Contaminated air, dust and water can add to consumer exposure. BPA can leach into food from the protective internal epoxy resin coatings of canned foods and from consumer products such as polycarbonate tableware, food storage containers, water bottles, and baby bottles. The degree to which BPA leaches from polycarbonate bottles into liquids may depend on the temperature of the liquid or bottle, heating duration and water hardness as well as on the detergents used by washing. Results from studies carried out by the German Federal Environment Agency (UBA, 2010) show that BPA concentrations from drinking water from technical storage systems and devices for the distribution of drinking water that are coated with epoxy resin for corrosion protection amounts to 30 µg/L where excessive heating (> 70°C) occurred in coated hot-water pipes. Other studies assess the average daily intake of adults and children at between 0.03 and 0.07 micrograms per kilogram body weight and day (µg/kg bw/day) and the highest daily intake by German children was identified as 7 µg/kg bw/day (Becker at al., 2009). A Japanese study from 2003 found that the levels of BPA in urine of tested persons dropped by 50% after the can linings change was made in 1997 (ConsumerReport.org, 2009).

Consumers who are concerned might be able to reduce their exposure to BPA by taking the following steps:

- Consider alternatives to canned food, beverages, juices, and infant formula
- Minimize the use of canned foods and canned drinks
- Use glass containers when heating food in microwave ovens
- Follow product labeling
- Discard old or damaged bottles
- Avoid polycarbonate plastic food containers. These may be labeled ‘PC’ underneath a plastic code 7 in the recycling triangle (see Figure 2)
- Use BPA-free dental resins sealants and composite fillings
- Choose fresh food whenever possible

7
OTHER

Figure 2: Logo, plastic resin code 7

More information on this topic can be found in consumer reports:

- ConsumerReports.org, http://www.consumerreports.org/cro/2012/05/concern-over-canned-foods/index.htm
- Alliance for a Clean and Healthy Meaine, http://www.cleanandhealthyme.org/BodyofEvidenceReport/TheChemicals/BisphenolAHormoneDisrupter/tabid/99/Default.aspx

Environmental release – In general, BPA mainly enters the environment through wastewater. Small amounts of BPA may be released from wastewater-treatment plants and BPA production and processing plants into environment. Once released, BPA residues can remain in sewage sludge. If this sludge is used for farmland fertilization, as is the case in some European countries, BPA can enter into the soil. Microorganisms can degrade BPA in water under aerobic conditions. Laboratory tests show that BPA is degraded almost completely within 2 – 17 days (EC, 2010). This means BPA it is not expected to be persistent in the environment. However, it is harmful to aquatic organisms (UBA, 2010).

3 Legal issue

How dangerous BPA can be for human health is presently a matter of debate. While some scientists are very concerned, others play down the issue.

The European Union Risk Assessment Report on BPA from 2008, published by the European Commission and European Food Safety Authority (EFSA), concluded that BPA-based products, such as polycarbonate plastics and epoxy resins, are safe for consumers and the environment when used as intended. The current Tolerable Daily Intake (TDI) level for BPA amounts to 0.05 mg/kg bodyweight.

EU Regulation No. 10/2011 determines the limit values on plastic materials and articles intended to come into contact with food. According to this regulation, the maximum permissible quantity of BPA that may migrate from plastic packaging into food, the Specific Migration Level (SML), amounts to 0.6 milligrams per kilogram of food. The SML is based on a daily intake of 0.01 milligrams of BPA per kg of body weight during life without appreciable health risks. This value was derived by the Scientific Committee on Food (SCF) in 2002.

The EU (2010), Canada, China, South Africa and Malaysia have already banned BPA in baby bottles. In addition, ten US states have barred BPA from children's products or infant formula cans, and the French National Assembly (lower house of the bicameral Parliament of France) will impose a use restriction on all BPA-based food contact packaging in France. The ban will come into effect on 1 January 2015.

In Japan, most major manufacturers voluntarily changed their can linings in 1997 to cut or eliminate the use of BPA because of concerns about health effects.

Furthermore, consumers unions, a nonprofit publisher of consumer reports, proclaims that manufacturers and government agencies should act to eliminate the use of BPA in all materials that come into contact with food.

4 Preliminary identification of alternatives

4.1 Use in bottles and containers for foods and drinks

Possible alternatives to bottles and containers containing BPA are shown in table 3. Some alternatives available on the market are materials that have been used safely for many years like glass and stainless steel. Glass baby bottles and stainless steel water bottles are known as reusable and environmentally friendly alternatives.

Table 3: Alternatives for BPA in bottles and containers

Alternative	Description	Source
Glass	baby bottles	Oregon Environmental Council, 2013; Det Økologiske Råd, 2013
Stainless steel	baby bottles	Oregon Environmental Council, 2013; Det Økologiske Råd, 2013
Tritan Copolyester™	baby bottles; reusable bottles; plastic dishware; sports bottles; bulk water bottles	SUBSPORT, Oregon Environmental Council, 2013; Det Økologiske Råd, 2013

Alternative	Description	Source
Polypropylene (PP)	reusable food storage containers; baby bottles; food packaging; plastic parts; laboratory equipment	Oregon Environmental Council, 2013; Det Økologiske Råd, 2013; BfR, 2013
Polyethylene Terephthalate (PET)	water and beverages bottles for one-time use; single-use containers	Coca-Cola Company; Oregon Environmental Council, 2013; Det Økologiske Råd, 2013;
Polyamide	drinking containers, tins and screw caps	SUBSPORT; Det Økologiske Råd, 2013
Polyethersulfone (PES)	baby bottles	BfR, 2013
Polystyrene (PS)	baby bottles; food service packaging (cups, plates, bowls, trays, yogurt)	http://www.maine.gov/dep/safechem/documents/AAR-Report-December2012.pdf
Polyphenylsulfone (PPS)	baby bottles	http://www.safemilk.org/learn/factsheets/bpainfood/
Polyethylene (PE)	containers; gallon milk jugs; various bottles	http://www.maine.gov/dep/safechem/documents/AAR-Report-December2012.pdf

4.2 Use in beverage and food can liners

BPA is found in epoxy resins which are also used in internal linings of food and beverage cans. BPA is a contaminant resulting from the manufacturing process. Coating is necessary to prevent corrosion of the tin and release of metals which would cause contamination of the food as well as discolouration and impairment of the flavour (LaKind, 2013). Several can coating resin types are commercially available, including oleo-resinous compounds (natural oil-based coatings derived from fossil gums) and synthetic resins (acrylic, epoxy, phenolic, polyester and vinyl resins).

Eden Organics, for example, switched to BPA-free liners in 1999. They use oleoresin, a mixture of oil and resin extracted from plants such as pine or balsam fir. The cost of avoiding BPA containing food cans was a 14% premium and continues to increase (Eden Foods, 2013). There are also other food manufactures that have made the transition to BPA-free cans: Native Forest, Trader Joe's, Vital Choice, Oregon's Choice, Eco Fish and Wild Planet.

Table 4: Alternatives for BPA in beverage and food can liners

Alternative	Description	Source
Oleoresin	metal cans of food; low-acid canned foods	Eden Foods, 2013; Det Økologiske Råd, 2011; LaKind, 2013
Acrylic resin	metal cans of food	LaKind, 2013; http://cen.acs.org/articles/91/i6/Clear-Winner-Race-Find-Non.html
Phenolic resin	metal cans of food	LaKind, 2013; http://cen.acs.org/articles/91/i6/Clear-Winner-Race-Find-Non.html
Polyester resin	metal cans of food	LaKind, 2013; http://cen.acs.org/articles/91/i6/Clear-Winner-Race-Find-Non.html

Alternative	Description	Source
Vinyl resin	metal cans of food	LaKind, 2013; http://cen.acs.org/articles/91/i6/Clear-Winner-Race-Find-Non.html
Epoxy resin	metal cans of food	www.aafcs.org/res/policy/BPA.ppt
Isosorbide	metal cans of food	Det Økologiske Råd, 2011
2,2,4,4-tetramethyl-1,3-cyclobutanediol (TMCD)	metal cans of food, beverages and infant formulas	http://www.uml.edu/News/stories/2013/BPA-substitute.aspx
4-[2-(4-hydroxycyclohexyl)propan-2-yl]cyclohexan-1-ol (HBPA)	can liners	Seattle Polymer LLC
Provalin	can liners	Actega DS; Pano Verschluss GmbH
DAREX Polyester	low-acid canned foods	http://www.calwic.org/storage/documents/state/2010/bpa_alternatives.pdf
Polyethylene Terephthalate	can liners	http://www.calwic.org/storage/documents/state/2010/bpa_alternatives.pdf
Tetra Pak	components: 70% paper, 24% Low dencity polyethylene, 6% aluminum foil; can be used for highly acidic foods	http://www.calwic.org/storage/documents/state/2010/bpa_alternatives.pdf

4.3 Use in thermal papers

BPA is widely used as a developer in thermal paper because it is efficacious, available and affordable (Mendum et al., 2011). Thermal paper is used for thermal printing systems which are integrated in cash registers, ticket offices, parking meters as well as printers for receipts and bank statements. There the substance is used as colour former. According to tests done by various laboratories, thermal papers contain free BPA which is not bound in the material and which therefore can easily be released (BfR, 2013). Information about potential substitutes for BPA can also be found at the US EPA website[1].

Table 5: Alternatives for BPA in thermal paper

Alternative	Description	Source
Methyl bis(4-hydroxyphenyl)acetate (MBHA)	developer in thermal paper	http://healthandenvironmentonline.com/2012/08/06/just-the-ticket-alternatives-to-bpa-in-receipt-paper/
4,4'-(1-Phenylethylidene)bisphenol (BPAP)	developer in thermal paper	http://healthandenvironmentonline.com/2012/08/06/just-the-ticket-alternatives-to-bpa-in-receipt-paper/

[1] http://www.epa.gov/dfe/pubs/projects/bpa/index.htm

Alternative	Description	Source
4-hydroxyphenyl sulfone (sometimes called (BPS)	developer in thermal paper	Appleton, http://www.appletonideas.com/Appleton/jsps/pdf/thermal/BPA_Statement.pdf
bis-(3-allyl-4-hydroxyphenyl) sulfone (TGSA)	developer in thermal paper	http://healthandenvironmentonline.com/2012/08/06/just-the-ticket-alternatives-to-bpa-in-receipt-paper/
Phenol,4-[[4-(2-propen-1-yloxy)phenyl]sulfonyl]- (BPS-MPE)	developer in thermal paper	http://healthandenvironmentonline.com/2012/08/06/just-the-ticket-alternatives-to-bpa-in-receipt-paper/
4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl]phenol (D-90)	developer in thermal paper	http://healthandenvironmentonline.com/2012/08/06/just-the-ticket-alternatives-to-bpa-in-receipt-paper/
N-(p-Toluenesulfonyl)-N'-(3-p-toluenesulfonyloxyphenyl)urea (Pergafast 201)	color developer in most grades of thermal paper	SUBSPORT, http://www.subsport.eu/case-stories/164-en; BASF, http://live.rig2012.aperto.de/70490/2011-06-27-basf,sourcePageId=66940.html
Urea Urethane Compound (UU)	developer in thermal paper	http://healthandenvironmentonline.com/2012/08/06/just-the-ticket-alternatives-to-bpa-in-receipt-paper/

5 Screening out regrettable substitutes

The purpose of this chapter is to eliminate any alternatives that would pose a high risk to the environment or human health. SUBSPORT developed a database containing substances that are not acceptable as alternatives due to their hazards (http://www.subsport.eu/listoflists?listid=31). Alternatives are all screened against this database. If a substance meets any of the SUBSPORT screening criteria, it is removed from further consideration as an appropriate alternative, unless SUBSPORT regards the alternative safer under certain conditions than the original substance.

5.1 Screening of alternatives to BPA-containing bottles and food containers

The alternatives that are not listed on the SDSC are:

- Polypropylene
- Polyethylene
- Polyethylene Terephthalate
- Polystyrene
- Glass

Table 6: Screening of alternative bottles and containers for food and drinks*

Alternative	SDSC	Comments	Source
Glass CAS 65997-17-3	No	Glass products do not present health hazard. However, operations such as manufacturing may present hazards. H350	MSDS REACH registration dossiers
Polypropylene (PP) CAS 9003-07-0	No	-	
Polyethylene CAS 9002-88-4	No	H412	C&L Inventory database
Polyethylene Terephthalate (PET) CAS 25038-59-9	No	Monomers: CAS 100-21-0 and 107-21-1. PET bottles enter with time in low doses antimony into liquid.	Shotyk et al. (2006)
Polystyrene CAS 9003-53-6	No	Monomer: styrene CAS 100-42-5	
Polyphenylsulfone (Radel® R-5500 and R-5000 Series; components: CAS 1333-86-4 and 13463-67-7)	Yes	Components are listed as carcinogen group 2B. H319, H335, H351, H372, H413	IARC C&L Inventory database
Stainless Steel	Could not be checked	-	
Tritan copolyester™	Could not be checked	Monomers: CAS 120-61-6, 105-08-8 and 3010-96-6.	
Polyamide	Could not be checked	-	
Polyethersulfone	Could not be checked	-	

*Some monomers or precursor materials that are used for the production of alternatives can be listed on SDSC as carcinigen or endocrine disruptor. Workers may be exposed to them in the manufacturing process.

The alternatives that can no longer be considered in this study are stainless steel, polyamide, polyethersulfone and Tritan copolyester™ because the identification numbers (CAS, EC, INDEX) of ingredients are not available and a hazard assessment could not be done. Polyphenylsulfone is screened out because of its hazardous properties, which are listed on the SDSC.

5.2 Screening of alternative beverage and food can liners

Oleoresin, acrylic resin, polyester resin, vinyl resin, epoxy resin, Provalin, DAREX Polyester and Tetra Pak can be possible alternatives to BPA in beverage and food can coatings but the identification numbers (CAS, EC, INDEX) are not available, a hazard assessment could not be done. These alternatives are not further considered in this study.
The alternatives that are not listed on the SDSC are:

- Isosorbide
- 2,2,4,4-tetramethyl-1,3-cyclobutanediol
- 4-[2-(4-hydroxycyclohexyl)propan-2-yl]cyclohexan-1-ol
- Polyethylene Terephthalate

Table 7: Screening of alternative beverage and can liners*

Alternative	SDSC	Comments	Source
Isosorbide CAS 652-67-5	No	-	
2,2,4,4-tetramethyl-1,3-cyclobutanediol (TMCD) CAS 3010-96-6	No	H302	REACH registration dossiers
4-[2-(4-hydroxycyclohexyl)propan-2-yl]cyclohexan-1-ol (HBPA) CAS 80-04-6	No	H412	REACH registration dossiers
Polyethylene Terephthalate (PET) CAS 25038-59-9	No	Monomers: CAS 100-21-0 and 107-21-1	
Oleoresin	Could not be checked	Monomer tall oil CAS 8002-26-4	
Acrylic resin	Could not be checked	Possible monomers: CAS 96-33-3, 80-62-6 and 79-10-7	
Phenolic resin	Could not be checked	-	
Polyester resin	Could not be checked	Possible monomer CAS 100-21-0	
Vinyl resin	Could not be checked	Monomer CAS 75-01-4	
Epoxy resin	Could not be checked	Possible monomer CAS 106-89-8	
Provalin	Could not be checked	-	
DAREX Polyester	Could not be checked	-	
Tetra Pak	Could not be checked	-	

*Some monomers that are used for the production of alternatives can be listed on SDSC as carcinogen, endocrine disruptor or sensitizer. Workers may be exposed to them in the manufacturing process.

5.3 Screening of alternatives for BPA in thermal papiers

TGSA cannot be recommended because of its hazardous properties, according to SDSC.

Table 8: Screening of alternatives for BPA in thermal paper

Alternative	SDSC	Comments	Source
Methyl bis(4-hydroxyphenyl)acetate (MBHA) CAS 5129-00-0	No	-	
4,4'-(1-Phenylethylidene)bisphenol (BPAP) CAS 1571-75-1	No	H400, H410 H319	ESIS C&L Inventory database
4-hydroxyphenyl sulfone (BPS) CAS 80-09-1	No	H319, H412	C&L Inventory database
bis-(3-allyl-4-hydroxyphenyl) sulfone (TGSA) CAS 41481-66-7	Yes	Listed on SDSC as sensitizer. H317, H411	CLP Regulation No 1272/2008 ESIS
Phenol,4-[[4-(2-propen-1-yloxy)phenyl]sulfonyl]- (BPS-MPE) CAS 63134-33-8	No	-	
4-[4'-[(1'-methylethyloxy) phenyl]sulfonyl] phenol (D-90) CAS 191680-83-8	No	-	
N-(p-Toluenesulfonyl) -N'- (3-p-toluenesulfonyloxyphenyl)urea (Pergafast 201) CAS 232938-43-1	No	H411	ESIS
Urea Urethane Compound (UU) CAS 32186-75-7	No	-	

6 Characterizing alternatives for BPA-containing polycarbonate plastic containers for food and drinks

BPA is one of the most important commercial chemical substances and the manufacture of polycarbonate plastics is its most important use. The use of BPA has been severely criticised based on human health and environmental concerns. There are readily available alternatives for polycarbonate plastics containing BPA on the market.

6.1 Hazard characteristics of alternatives

The hazard characterisation of the alternatives is performed according to the same methodology as described for the hazard characterisation of BPA.

Tables 9-11 present the hazard characteristics of alternative bottles and containers.

Table 9: Hazard characteristic of polyethylene

	Properties	Source
	Physical Hazards	
Explosivity	Conclusive but not sufficient for classification	C&L Inventory database
Flammability	Conclusive but not sufficient for classification	C&L Inventory database
Oxidizing	Conclusive but not sufficient for classification	C&L Inventory database
Other properties of reactivity	No data	
	Human Health Hazards	
Acute toxicity	Conclusive but not sufficient for classification	C&L Inventory database
Skin or eye corrosion / irritation	Conclusive but not sufficient for classification	C&L Inventory database
Carcinogenicity	Not listed	IARC
Mutagenicity	Data lacking	C&L Inventory database
Reproductive toxicity (including developmental toxicity)	Data lacking	C&L Inventory database
Endocrine disruption	Not listed	EC endocrine disruptor database
Respiratory or skin sensitization	Conclusive but not sufficient for classification	C&L Inventory database
Neurotoxicity	Not listed	Vela et al. (2003)
Immune system toxicity	No data	
Systemic Toxicity	No data	
Toxic metabolites	No data	
	Environmental hazards	
Acute/chronic aquatic toxicity	H412: Harmful to aquatic life with long lasting effects	C&L Inventory database
Bioaccumulation	No data	
Persistence	No data	
Greenhouse gas formation potential	Not listed	Kyoto protocol- Annex A
Ozone-depletion potential	Not listed	Ozone Depleting Substances List (Montreal Protocol)
Monitoring – has the substance been found in human or environmental samples?	No data	

Table 10: Hazard characteristic of polypropylene

	Properties	Source
Physical Hazards		
Explosivity	Data lacking	C&L Inventory database
Flammability	H228: Flammable solid	C&L Inventory database
Oxidizing	Data lacking	C&L Inventory database
Other properties of reactivity	No data	
Human Health Hazards		
Acute toxicity	Data lacking	C&L Inventory database
Skin or eye corrosion / irritation	Data lacking	C&L Inventory database
Carcinogenicity	Not listed	IARC
Mutagenicity	Data lacking	
Reproductive toxicity (including developmental toxicity)	Data lacking	C&L Inventory database
Endocrine disruption	Not listed	EC endocrine disruptor database
Respiratory or skin sensitization	Data lacking	C&L Inventory database
Neurotoxicity	Not listed	Vela et al. (2003)
Immune system toxicity	No data	
Systemic Toxicity	No data	
Toxic metabolites	No	HSDB
Environmental hazards		
Acute/chronic aquatic toxicity	No data	
Bioaccumulation	No data	
Persistence	No data	
Greenhouse gas formation potential	Not listed	Kyoto protocol- Annex A
Ozone-depletion potential	Not listed	Ozone Depleting Substances List (Montreal Protocol)
Monitoring – has the substance been found in human or environmental samples?	No data	

Table 11: Hazard characteristic of polyethylene terephthalate

	Properties	Source
	Physical Hazards	
Explosivity	No data	
Flammability	No data	
Oxidizing	No data	
Other properties of reactivity	No data	
	Human Health Hazards	
Acute toxicity	No	HSDB
Skin or eye corrosion / irritation	Patch tests with humans resulted in no skin irritation. Decomposition products caused by overheating PET may cause skin, eye or respiratory tract irritation	HSDB
Carcinogenicity	Not listed	IARC
Mutagenicity	No data	
Reproductive toxicity (including developmental toxicity)	No data	
Endocrine disruption	Not listed	EC endocrine disruptor database
Respiratory or skin sensitization	No data	
Neurotoxicity	Not listed	Vela et al. (2003)
Immune system toxicity	No data	
Systemic Toxicity	No data	
Toxic metabolites	No data	
	Environmental hazards	
Acute/chronic aquatic toxicity	No	HSDB
Bioaccumulation	No data	
Persistence	No data	
Greenhouse gas formation potential	Not listed	Kyoto protocol- Annex A
Ozone-depletion potential	Not listed	Ozone Depleting Substances List (Montreal Protocol)
Monitoring – has the substance been found in human or environmental samples?	No data	

PE, PET and PP are unreactive and stable. PP is flammable. There are no health implications associated with use of all these polymers as a food packaging alternative and the compounds' widespread use.

Some monomers that are used for the production of alternatives can be listed on SDSC. Workers, however, may be exposed to them in the manufacturing.

6.2 Technical and economic aspects of substitution of BPA-containing polycarbonate

Polyethylene

PE products are an alternative for infant formula packages , which can be easily recycled and reused. An advantage of PE products are low production costs and ease of processing to form a variety of containers. PE is a good selection for thermoplastics requiring moisture resistance. It has good food preservation capacity. However, PE coatings are not approved for use with acidic foods (Kline and Ruhter, 2012).

Polyethylene terephthalate

PET is a common material used for disposable bottles and is regarded a cost-competitive alternative for lightweight and large-capacity containers and shatter-resistant containers.
PET bottles with carbonated drinks release over time low doses of acetaldehyde and antimony (both potential carcinogens) into liquid (Schmutterer, 2010). Following the German Federal Institute for Risk Assessment (BfR), the dose of acetaldehyde and of antimony in PET bottles is harmless because of the small amount. Antimony trioxide is used as catalyst in PET production. According to another study, antimony trioxide could be released during recycling or incineration (CPA, 2012).

Polypropylene

PP products are readily available in the marketplace, made by various manufacturers. An advantage of PP products is that they are economical and relatively inexpensive to manufacture. PP products are more rigid than PE plastics and have a high melting point. They have a higher temperature limit to maintain form and function than PE. PP has proved versatile due to its impact strength, resistance to repetitive stress, chemical resistance, and ease of use/processability. A disadvantage of PP products is durability when subjected to low temperatures for prolonged periods, which lowers their impact strength (Kline and Ruhter, 2012). PP products are regarded as having a long shelf-life, including effective protection against light and heat, transmission of gases (including humidity), mechanical stresses, and contamination by e. g. micro-organisms. PP containers are recyclable but they are not biodegradable.

The following table presents the technical and economical comparison of feasible alternatives to BPA-containing bottles and containers.

Table 12: Technical and economical comparison of feasible alternatives

Product	Use	Cost	Performance	Use pattern	Avaliability
Polyethylene	Bottles and containers for food and drinks	Comparable material costs	Technically viable alternative	Similar to BPA products	Commercially available
Polyethylene terephthalate	Bottles and containers for food and drinks	Comparable material costs	Technically viable alternative	Similar to BPA products	Commercially available
Polypropylene	Bottles and containers for food and drinks	Comparable material costs	Technically viable alternative	Similar to BPA products	Commercially available

7 Comparing alternatives

There are many alternatives to plastic products containing BPA available for use as bottles and containers for foods and drinks. Therefore, SUBSPORT conducted an assessment to determine those alternatives that are most feasible and/ or that are representing a class of alternatives, based upon the SUBSPORT methodology criteria.

The presented alternatives for plastic products containing BPA have achieved growing market acceptance as BPA-free applications. Each of the alternatives are used by at least one major plastic products manufacturer. The preferred alternatives are PE, PET and PP. Table 13 presents the comparison of the alternatives.

Table 13: Comparing alternatives

	Polyethylene	Polyethylene terephthalate	Polypropylene
Health aspects	PROS: no suspected risks to human health CONS:	PROS: no suspected risks to human health CONS:	PROS: no suspected risks to human health CONS:
Environmental aspect	PROS: CONS: harmful to aquatic life with long lasting effects	PROS: no suspected risks to the environment CONS:	PROS: no suspected risks to the environment CONS:
Performance aspects	PROS: performance aspects similar to BPA products CONS:	PROS: performance aspects similar to BPA products CONS:	PROS: performance aspects similar to BPA products CONS :
Cost aspects	PROS: Comparable cost of substance CONS:	PROS: Comparable cost of substance CONS:	PROS: Comparable cost of substance CONS:

Examples of related case stories:

Replacement of bisphenol A in food and beverage packing, http://www.subsport.eu/case-stories/247-en

An alternative engineering plastic completely free from brominated flame retardants, PVC and plasticizers for electronics, http://www.subsport.eu/case-stories/200-en

Replacing an epoxy resin material for pipe relining with a silane/silicone polymer alternative, http://www.subsport.eu/case-stories/193-en

A potential alternative to the use of Bisphenol A as a colour developer in thermal paper, http://www.subsport.eu/case-stories/164-en

Animal dolls made without synthetic materials, flame-retardants, allergens or PVC, http://www.subsport.eu/case-stories/191-en

Substitution of brominated flame retardants with non-halogenated alternatives using the GreenScreen™ for safer chemicals alternatives assessment tool, http://www.subsport.eu/case-stories/124-en

Different ways to reduce halogenated flame retardants in electronics, http://www.subsport.eu/case-stories/074-en

Evaluation of different halogen-free flame retardants in polypropylene formulations as alternatives to flame retardants containing halogens, http://www.subsport.eu/case-stories/072-en

Fire resistant composition in particular for energy or telecommunication cables, http://www.subsport.eu/case-stories/061-en

A review of different fire retardant technologies from a safe environmental hazard and risk performance, http://www.subsport.eu/case-stories/051-en

8 Conclusions

BPA is a well-known human endocrine disruptor and senisitizer, and is suspected of damaging fertility. Furthermore, BPA is classified as harmful to aquatic organisms. The most humans are being exposed to plastic products containing BPA, given its widespread distribution. BPA may be released to the environment from wastewater-treatment plants and processing plants.

Possible routes of BPA exposure include:

- inhalation of BPA-containing particles of dust in air in manufacturing operations
- ingestion of contaminated foods and drinks from plastic bottles and containers
- dermal absorption by contact with sales slips of thermal paper

This study considers aspects of the substitution of BPA and identifies available alternatives for the main uses of BPA. Many of the alternatives, which were screened using the hazardous Substance Database according to SUBSPORT Screening Criteria (SDSC), passed the hazard criteria applied.

The focus of this report is, however, on BPA-free plastic bottles and containers for foods and drinks. The following alternatives were further assessed regarding hazard characteristics and economical and technical feasibility:

- Polyethylene
- Polyethylene terephthalate
- Polypropylene

The three alternatives are available in the marketplace. They are economical and relatively inexpensive to manufacture. Moreover, PP and PET are declared to be environmentally-friendly.

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