Occurrence of bisphenol A and its effects on the human body

Elżbieta Włodarczyk¹,_{A,E,FB}

¹ Department of Toxicology and Bioanalytics, Koszalin University of Technology

Abstract

Bisphenol A (BPA) is a key component of polycarbonate plastics and epoxy resins, which are widely used for production of food storage containers and numerous other products, including contact lenses, protective glasses, infant incubators, CDs and DVDs. Moreover, BPA is an additive in the production of dental composites, paints, fungicidal and inflammability reducing agents.

Bisphenol A primarily gets to the human body from food products kept in BPA containers. The other important sources of BPA are thermal printing paper tickets and receipts, contaminated water, air and dust.

Study findings have confirmed its presence in all body fluids (follicular and amniotic fluids, umbilical blood, milk, urine, foetal serum) as well as numerous tissues and organs (placenta). Bisphenol A can cause various conditions, e.g. cardiovascular diseases, chronic respiratory failure, breast cancer, endometriosis, developmental disorders or autoimmune diseases. The permissible dose of BPA, which can be absorbed within 24 hours, is 0.05mg/kg body weight.

The materials containing BPA are found worldwide, particularly in quickly developing countries; due to its health-related risks, bisphenol A should be monitored in all elements of natural environment and BPA-containing products.

Key words: bisphenol A (BPA), sources, risks

Introduction

Bisphenol A (BPA) was first described by Alexander Dianin in 1891 [1]. In the 30ties of the previous century, BPA was investigated for its estrogenic properties and possible therapeutic applications. As a synthetic estrogen, BPA was soon replaced with diethylstilbestrol (DES), which was found to exert more potent estrogenic effects. In 1940, researchers renewed their interest in BPA as a major component used in the production of some plastics [2,3]. Since then, demands for BPA have been increasing. In 1964, 42 tons of BPA were produced in the United States, whereas in 2003 its global production was 3.2 million tons, one-third of which came from the United States [4]. According to Huang [1], the amount of BPA produced in 2012 reached almost 6 million tons.

Use of bisphenol A

Approximately 95% of BPA is used in the production of polycarbonate (PC) plastics and epoxy resins. Polycarbonates are applied in the production of bottles and containers, e.g. bottles for infants, food, beverage and microwave containers. Moreover, they are used in the construction indu-

stry (roofing, glass-making, roof lights, ski lifts, road signs, protective panels), in medicine and health protection (contact lenses, incubators of newborns, inhalators, oxygenators, dialysis machines), and in the field of safety measures (helmets, protective glasses, sunglasses). BPA is found in electric and electronic devices (hair dryers, electric shavers, kettles, refrigerators, mixers, computers, fax machines, cell phones), visual media (CDs, DVDs) and in the automotive industry (dashboards, bumpers) [1, 5, 6]. Epoxy resins are used for coating the insides of cans, food cartons and containers, water pipes [1]. The remaining 5 % of BPA is used in the production of phenol, polysulfone, polyacryl and polyester resins, polyvinyl chloride (PVC) plastics, agents reducing inflammability, and as additives for the production of paints, paint developers, dental composites, synthetic textiles, and fungicidal agents [1,3]. Special attention should be paid to BPA in thermal paper used for some self-adhesives, fax paper and cash receipts [6,7]. The estimated daily intake (EDI) of BPA ranges from 2 to 347 µg/day (on average 40.4 µg/day) for supermarket cashiers and from 0.24 to 3.98 µg/day (on average 0.69 µg/day) for the general population [6]. Table 1 presents the amounts of BPA on the surface of thermo-active paper used in cash registers and payment ter-

minals. Thermal printers are commonly used for printing receipts, train, plane and bus tickets or lottery tickets. Furthermore, BPA is present in waste paper, toilet paper and kitchen towels. According to Lu et al. [6], average BPA amounts found in cash register receipts are 9.38 mg/g, in thermal paper – 1.0 mg/g, and in paper currencies – 4.94 µg/g.

Table 1. BPA content in various papers used in thermal printers

Material	Concentration	References
recycled paper kitchen towel	0.6-24.1 mg/kg	[8]
virgin paper kitchen towel	0.03-0.1 mg/kg	[8]
waste paper	0.09-5.10 mg/kg dm	[9]
toilet paper	3.2-46.1 mg/kg dm	[9]
virgin paper products: coffee filters cooking paper mugs kitchenware napkins tea-bags tissues fried chicken paper boxes	ND-0.36 µg/g 0.034-0.048 µg/g ND-0.36 µg/g 0.064 µg/g ND-0.034 µg/g 0.048-0.09 µg/g 0.068 µg/g 0.044 µg/g 0.034 µg/g	[10]
waste paper products: cartons sweet boxes fried chicken boxes fried potato boxes newspapers pizza boxes sandwich boxes	0.19-26 µg/g 2.0 µg/g 0.89 µg/g 2.04 µg/g 0.74 µg/g 0.19 µg/g 0.37-1.3 µg/g 26 µg/g	[10]
train receipts	12 g/kg	[7]
canteen receipts	17 g/kg	[7]
shop receipts	<0.0005-17 g/kg	[7]
paper from recorders for chromatographic devices	11-16 g/kg	[7]
tram tickets	<0.0005 g/kg	[7]
parking tickets	32000 mg/kg	[11]
plane ticket	5800 mg/kg	[11]
train tickets	14000 mg/kg	[11]
bus tickets	23000 mg/kg	[11]
machine printouts	16000 mg/kg	[11]
shop receipts	9500-19000 mg/kg	[11]
labels	5000 mg/kg	[11]
cash machine printouts	19000 mg/kg	[11]
cash receipts	ND-17000 mg/kg	[12]
thermal paper receipts	<1 ng/g-13.9 mg/g	[13]
paper currencies	0.001 to 82.7 µg/g	[14]
credit card receipts	0.01-1.79 mg/100 mg	[15]
gas station receipts	1.16-1.19 mg/100 mg	[15]
parking receipts	1.71 mg/100 mg	[15]
restaurant receipts	1.69-2.00 mg/100 mg	[15]
shop receipts	0.97-2.09 mg/100 mg	[15]

thermal printing paper	0.53–12.9 mg/g	[16]
shop receipts	12.9 mg/g	
restaurant receipts	12.5 mg/g	
bank receipts	9.96 mg/g	
pharmacy receipts	8.31 mg/g	
cinema receipts	5.89 mg/g	
train tickets	0.53 mg/g	
shop receipts	2.58–14.7 mg/g	[6]

ND - not determined

Bisphenol A content in food

The essential route of exposure to BPA is diet. The compound in question can migrate to food from metal tops of jars and containers lined with epoxy resin, protecting the food against direct contact with metal, as well as from other polycarbonate plastics, e.g. bottles for infants, tableware, water bottles, or food containers [17].

The amount of BPA that migrates from these containers depends mainly on liquid temperature (higher migration at higher temperature) and on container size, although to a lesser degree. Effects of high temperature can be purposeful (sterilisation, warming) or unintended, e.g. during storage in shopping centres and storage spaces.

In this way, the amount of BPA and its derivatives migrating from the layer coating a can to food is 7–380 g/kg and to beverages 7–58 µg/g [18, 19]. The study by Greens et al. [20] has demonstrated that the average concentration of BPA in canned beverages is 1.0ng/ml and in canned foods – 40.3 ng/g. Moreover, the authors emphasise that BPA has not been determined in non-canned beverages (<0.02 ng/ml), whereas non-canned food products contained a very low amount of BPA, i.e. 0.46 ng/g. The other authors also highlight that the amount of BPA in food depends on the type of container. According to Sajiki et al. [21], the amount of BPA in canned food products is 0–842 ng/g, in plastic containers - 0–14 ng/g while in paper containers - 0 to 1 ng/g. In the majority of studies, BPA is analysed in processed and canned products (Table 2).

Table 2. Concentration of BPA in canned food products

Groups of products	Type	Concentration	References
Dairy products	condensed milk	15.3 ng/g	[17]
	concentrated milk	<1.7-15.2 ng/g	[22]
Vegetables	canned vegetables	ND-21.5 µg/kg	[23]
	roasted beans	23.5 ng/g	[17]
	canned vegetable juice	0.53 ng/g	[17]
	tomatoes	20 ng/g	[24]
	tomatoes	<10-21 µg/kg	[25]
	tomato paste	1.23 µg/kg	[26]
	tomato sauce	2.59 ng/g	[17]
	mushrooms	0.04 mg/kg	[27]
	corn	2.3-75 ng/g	[28]
	corn	28 ng/g	[24]
	corn	<10-20 µg/kg	[25]
	corn	2.12 µg/kg	[26]
	beetroots	13-24 µg/kg	[25]
	pea	8.5 ng/g	[24]
	pea	<10-17 µg/kg	[25]
	pea	0.05 mg/kg	[27]
	beans	3.5-26 ng/g	[28]
	beans	26-35 ng/g	[24]
	lentils	26 ng/g	[24]
	olives	<10-23 µg/kg	[25]
Fruit	fruit salad	<10 µg/kg	[25]
	fruits	ND-54.56 µg/kg	[23]
	sour cherries	3.24 ng/g	[17]
	apricots	<10 µg/kg	[25]
	peaches	6.4 ng/g	[24]
	peaches	<10 µg/kg	[25]
	mango	24 ng/g	[24]
	mango	0.16 mg/kg	[27]
	lychee	6.8 ng/g	[24]
	pineapple	5.0 ng/g	[24]
	pineapple	<10 µg/kg	[25]
	pineapple	0.03 mg/kg	[27]
	pineapple	1.20 ng/g	[17]
	roasted nuts	0.10 mg/kg	[27]
Beverages	soft drinks	<10 µg/kg	[25]
	soft drinks	0.32 ng/g	[17]
	beverages	0.03-4.70 µg/l	[29]
	orange fizzy drink	607 ng/l	[30]
	orange drink	0.4 ng/ml	[24]
	lemon drink	0.1 ng/ml	[24]
	lemon fizzy drink	232-433 ng/l	[30]
	energy drink	<0.9-3.4 ng/ml	[24]
	energy drink	561 ng/l	[30]
	tonic	44 ng/l	[30]

	apple juice	0.36 ng/g	[17]
	apple fizzy drink	503 ng/l	[30]
	soft drinks	0.032-4.5 µg/l	[31]
	Coca-Cola	0.4-0.7 ng/ml	[24]
	Coca-Cola	522 ng/l	[30]
	beer	1.5 ng/ml	[24]
	beer	0.081-0.54 µg/l	[32]
	coffee	ND-136.14 µg/kg	[23]
	tea	ND-14.26 µg/kg	[23]
Fish	fish	ND-125.25 µg/kg	[23]
	fish	106 ng/g	[17]
	tuńczyk w oleju	43 ng/g	[24]
	tuńczyk	<7.1-102.7 µg/kg	[33]
	tuna in oil	<20-109 µg/kg	[25]
	tuna	0.11 mg/kg	[27]
	tuna	ND-116.88 µg/kg	[23]
	tuna	32.55 µg/kg	[26]
	tuna in oil	ND-99.9 µg/kg	[34]
	natural tuna	2.2-32.8 µg/kg	[34]
	mackerel in vegetable oil	9.9-33.5 µg/kg	[34]
	sardines in oil	2.1 ng/g	[24]
	sardines	ND-9.2 µg/kg	[34]
	salmon	<20-24 µg/kg	[25]
Seafood	mussels in oil	1.4-49.2 µg/kg	[34]
	octopus	5.6-54.9 µg/kg	[34]
	squid	11.1-43.8 µg/kg	[34]
Meat	meat	<20-98 µg/kg	[25]
	meat	ND-98.3 µg/kg	[23]
	corned beef	17-602 ng/g	[28]
	luncheon meat	10.5 ng/g	[17]
	pork	0.04-0.14 mg/kg	[27]
	sauce	<10-21 µg/kg	[25]
	stew	9.6-22 ng/g	[24]
	stew	16.75 µg/kg	[26]
	spaghetti	<10 µg/kg	[25]
Soups	potato	9.6-20.7 ng/g	[24]
	broth	44.4 ng/g	[17]
	soup	<20 µg/kg	[25]
	meat soup	29.1 ng/g	[17]
	cream soup	22.2 ng/g	[17]
Food for children	formulas for infants	45-113 ng/g	[35]
	vegetable	<10 µg/kg	[25]
	desserts	<10 µg/kg	[25]
	milk drinks	2.75 ng/g	[17]
Miscellaneous	coconut cream (sweetened)	29.7 ng/g	[24]
	coconut cream	<20-192 µg/kg	[25]
	desserts	<20 µg/kg	[25]

The findings of some other studies reveal that BPA is also present in fresh fruits and vegetables as well as non-canned food products (table 3).

Table 3. BPA concentration in non-canned food products

Groups of products	Type	Concentration	References
Dairy products	cheese	2.24 ng/g	[17]
	processed cheese	0.68 ng/g	[17]
	butter	0.53 ng/g	[17]
	milk	ND-0.49 µg/kg	[36]
	eggs and dairy products	<2-2.4 ng/g	[37]
	fats (butter, margarine, oil mayonnaise)	<4 ng/g	[37]
Bread and cereals	cereal products	<2 ng/g	[37]
	wheat bread	0.40 ng/g	[17]
	rye bread	1.73 ng/g	[17]
	cornflakes, rice, bran	0.65 ng/g	[17]
	wholemeal flour	0.44 ng/g	[17]
Vegetables	potatoes	<2-2.2 ng/g	[37]
	cauliflower	0.41 ng/g	[17]
	mushrooms	1.17 ng/g	[17]
Fruit	fresh and dried plums	0.62 ng/g	[17]
	raisins	0.51 ng/g	[17]
	apricots	0.57 ng/g	[17]
Meat	sausages	0.48 ng/g	[17]
	poultry liver pate	0.67 ng/g	[17]
Fish and seafood	salt water fish	0.48 ng/g	[17]
	sea fish	0.89 ng/g	[17]
Beverages	bottled wine	0,74 ng/g	[17]
	coffee	0,22 ng/g	[17]
	mineral water (Pet bottle)	2-10 ng/l	[38]
Fast food	frozen dinner dishes	2.02 ng/g	[17]
	French fries	1.10 ng/g	[17]
	hamburger	10.9 ng/g	[17]
	poultry hamburger	1.45 ng/g	[17]
	hot-dog	2.32 ng/g	[17]
	sandwiches	1.24 ng/g	
Food for children - dinner dishes (cornflakes, vegetables, meat) in jars	fruits (apples, peaches) in jars		
	meat, poultry or eggs in jars		
	vegetables, pea in jars,		
Miscellaneous	baking soda,		
	yeast,		
	soya sauce		
	honey in a plastic container		
	honey in aglass container		
	bottled honey		
	eggs		
	eggs		

The tolerable daily intake (TDI) of BPA accepted by the European Union and the reference dose (RfD) established by the US Environmental Protection Agency (US EPA) are 50 µg BPA/kg b.w./day; whereas the Health Canada sets the temporary TDI for BPA at 25 µg/kg b.w./day [17].

According to Cao et al., the daily dose of BPA for infants is 1.2-2.2 µg/day, for children and teenagers below the age of 19 years – 3.3-4.7 µg/day and for adults – 3.3 – 5.8 µg/day. The daily intake of this compound with the diet per kg b.w. reaches 0.16-0.33 µg/kg b.w./day for infants and is substantially higher than for adults (0.052-0.082 µg/kg b.w./day; the estimated daily intake for children and teenagers is 0.088-0.23 µg BPA/kg b.w./day. Moreover, the average intake of BPA based on its amount in urine reported by LaKind and Naiman [40]) is 49.1–59 ng/kg/day for men and 36.2–46.5 ng/kg/day for women, as compared to 28–49 ng/kg/day and 34–59 ng/kg/day, respectively given by Miyamoto and Kotake. In Belgium, the BPA intake with food and canned beverages in adults is 1.05 µg/day, which gives 0.015 µg/kg b.w./day per average body weight of an adult of 70kg [20]. In Japan, the daily intake of BPA with canned food has been defined at 644 ng/person/day, which is significantly lower than TDI accepted by EFSA and USEPA [42].

Presence of BPA in the human body

The concentration of BPA can be measured directly in human blood, urine, milk and other fluids and tissues (Table 4). The study carried out by Calafat et al. [43] has revealed the presence of this compound in 95% of human urine samples.

Urine is a commonly used matrix in bio-monitoring of unstable chemical compounds, such as bisphenol A, whose half-life is shorter than 6 hours. Administered orally, BPA is quickly and effectively absorbed from the gastrointestinal tract and undergoes the extensive first-pass effect occurring in the intestinal and liver wall. At this stage, the main pathway of biotransformation is its biotransformation to glucuronide, which is biologically inactive [44]; 13-28% of the BPA glucuronide formed is removed from the body with urine while 56-82% of free bisphenol A is excreted with faeces [45]. Understanding the extent of BPA metabolism is essential to determine whether the compound represents a potential risk to reproduction and development of humans.

Table 4. Concentration of BPA in the human body

Country	Study group	Sample	Method of detection	Limit of detection	Concentration	Reference
Japan	21 adults (aged 30-50 years)	serum	HPLC	0.1 ng/ml	0-1.6 ng/ml	[46]
Japan	5 individuals	serum	HPLC-ED	0.01 ng/ml	0.32 ng/ml	[47]
Germany	37 newborns	foetal plasma	GC-MS	0.01 ng/ml	0.2-9.2 ng/ml	[48]
Germany	37 pregnant women (gestational week 32-41 t)	maternal plasma	GC-MS	0.01 ng/ml	0.3-18.9 ng/ml	[48]
Germany	37 women	placental tissue	GC-MS	0.01 ng/ml	1.0-104.9 ng/g	[48]
Korea	30 adults	urine	HPLC-FD	0.28 ng/ml	0.85-9.83 ng/ml	[49]
Japan	3 women	milk	GC-MS	0.09 ng/g	<0.09-0.70 ng/g	[50]
Malaysia	180 samples	umbilical blood	GC-MS	0.05 ng/ml	ND-4.05 ng/ml	[51]
Japan	23 women	milk	HPLC	0.11 ng/ml	0.28-0.97 ng/ml	[52]
USA	20 samples	milk	HPLC-MS/MS	0.28 ng/ml	<0.28-7.3 ng/ml	[53]
Japan	101 samples	colostrum	ELISA	0.3 ng/ml	1-7 ng/ml	[54]
Germany	15 adults	urine	GC-MS	3 ng/ml	ND-55 ng/ml	[55]
Korea	300 pregnant women	maternal blood	HPLC	0.625 µg/L	<LOD-66.48 µg/l	[56]
Korea	296 newborns	placental blood	HPLC	0.625 µg/L	<LOD-8.86 µg/l	[56]
USA	40 pregnant women	blood	HPLC-ESI-MS/MS	0.5 ng/ml	0.5-22.3 ng/ml	[57]

Germany	287 individuals (aged 5-52 years)	urine	LC-MS/MS	0.3 µg/l	<0.3-2.5 µg/l	[58]
USA	60 pre-menopausal women	urine	HPLC-MS/MS	0.18 ng/ml	0.17-33.78 ng/ml	[59]
Korea	167 women	blood	HPLC/FD	0.012 µg/l	0-13.87 µg/L	[60]
Canada	5476 individuals (aged 6-79 years)	urine	GC-MS/MS	0.2 µg/l	ND-1.38 µg/l	[61]
USA	375 men (aged 18-53 years)	urine	LC-MS/MS	0.4 µg/l	<0.4-6.5 µg/l	[62]
Taiwan	97 pregnant women	maternal blood	HPLC	0.13 ng/ml	0.3-29.4 ng/ml	[63]
Taiwan	97 newborns	umbilical blood	HPLC	0.13 ng/ml	0.3-18.5 ng/ml	[63]
Germany	47 infants (aged 1-5 months)	urine	LC-MS/MS	0.15 µg/l	<0.15-16.0 µg/l	[64]
Canada	20 individuals (aged 21-68 years)	serum	LC-MS	0.2 ng/ml	0-30 ng/ml	[65]
Canada	20 individuals (aged 21-68 years)	urine	LC-MS	0.2 ng/ml	0-42 ng/ml	[65]
Canada	20 individuals (aged 21-68 years)	sweat	LC-MS	0.2 ng/ml	0-82 ng/ml	[65]

Occurrence of bisphenol A in the environment

Bisphenol A is present in the aquatic environment and in the air, both out- and in-doors [66]. Each year, approximately 100 tons of BPA leak into the atmosphere during its production [67]. BPA can be determined in aerosol and dust even in the most remote places, such as Arctic or Antarctic. The secondary source of environmental pollution with BPA is sewage sludge, as well as untreated and treated sewage (Table 5).

Table 5. Bisphenol A in the environment and sewage

Environmental samples	Country	Technique	Limit of detection	Concentration	Reference
Surface water					
rivers	Germany	HRGC-(NCI)-MS	40 pg/l	500 pg/l - 14 ng/l	[68]
rivers, canals	Holland	GC-MS/MS	11 ng/l	ND-170 ng/l	[69]
estuaries	Holland	GC-MS/MS	11 ng/l	ND-330 ng/l	[69]
rivers, lakes, canals	Germany	GC-MS/MS	0.1 ng/l	0.0005-0.41 µg/l	[70]
sea water	Singapore	GC-MS	0.014 µg/l	0.04-0.19 µg/l	[71]
river	China	GC-MS	0.17 ng/l	19.1 ng/l - 8.30 µg/l	[72]
rivers	Japan	GC-MS	0.005 µg/l	ND-0.08 µg/l	[73]
river	Italy	LC-MS/MS	0.2 ng/l	15-29 ng/l	[74]
river	Great Britain	GC-MS	5.3 ng/l	<LOD-24 ng/l	[75]
river, canal, sea water	Spain	HPLC-(ESI)-MS	0.002 µg/l	ND-0.02 µg/l	[76]
rivers	Japan	GC-MS	0.32 ng/l	20.2-30.1 ng/l	[77]
river	Spain	LC-MS	0.014 µg/l	0.12-0.271 µg/l	[78]
river	Spain	LC-MS	0.05 µg/l	<0.05 µg/l	[79]
river	Switzerland	GC-MS	2.4 ng/l	9-76 ng/l	[80]
rivers	Belgium	LC-MS/MS	2 ng/l	0.003-0.055 µg/l	[81]

rivers	Italy	LC-MS/MS	2 ng/l	0.036-0.175 µg/l	[81]
River and lake sediments					
	Germany	GC-MS	0.5 µg/kg s.m.	<0.5-15 µg/kg d.m.	[82]
	Germany	GC-MS/MS	1 µg/kg s. m.	0.01-0.19 mg/kg	[70]
	Japan	GC-MS	0.5 µg/kg	ND-13 µg/kg	[73]
	Japan	GC-MS	0.05 ng/g	0.11-48.0 ng/g	[77]
	China	GC-MS	0.1 ng/g s. m.	0.6-4.0 ng/g	[83]
	Japan	LC-MS/MS	0.6 ng/g	ND-22.0 µg/kg	[84]
	China	GC-MS	0.7 ng/g	0.72-13.2 ng/g	[85]
Air					
Solid particles	Japan	GC-MS	0.01 ng/m ³	0.01-1.92 ng/m ³	[86]
aerosol	India (urban area)	GC-MS	0.3 pg/µl	100-17400 pg/m ³	[87]
aerosol	China (urban area)	GC-MS	0.3 pg/µl		
	30-2340 pg/m ³	[87]			
aerosol	China (urban area)	GC-MS	0.3 pg/µl	30-240 pg/m ³	[87]
aerosol	Japan (Urban area)	GC-MS	0.3 pg/µl	10-930 pg/m ³	[87]
aerosol	New Zealand(Urban area)	GC-MS	0.3 pg/µl	4-1480 pg/m ³	[87]
aerosol	Atlantic Ocean(-north)	GC-MS	0.3 pg/µl	4-6 pg/m ³	[87]
aerosol	Pacific (north)	GC-MS	0.3 pg/µl	1-2 pg/m ³	[87]
aerosol	Chinese Sea(east)	GC-MS	0.3 pg/µl	7-27 pg/m ³	[87]
aerosol	Japanese Sea(-north)	GC-MS	0.3 pg/µl	4-32 pg/m ³	[87]
aerosol	Arctic	GC-MS	0.3 pg/µl	1-17 pg/m ³	[87]
aerosol	Antarctic	GC-MS	0.3 pg/µl	1-11 pg/m ³	[87]
dust (office, house)	USA	GC-MS-SIM	0.0038 µg/ extract	0.25-0.48 µg/g	[88]
air (office, house)	USA	GC-MS-SIM	0.0038 µg/ekstrakt	0.002-0.003 µg/m ³	[88]
plastic production plant	USA	GC-MS-SIM	0.0038 µg/ extract	0.208 µg/m ³	[88]
indoor air	USA	GC-MS	0.9 ng/m ³	<0.9-193 ng/m ³	[89]
outdoor air	USA	GC-MS	0.9 ng/m ³	<0.9-51.5 ng/m ³	[89]
dust	USA	GC-MS	20 ng/g	<20-707 ng/g	[89]
household dust	USA	HPLC-MS/MS	0.5 ng/g	<0.5-10200 ng/g	[90]
Sewage					
raw sewage	Italy	LC-MS/MS	3.0 ng/l	332-339 ng/l	[74]
raw sewage	Spain	LC-MS	0.05 µg/l	0.06-1.51 µg/l	[79]
raw sewage	China	GC-MS	13.8 ng/l	699.9-1416.7 ng/l	[91]
treated sewage	Germany	GC-MS/MS	0.1 ng/l	0.018-0.702 µg/l	[70]
treated sewage	Italy	LC-MS/MS	1.0 ng/l	13-36 ng/l	[74]
treated sewage	Spain	LC-MS	0.05 µg/l	<0.05-0.33 µg/l	[79]
treated sewage	China	GC-MS	13.8 ng/l	56.9-138.4 ng/l	[91]
sewage sludge	Germany	GC-MS/MS	1 µg/kg s. m.	0.004-1.363 mg/kg d.m..	[70]
sewage sludge	Australia	GC-MS	10 µg/kg	<10 µg/kg -1.47 mg/kg	[92]

HRGC-(NCI)-MS - high-resolution gas chromatography with negative chemical ionization mass spectrometric detection;
GC-MS/MS - gas chromatography/tandem mass spectrometry;
GC-MS - gas chromatography-mass spectrometry;
LC-MS/MS - liquid chromatography tandem-mass spectrometry;

HPLC-(ESI)-MS - high-performance liquid chromatography-electrospray ionization-mass spectrometry;
GC-MS-SIM - gas chromatography-mass spectrometry with selected ion monitoring;

Effects of BPA on human health

Bisphenol A is characterised by marked lipophilicity. This feature enables it to cross biological membranes, permeate into the cell interior, and accumulate in the adipose tissue. Moreover, BPA penetrates through the blood-brain barrier and placental barrier, affecting the development of organisms in the earliest stages of life. As far as its chemical structure is concerned, the compound mimics the action of endogenous hormones, i.e. estradiol. It impairs proper functioning of the endocrine system, hence is rated among the endocrine disrupting compounds (EDCs) [93].

BPA present in the human body can cause various conditions, e.g. obesity in children [94]. Hiroi et al. [95] have noticed a correlation between exposure to BPA, complex endometrial hyperplasia and endometrial cancer. Furthermore, based on preliminary analysis of Korean women, Yang et al. [60] have suggested the risk of breast cancer due to exposure to BPA. According to Krieter et al. [96], the concentration of BPA is highly and reversely correlated with proper functioning of kidneys. Some other studies have also demonstrated adverse effects of BPA. In their study in 1455 adults, Lang et al. [97] have observed that high concentration of bisphenol A in urine is correlated with increased incidence of cardiovascular diseases, diabetes and disorders of hepatic enzymes. According to Galloway et al. [98], hormonal changes in men can be associated with high exposure to BPA; a correlation had been found between daily excretion of high amounts of BPA and an increase in total concentration of testosterone in serum. Moreover, exposure of men to BPA is likely to affect the quality of sperm, hence the quality of an embryo, which was observed during in vitro fertilisation [99]. According to Fujimoto et al. [100], exposure of women to BPA during in vitro fertilisation affects the quality of oocytes.

Furthermore, exposure of pregnant women to BPA can influence the proper development of children. According to Chou et al. [63], the level of BPA detected in the placental blood evidences that the compound can be transported through the placental barrier to a foetus. Increased prenatal exposure to BPA increases the risk of low birth weight and reduced gestational age and causes adverse effects on adipokines in newborns, particularly in male infants. Some authors have investigated the relation between prenatal exposure to BPA and

wheeze in children aged 6 months based on the amount of BPA in maternal urine [101]. According to Braun et al. [102], gestational exposure to BPA can cause anxiety, depression and hyperexcitability regarding impaired regulation of behaviour in children aged 3 years. It has been noted that such effects are more pronounced in girls than in boys, which can result from their higher susceptibility to BPA during the prenatal period. Otherwise, exposure during childhood does not affect the behaviour and executive functions of children at this age (3 years).

Summary

Bisphenol A is a typical example of xenobiotics commonly occurring in almost each sphere of life of modern man. People are continuously exposed to direct contact with a whole range of products containing BPA, which is reflected in well-documented presence of this compound in the human body. Since its effects on metabolism have not been fully elucidated and literature findings suggest its adverse effects on human health, it is essential to monitor the environmental fate of bisphenol A.

References

1. Huang YQ, Wong CKC, Zheng JS, Bouwman H, Bara R, Wahlström B, Neretin L, Wong MH. Bisphenol A (BPA) in China: A review of sources, environmental levels, and potential human health impacts. *Environ. Int.* 2012; 42:91–99.
2. Rubin BS, Soto AM. Bisphenol A: Perinatal exposure and body weight. *Mol. Cell. Endocrinol.*, 2009; 304:55–62.
3. Rubin BS. Bisphenol A: An endocrine disruptor with widespread exposure and multiple effects. *J. Steroid Biochem. Mol. Biol.* 2011; 127:27–34.
4. Flint S, Markle T, Thompson S, Wallace E. Bisphenol A exposure, effects, and policy: a wildlife perspective. *J. Environ. Manage.* 2012; 104:19–34.
5. Geens T, Goeyens L, Covaci A. Are potential sources for human exposure to bisphenol-A overlooked? *Int. J. Hyg. Environ. Health.* 2011; 214: 339–347.
6. Lu SY, Chang WJ, Sojinu SO, Ni HG. Bisphenol A in supermarket receipts and its exposure to human in Shenzhen, China. *Chemosphere*, 2013; 92:1190–1194.
7. Biedermann S, Tschudin P, Grob K. Transfer of bisphenol A from thermal printer paper to the skin. *Anal. Bioanal. Chem.* 2010; 398(1):571–576.
8. Vinggaard AM, Korner W, Lund KH, Bolz U, Petersen JH. Identification and quantification of estrogenic compounds in recycled and virgin paper for household use as determined by an in vitro yeast estrogen screen and chemical analysis. *Chem. Res. Toxicol.* 2000; 13(12):1214–1222.

9. Gehring M, Tennhardt L, Vogel D, Weltin D, Bilitewski B. 2004. Bisphenol A contamination of wastepaper, cellulose and recycled paper products. In: Brebbia C.A., Kungulos S., Popov V., Itoh H. red., Waste Management and the Environment II. Southampton, Boston: WIT Press; 2004. p. 294–300.
10. Ozaki A, Yamaguchi Y, Fujita T, Kuroda K, Endo G. Chemical analysis and genotoxicological safety assessment of paper and paperboard used for food packaging. *Food Chem. Toxicol.* 2004; 42(8):1323–1337.
11. Östberg T, Noakson E. Bisfenol A i svenske kvitton. Analysresultat. Jegrelius for Jämtlands Läns Landsting. 2010.
12. Lassen C, Mikkelsen SH, Brandt UK. Migration of bisphenol A from cash register receipts and baby dum-mies. Survey of Chemical Substances in Consumer Pro-ducts, No. 110 2011. Danish Ministry of the Environ-ment; 2011.
13. Liao C, Kannan K. Widespread occurrence of bis-phenol A in paper and paper products: implications for human exposure. *Environ. Sci. Technol.* 2011; 45(21):9372–9379.
14. Liao C, Kannan K. High levels of bisphenol A in paper currencies from several countries, and implica-tions for dermal exposure. *Environ. Sci. Technol.* 2011; 45(16):6761–6768.
15. Geens T, Goeyens L, Kannan K, Neels H, Covaci A. Levels of bisphenol-A in thermal paper receipts from Belgium and estimation of human exposure. *Sci. Total Environ.* 2012; 435–436:30–33.
16. Gao L, Zou J, Liu H, Zeng J, Wang Y, Chen X. Deter-mination of bisphenol A in thermal printing papers trea-ted by alkaline aqueous solution using the combination of single-drop microextraction and HPLC. *J. Sep. Sci.* 2013; 36:1298–1303.
17. Cao XL, Perez-Locas C, Dufresne G, Clement G, Popovic S, Beraldin F, Dabeka RW, Feeley M. Concen-trations of bisphenol A in the composite food samples from the 2008 Canadian total diet study in Quebec City and dietary intake estimates. *Food Addit. Contam.* 2011; 28(6):791–798.
18. Brotons JA, Olea-Serrano ME, Villalobos M, Olea N. Xenoestrogens released from lacquer coating in food cans. *Environ. Health Perspect.* 1994; 103:608–612.
19. Biles JE, McNeal TP, Begley TH, Hollifield HC. De-termination of bisphenol-A in reusable polycarbonate food-contact plastics and migration to food simulating liquids. *J. Agric. Food Chem.* 1997; 45:3541–3544.
20. Geens T, Apelbaum TZ, Goeyens L, Neels H, Co-vaci A. Intake of bisphenol A from canned beverages and foods on the Belgian market. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess.* 2010; 27(11):1627–1637.
21. Sajiki J, Miyamoto F, Fukata H, Mori C, Yonekubo J, Hayakawa K. Bisphenol A (BPA) and its source in foods in Japanese markets. *Food Addit. Contam.* 2007; 24(1):103–112.
22. Maragou NC, Lampi EN, Thomaidis NS, Kouppa-ris MA. Determination of bisphenol A in milk by so-lid phase extraction and liquid chromatography–mass spectrometry. *J. Chromatogr. A*, 2006; 1129:165–173.
23. Lim DS, Kwack SJ, Kim KB, Kim HS, Lee BM. Risk assessment of bisphenol A migrated from canned foods in Korea. *J. Toxicol. Environ. Health A.*, 2009; 72(21–22):1327–1335.
24. Braunrath R, Podlipna D, Padlesak S, Cichna-Markl M. Determination of bisphenol A in canned food by im-munoaffinity chromatography, HPLC, and fluorescence detection. *J. Agric. Food Chem.* 2005; 53(23):8911–8917.
25. Thomson BM, Grounds PR. Bisphenol A in canned foods in New Zealand: An exposure assessment. *Food Addit. Contam.* 2005; 22(1):65–72.
26. Rastkari N, Yunesian M, Ahmadvhaniha R. Levels of bisphenol A and bisphenol F in canned foods in Iranian markets. *Iran. J. Environ. Health. Sci. Eng.* 2011, 8(1):95–100.
27. Sun C, Leong LP, Barlow PJ, Chan SH, Bloodworth BC. Single laboratory validation of a method for the determination of bisphenol A, bisphenol A diglycidyl ether and its derivatives in canned foods by reversed-phase liquid chromatography. *J. Chromatogr. A*, 2006; 1129:145–148.
28. Imanaka M, Sasaki K, Nemoto S, Ueda E, Muraka-mi E, Miyata D, Tonogai Y. Determination of bisphenol A in foods using GC/MS. *J. Food Hyg. Soc. Jpn.* 2001; 42(2):71–78.
29. Cunha SC, Almeida, Mendes E, Fernandes JO. Simul-taneous determination of bisphenol A and bisphenol B in beverages and powdered infant formula by dispersive liquid–liquid micro-extraction and heart-cutting mul-tidimensional gas chromatography–mass spectrometry. *Food Addit. Contam. Part A.*, 2011; 28(4):513–526.
30. Gallart-Ayal H, Moyano E, Galceran MT. Analysis of bisphenols in soft drinks by on-line solid phase extrac-tion fast liquid chromatography–tandem mass spectro-metry. *Anal. Chim. Acta*, 2011; 683:227–233.
31. Cao XL, Corriveau J, Popovic S. Levels of bisphenol A in canned soft drink products in Canadian markets. *J. Agric. Food Chem.* 2009, 57(4):1307–1311.
32. Cao XL, Corriveau J, Popovic S. Sources of low con-centrations of bisphenol A in canned beverage products. *J. Food Prot.* 2010; 73(8):1548–1551.
33. Munguía-López EM, Gerardo-Lugo S, Peralta E, Bolumen S, Soto-Valdez H. Migration of bisphenol A (BPA) from can coatings into a fatty-food simulant and tuna fish. *Food Addit. Contam.* 2005; 22(9):892–898.
34. Cunha SC, Cunha C, Ferreira AR, Fernandes JO. Determination of bisphenol A and bisphenol B in can-ned seafood combining QuEChERS extraction with dispersive liquid–liquid microextraction followed by gas chromatography–mass spectrometry. *Anal. Bioanal. Chem.* 2012; 404:2453–2463.
35. Kuo HW, Ding WH. Trace determination of bisphe-nol A and phytoestrogens in infant formula powders by

- gas chromatography–mass spectrometry. *J. Chromatogr. A*, 2004; 1027:67–74.
36. Shao B, Han H, Tun X, Huang L. Analysis of alkylphenol and bisphenol A in eggs and milk by matrix solid phase dispersion extraction and liquid chromatography with tandem mass spectrometry. *J. Chromatogr. B*, 2007; 850:412–416.
 37. Gyllenhammar I, Glynn A, Darnerud PO, Lignell S, van Delft R, Aune M. 4-Nonylphenol and bisphenol A in Swedish food and exposure in Swedish nursing women. *Environ. Int.* 2012; 43:21–28.
 38. Toyooka T, Oshige Y. Determination of alkylphenols in mineral water contained in PET bottles by liquid chromatography with coulometric detection. *Anal. Sci.* 2000; 16:1071–1076.
 39. Inoue K, Murayama S, Takeba K, Yoshimura Y, Nakazawa H. Contamination of xenoestrogens bisphenol A and F in honey: safety assessment and analytical method of these compounds in honey. *J. Food Compos. Anal.* 2003; 16:497–506.
 40. LaKind JS, Naiman DQ. Bisphenol A (BPA) daily intakes in the United States: estimates from the 2003–2004 NHANES urinary BPA data. *J. Expo. Sci. Environ. Epidemiol.* 2008; 18(6):608–615.
 41. Miyamoto K, Kotake M. Estimation of daily bisphenol A intake of Japanese individuals with emphasis on uncertainty and variability. *Environ. Sci.* 2006; 13(1):15–29.
 42. Kawamura Y, Etoh M, Hirakawa Y, Abe Y, Mutsuga M. Bisphenol A in domestic and imported canned foods in Japan. *Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess.* 2014; 31(2):330–40.
 43. Calafat AM, Kuklenyik Z, Reidy JA, Caudill SP, Ekong J, Needham LL. Urinary concentrations of bisphenol A and 4-nonylphenol in a human reference population. *Environ. Health Perspect.* 2005; 113(4):391–395.
 44. Dekant W, Völkel W. Human exposure to bisphenol A by biomonitoring: methods, results and assessment of environmental exposures. *Toxicol. Appl. Pharmacol.* 2008; 228:114–134.
 45. Kang JH, Kondo F, Katayama Y. Human exposure to bisphenol A. *Toxicology*, 2006; 226:79–89.
 46. Sajiki J, Takahashi K, Yonekubo J. 1999 Sensitive method for the determination of bisphenol-A in serum using two systems of high-performance liquid chromatography. *J. Chromatogr. B*, 1999; 736:255–261.
 47. Inoue K, Kato K, Yoshimura Y, Makino T, Nakazawa H. Determination of bisphenol A in human serum by high-performance liquid chromatography with multi-electrode electrochemical detection. *J. Chromatogr. B*, 2000; 749:17–23.
 48. Schönfelder G, Wittfoht W, Hopp H, Talsness CE, Paul M, Chahoud I. Parent bisphenol A accumulation in the human maternal–fetal–placental unit. *Environ. Health Perspect.* 2002; 110:703–707.
 49. Kim YH, Kim CS, Park S, Han SY, Pyo MY, Yang M. Gender differences in the levels of bisphenol A metabolites in urine. *Biochem. Biophys. Res. Commun.* 2003; 312:441–448.
 50. Otaka H, Yasuhara A, Morita M. Determination of bisphenol A and 4-nonylphenol in human milk using alkaline digestion and cleanup by solid-phase extraction. *Anal. Sci.* 2003; 19(12):1663–1666.
 51. Tan BL, Mohd MA. Analysis of selected pesticides and alkylphenols in human cord blood by gas chromatograph–mass spectrometer. *Talanta*, 2003; 61:385–391.
 52. Sun Y, Irie M, Kishikawa N, Wada M, Kuroda N, Nakashima K. Determination of bisphenol A in human breast milk by HPLC with column switching and fluorescence detection. *Biomed. Chromatogr.* 2004; 18:501–507.
 53. Ye X, Kuklenyik Z, Needham LL, Calafat AM. Measuring environmental phenols and chlorinated organic chemicals in breast milk using automated on-line column-switching–high performance liquid chromatography–isotope dilution tandem mass spectrometry. *J. Chromatogr. B*, 2006; 831(1–2):110–115.
 54. Kuruto-Niwa R, Tateoka Y, Usuki Y, Nozawa R. Measurement of bisphenol A concentrations in human colostrum. *Chemosphere*, 2007; 66(6):1160–1164.
 55. Moors S, Blaszkewicz M, Bolt HM, Degen GH. Simultaneous determination of daidzein, equol, genistein and bisphenol A in human urine by a fast and simple method using SPE and GC-MS. *Mol. Nutr. Food Res.* 2007; 51(7):787–798.
 56. Lee YJ, Ryu HY, Kim HK, Min CS, Lee JH, Kim E, Nam BH, Park JH, Jung JY, Jang DD, Park EY, Lee KH, Ma JY, Won HS, Im MW, Leem JH, Hong YC, Yoon H.S. Maternal and fetal exposure to bisphenol A in Korea. *Reprod. Toxicol.* 2008; 25:413–419.
 57. Padmanabhan V, Siefert K, Ransom S, Johnson T, Pinkerton J, Anderson L, Tao L, Kannan K. Maternal bisphenol-A levels at delivery: a looming problem? *J. Perinatol.* 2008; 28:258–263.
 58. Völkel W, Kiranoglu M, Fromme H. Determination of free and total bisphenol A in human urine to assess daily uptake as a basis for a valid risk assessment. *Toxicol. Lett.* 2008; 179:155–162.
 59. Nepomnaschy PA, Baird DD, Weinberg CR, Hoppin JA, Longnecker MP, Wilcox AJ. Within-person variability in urinary bisphenol A concentrations: measurements from specimens after long-term frozen storage. *Environ. Res.* 2009; 109(6):734–737.
 60. Yang M, Ryu JH, Jeon R, Kang D, Yoo KY. Effects of bisphenol A on breast cancer and its risk factors. *Arch. Toxicol.* 2009; 83:281–285.
 61. Bushnik T, Haines D, Levallois P, Levesque J, Van Oostdam J, Viau C. Lead and bisphenol A concentrations in the Canadian population. *Health Rep.* 2010; 21(3):7–18.

62. Mendiola J, Jørgensen N, Andersson AM, Calafat AM, Ye X, Redmon JB, Drobni EZ, Wang C, Sparks A, Thurston SW, Liu F, Swan SH. Are environmental levels of bisphenol A associated with reproductive function in fertile men? *Environ. Health Perspect.* 2010; 118(9):1286–1291.
63. Chou WC, Chen JL, Lin CF, Chen YC, Shih FC, Chuang CY. Biomonitoring of bisphenol A concentrations in maternal and umbilical cord blood in regard to birth outcomes and adipokine expression: a birth cohort study in Taiwan. *Environ. Health*, 2011, 10:94–103.
64. Völkel W, Kiranoglu M, Fromme H. Determination of free and total bisphenol A in urine of infants. *Environ. Res.* 2011; 111:143–148.
65. Genuis SJ, Beesoon S, Birkholz D, Lobo RA. Human excretion of bisphenol A: blood, urine, and sweat (BUS) study. *J. Environ. Public Health*, 2012; (2012):185731.
66. Rudkowski Z. Narażenie środowiskowe i wpływ na zdrowie dzieci chemikaliów zawartych w materiałach plastikowych – wyzwania także dla pediatrów *Environmental risk and influence of chemicals from plastic materials on children's health – the challenge also for paediatricians. Environmental Medicine*, 2013; 16(1):7–15.
67. Vandenberg LN, Maffini MV, Sonnenschein C, Rubin BS, Soto AM. Bisphenol-A and the great divide: a review of controversies in the field of endocrine disruption. *Endocr. Rev.* 2009; 30(1):75–95.
68. Kuch HM, Ballschmiter K. Determination of endocrine-disrupting phenolic compounds and estrogens in surface and drinking water by HRGC-(NCI)-MS in the picogram per liter range. *Environ. Sci. Technol.* 2001; 35:3201–3206.
69. Belfroid A, van Velzen M, van der Horst B, Vethaak D. Occurrence of bisphenol A in surface water and uptake in fish: evaluation of field measurements. *Chemosphere*, 2002; 49:97–103.
70. Fromme H, Küchler T, Otto T, Pilz K, Müller J, Wenzel A. Occurrence of phthalates and bisphenol A and F in the environment. *Water Res.* 2002; 36:1429–1438.
71. Basheer C, Lee HK. Analysis of endocrine disrupting alkylphenols, chlorophenols and bisphenol-A using hollow fiber-protected liquid-phase microextraction coupled with injection port-derivatization gas chromatography-mass spectrometry. *J Chromatogr. A*, 2004; 1057(1-2):163–169.
72. Jin XL, Jiang GB, Huang GL, Liu JF, Zhou QF. Determination of 4-tert-octylphenol, 4-nonylphenol and BPA in surface waters from the Haihe River in Tianjin by gas chromatography-mass spectrometry with selected ion monitoring. *Chemosphere*, 2004; 56(11):1113–1119.
73. Kawahata H, Ohta H, Inoue M, Suzuki A. Endocrine disrupter nonylphenol and bisphenol A contamination in Okinawa and Ishigaki Islands, Japan-within coral reefs and adjacent river mouths. *Chemosphere*, 2004; 55(11):1519–1527.
74. Laganà A, Bacaloni A, de Leva I, Faberi A, Fago G, Marino A. Analytical methodologies for determining the occurrence of endocrine disrupting chemicals in sewage treatment plants and natural waters. *Anal. Chim. Acta*, 2004; 501(1):79–88.
75. Liu R, Zhou JL, Wilding A. Simultaneous determination of endocrine disrupting phenolic compounds and steroids in water by solid-phase extraction-gas chromatography-mass spectrometry. *J. Chromatogr. A*, 2004; 1022:179–189.
76. Brossa L, Marce RM, Borrull F, Pocurull E. Occurrence of twenty-six endocrine-disrupting compounds in environmental water samples from Catalonia, Spain. *Environ. Toxicol. Chem.* 2005; 24(2):261–267.
77. Hashimoto S, Horiuchi A, Yoshimoto T, Nakao M, Omura H, Kato Y, Tanaka H, Kannan K, Giesy JP. Horizontal and vertical distribution of estrogenic activities in sediments and waters from Tokyo Bay, Japan. *Arch. Environ. Contam. Toxicol.* 2005; 48(2):209–216.
78. Rodriguez-Mozaz S, Lopez de Alda M, Barcelo D. Analysis of bisphenol A in natural waters by means of an optical immunosensor. *Water Res.* 2005; 39(20):5071–5079.
79. Céspedes R, Lacorte S, Ginebreda A, Barcelo D. Chemical monitoring and occurrence of alkylphenols, alkylphenol ethoxylates, alcohol ethoxylates, phthalates and benzothiazoles in sewage treatment plants and receiving waters along the Ter River basin (Catalonia, N. E. Spain). *Anal. Bioanal. Chem.* 2006; 385(6):992–1000.
80. Voutsas D., Hartmann P., Schaffner C., Giger W. Benzotriazoles, alkylphenols and bisphenol A in municipal wastewaters and in the Glatt River, Switzerland. *Environ. Sci. Pollut. Res. Int.* 2006; 13(5):333–341.
81. Loos R, Hanke G, Umlauf G, Eisenreich SJ. LC-MS-MS analysis and occurrence of octyl- and nonylphenol, their ethoxylates and their carboxylates in Belgian and Italian textile industry, waste water treatment plant effluents and surface waters. *Chemosphere*, 2007; 66(4):690–699.
82. Bolz U, Hagenmaier H, Koerner W. Phenolic xenoestrogens in surface water, sediments, and sewage sludge from Baden-Württemberg, south-west Germany. *Environ. Pollut.* 2001; 115(2):291–301.
83. Peng X, Wang Z, Yang C, Chen F, Mai B. Simultaneous determination of endocrine-disrupting phenols and steroid estrogens in sediment by gas chromatography-mass spectrometry. *J. Chromatogr. A*, 2006; 1116:51–56.
84. Kitada Y, Kawahata H, Suzuki A, Oomori T. Distribution of pesticides and bisphenol A in sediments collected from rivers adjacent to coral reefs. *Chemosphere*, 2008; 71:2082–2090.
85. Bian H, Li Z, Liu P, Pan J. Spatial distribution and deposition history of nonylphenol and bisphenol A in sediments from the Changjiang River (Yangtze River) Estuary and its adjacent East China Sea. *Acta Oceanol. Sin.* 2010; 29(5):44–51.
86. Matsumoto H, Adachi S, Suzuki Y. Bisphenol A in ambient air particulates responsible for the proliferation of MCF-7 human breast cancer cells and its concentra-

- tion changes over 6 months. *Arch. Environ. Contam. Toxicol.* 2005; 48(4):459–66.
87. Fu P, Kawamura K. Ubiquity of bisphenol A in the atmosphere. *Environ. Pollut.* 2010; 158(10):3138–3143.
88. Rudel RA, Brody JG, Spengler JD, Vallarino J, Geno PW, Sun G, Yau A. Identification of selected hormonally active agents and animal mammary carcinogens in commercial and residential air and dust samples. *Air & Waste Manage. Assoc.*, 2001; 51:499–513.
89. Wilson NK, Chuang JC, Morgan MK, Lordo RA, Sheldon LS. An observational study of the potential exposures of preschool children to pentachlorophenol, bisphenol-A, and nonylphenol at home and daycare. *Environ. Res.* 2007; 103:9–20.
90. Loganathan SN, Kannan K. Occurrence of bisphenol A in indoor dust from two locations in the eastern United States and implications for human exposures. *Arch. Environ. Contam. Toxicol.* 2011; (61):68–73.
91. Zhou H, Huang X, Wang X, Zhi X, Yang C, Wen X, Wang Q, Tsuno H, Tanaka H. Behaviour of selected endocrine-disrupting chemicals in three sewage treatment plants of Beijing, China. *Environ. Monit. Assess.* 2010; 161:107–121.
92. Langdon K, Warne M, Smernik R, Shareef A, Kookana R. Selected personal care products and endocrine disruptors in biosolids: An Australia-wide survey. *Sci. Total Environ.* 2011; 409(6):1075–1081.
93. Szychowski KA, Wójtowicz AK. Składniki tworzyw sztucznych zaburzające funkcje układu nerwowego Components of plastic disrupt the function of the nervous system. *Postępy Hig. Med. Dośw.* 2013; 67:499–506.
94. Bhandari R, Xiao J, Shanka A. Urinary bisphenol A and obesity in US children. *Am. J. Epidemiol.* 2013; 177(11):1263–1270.
95. Hiroi H, Tsutsumi O, Takeuchi T, Momoeda M, Ikezuki Y, Okamura A, Yokota H, Taketani Y. Differences in serum bisphenol A concentrations in premenopausal normal women and women with endometrial hyperplasia. *Endocr. J.* 2004; 51:595–600.
96. Krieter DH, Canaud B, Lemke HD, Rodriguez A, Morgenroth A, von Appen K, Dragoun GP, Wanner C. Bisphenol A in chronic kidney disease. *Artif. Organs*, 2013; 37(3):283–290.
97. Lang IA, Galloway TS, Scarlett A, Henley WE, Depledge M, Wallace RB, Melzer D. Association of urinary bisphenol A concentration with medical disorders and laboratory abnormalities in adults. *JAMA*, 2008; 300(11):1303–1310.
98. Galloway T, Cipelli R, Guralnik J, Ferrucci L, Bandinelli S, Corsi AM, Money C, McCormack P, Melzer D. Daily bisphenol A excretion and associations with sex hormone concentrations: results from the InCHIANTI adult population study. *Environ. Health Perspect.* 2010; 118:1603–1608.
99. Bloom MS, vom Saal FS, Kim D, Taylor JA, Lamb JD, Fujimoto VY. Serum unconjugated bisphenol A concentrations in men may influence embryo quality indicators during in vitro fertilization. *Environ. Toxicol. Pharmacol.* 2011; 32:319–323.
100. Fujimoto VY, Kim D, vom Saal FS, Lamb JD, Taylor JA, Bloom MS. Serum unconjugated bisphenol A concentrations in women may adversely influence oocyte quality during in vitro fertilization. *Fertil. Steril.* 2011; 95:1816–1819.
101. Spanier AJ, Kahn RS, Kunselman AR, Hornung R, Xu Y, Calafat AM, Lanphear BP. Prenatal exposure to bisphenol A and child wheeze from birth to 3 years of age. *Environ. Health Perspect.* 2012; 120:916–920.
102. Braun JM, Kalkbrenner AE, Calafat AM, Yoltan K, Ye X, Dietrich KN, Bruce P, Lanphear B.P. Impact of early-life bisphenol A exposure on behavior and executive function in children. *Pediatrics*, 2011; 128:873–882.

Correspondence address:

Elżbieta Włodarczyk, dr inż.
Department of Toxicology and Bioanalytics,
Koszalin University of Technology
ul. Śniadeckich 2
75-453 Koszalin
ewlod@wilsig.tu.koszalin.pl