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Bisphenol S – Evaluation of a BAR

Assessment Values in Biological Material – Translation of the German version from 2020

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Keywords

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Abstract

In 2019, the German Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area has derived a BAR (biological reference value) for urinary bisphenol S [80-09-1] based on altogether 15 study reports from several countries around the world.

Population-based human biomonitoring studies have revealed a general background concentration of bisphenol S in urine in European, North-American and Asian countries. Since the use of bisphenol S in consumer products varies from country to country, and additionally underlies changes over time due to the ongoing substitution of bisphenol A by bisphenol S, the main focus for the derivation of a BAR was laid on available data from Western European countries. Studies from North America show, however, that higher levels are observed in the United States (~ 4 µg/l), suggesting that urinary bisphenol S levels may still increase in other countries, including Germany. Therefore, the established BAR of 1 µg bisphenol S/l urine is explicitly 'provisional' and it should be re-evaluated when further studies are available.

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BAR (2019)	**1 µg bisphenol S (after hydrolysis)/l urine**
	Sampling time: end of exposure or end of shift
Synonyms	4,4′-dihydroxydiphenylsulfone 4,4′-sulfonyldiphenol
CAS No.	80-09-1
Formula	$C_{12}H_{10}O_4S$
Molar mass	250.28 g/mol
Melting point	242–248 °C (ECHA 2019)
Boiling point	no data
Vapour pressure at 25 °C	6.29×10^{-10} hPa (ECHA 2019)
Density at 20 °C	1.4 g/cm^3 (ECHA 2019)

Bisphenol S is used in the production of polymer plastics (for example polyethersulfones), leather tanning agents and paper chemicals (for example as colour developer in thermal papers). In the European Union bisphenol S is registered in a tonnage band of 10 000–100 000 t per year (ECHA 2019).

1 Metabolism and Toxicokinetics

The metabolism and toxicokinetics of bisphenol S were investigated in several in vitro studies (Gramec Skledar et al. 2015; Gramec Skledar and Peterlin Mašič 2016; Grignard et al. 2012; Le Fol et al. 2015) as well as in a study in humans with oral administration (Oh et al. 2018). Like the structurally related bisphenol A, bisphenol S is rapidly and almost completely glucuronidated or sulfated at the hydroxyl groups (Gramec Skledar and Peterlin Mašič 2016; Figure 1).

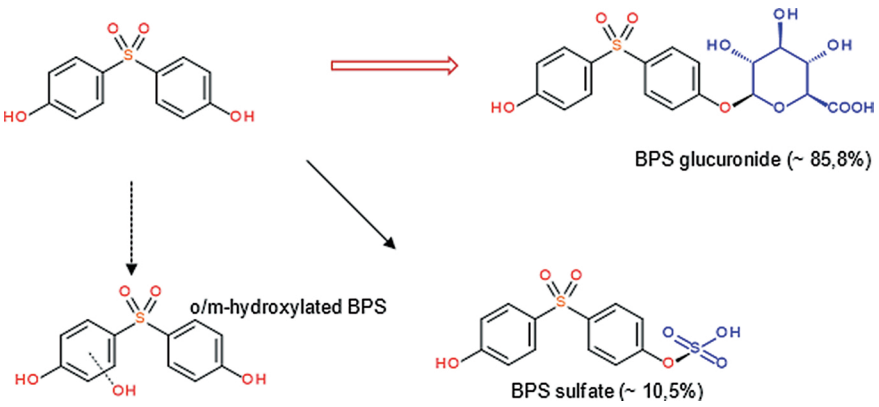

Fig. 1 Metabolism of bisphenol S in vitro (according to Gramec Skledar and Peterlin Mašič 2016)

In a human study, Oh et al. (2018) investigated the plasma concentrations and the elimination of glucuronidated/sulfated as well as unchanged d_4-bisphenol S in urine after oral administration to four men and three women over a period of 48 hours. The plasma concentration of both parameters increased rapidly within the first hour after ingestion of bisphenol S up to the maximum value.

The observed half-lives of glucuronidated/sulfated and metabolically unchanged d_4-bisphenol S in urine were 6.81 hours and 4.06 hours, respectively. Altogether 82% (range: 59% to 104%) of the absorbed dose were excreted within 48 hours of which 2.5% (range: 0.9% to 4.1%) as unchanged compound.

2 Critical Toxicity

According to CLP Regulation (EC) 1272/2008, bisphenol S is self-classified as presumably toxic to human reproduction (impairment of fertility) (Category 2) (ECHA 2019).

In animal experiments, the acute toxicity of bisphenol S in rats was found to be low with an LD_{50} of 2830 mg/kg body weight (bw) after oral administration and 2000 mg/kg bw after dermal application. No data are available for its acute toxicity after inhalation exposure. After chronic oral exposure of rats, effects on the reproductive organs, the liver and the haematopoietic system were observed. For chronic toxicity, from the data from experiments in rats, a DNEL (derived no effect level) of 7 mg/m^3 was derived for inhalation exposure and 20 mg/kg bw and day for dermal exposure of workers (ECHA 2019).

3 Exposure and Effects

To date, no studies are available for exposure and effects.

4 Selection of the Indicators

Oh et al. (2018) conducted an experimental study in humans, in which bisphenol S was determined both in the plasma and in the urine of seven test persons. In the majority of the studies published to date the total urinary concentration of bisphenol S after hydrolysis was determined as indicator of an exposure (for example Heffernan et al. 2016; Jäger et al. 2017; Liao et al. 2012; Ndaw et al. 2018; Philips et al. 2018; Rocha et al. 2016; Vela-Soria et al. 2014 a; Xue et al. 2015; Yang et al. 2014; Zhang et al. 2016; Zhou et al. 2014). In some cases, also the bisphenol S excreted in unchanged form was analysed (for example Ndaw et al. 2018; Yang et al. 2014; Zhou et al. 2014).

For the determination of bisphenol S in plasma samples studies are available using the LC-MS/MS technique (Grandin et al. 2017; Kolatorova et al. 2017; Kolatorova Soskorova et al. 2018). However, the results of these studies are not sufficient to derive reliable and representative concentrations of bisphenol S in a reference collective or in the general population. Deceuninck et al. (2015) reported about the determination of bisphenol S in mother's milk.

Due to the very good database available for the concentration of bisphenol S in urine after hydrolysis, which makes possible also a direct comparison with established procedures and results for bisphenol A and other bisphenols, this parameter is a suitable and preferred indicator of an exposure to bisphenol S.

5 Analytical Methods

The most frequently described and used method to determine and quantify bisphenol S in body fluids is liquid chromatography with tandem-mass spectrometric detection (HPLC-MS/MS) after preceding enzymatic hydrolysis of the conjugates and liquid-liquid extraction (for example Andra et al. 2015; Liao et al. 2012; Rocha et al. 2016; Zhou et al. 2014). Some studies described also gas chromatographic-mass spectrometric procedures (GC-MS/MS) (for example Deceuninck et al. 2015; Vela-Soria et al. 2014 b). The precision obtained in most procedures is good (5% to 10% in the environmentally relevant concentration range) and the communicated limits of detection and quantification vary between about 0.01 and 0.1 µg/l.

6 Background Exposure

For the background exposure of persons not occupationally exposed to bisphenol S results of altogether 15 studies since 2012 are available, which are summarized in Table 1.

Tab. 1 Investigations on the background exposure to bisphenol S

Collective	%> LOQ	Bisphenol S in urine [µg/l urine (µg/g creatinine)]					References
		Mean	Median	95th Percentile	Range	LOD/LOQ	
n = 315 (2–84 years)	81	0.168 (0.176) [a]	0.191 (0.200)	2.50 (2.62)	< LOQ–21.0 (< LOQ–14.0)	–/0.02	Liao et al. 2012
USA (n = 31)	97	0.299 (0.304) [a]	0.263 (0.262)	2.65 (1.40)	< LOQ–21.0 (< LOQ–7.57)		
China (n = 89)	82	0.226 (0.223) [a]	0.297 (0.300)	1.73 (2.51)	< LOQ–3.16 (< LOQ–6.64)		
India (n = 38)	76	0.072 (0.098) [a]	0.055 (0.111)	0.71 (1.50)	< LOQ–0.881 (< LOQ–4.72)		
Japan (n = 36)	100	1.180 (0.933) [a]	1.040 (0.827)	7.76 (4.83)	0.147–9.57 (0.148–14.0)		
Korea (n = 33)	42	0.030 (0.031) [a]	0.014 (0.025)	0.17 (0.12)	< LOQ–1.98 (< LOQ–2.70)		
Kuwait (n = 30)	70	0.172 (0.126) [a]	0.371 (0.158)	1.65 (1.78)	< LOQ–12.1 (< LOQ–6.69)		
Malaysia (n = 29)	76	0.071 (0.155) [a]	0.084 (0.121)	0.25 (2.36)	< LOQ–0.922 (< LOQ–5.22)		
Vietnam (n = 29)	100	0.160 (0.148) [a]	0.157 (0.129)	0.39 (0.42)	0.037–0.932 (0.050–0.660)		
n = 94, China (50 ♀, 26–79 years), (44 ♂, 26–84 years)	22.3	0.029 (0.028) [a]	< LOD	< LOQ [c]	< LOD–2.511 (< LOD–7.046)	0.01/0.032	Yang et al. 2014
n = 100, USA	78		0.13		< LOD–12.3	0.03/–	Zhou et al. 2014
n = 76, children, India (2–14 years)	70	0.04 (0.03) [a] 0.250 (0.17) [b]			0.01–12.2 (< 0.001–8.08)		Xue et al. 2015
n = 49 (high BMI)		0.050 (0.036) [b]					
n = 27 (normal BMI)		0.610 (0.408) [b]					
n = 616, USA						0.1/–	Ye et al. 2015
2000 (n = 79)	25	no data	< LOD	0.3			
2001 (n = 67)	19	no data	< LOD	0.7			
2007 (n = 27)	22	no data	< LOD	1.2			
2009 (n = 122)	73	0.18 [a]	0.1	1.1			
2010 (n = 43)	65	0.17 [a]	0.1	1.0			
2011 (n = 95)	63	0.17 [a]	0.1	1.5			
2013 (n = 141)	74	0.22 [a]	0.2	1.3			
2014 (n = 42)	74	0.25 [a]	0.2	1.8			

Tab. 1 *(continued)*

Collective	% > LOQ	Bisphenol S in urine [µg/l urine (µg/g creatinine)]					References
		Mean	Median	95th Percentile	Range	LOD/LOQ	
n = 158, China						–/0.12	Zhang et al. 2016
a) people living near waste recycling facilities (n = 116, 50 ♀, 66 ♂, 0.4–87 years)	97	0.361 (0.469) [a]	0.364 (0.500)		< BG–1.38 (< BG–2.48)		
b) rural residents (n = 22; 11 ♀, 11 ♂)	100	0.388 (1.030) [a]	0.398 (0.914)		0.192–1.07 (0.477–2.12)		
c) urban residents (n = 20; 11 ♀, 9 ♂)	100	0.652 (1.51) [a]	0.835 (1.680)		0.113–1.57 (0.412–4.21)		
n = 130, Saudi Arabia (36 ♀, 31 ♂, 1–87 years)	100	13.3 [b]	4.92		0.077–630		Asimakopoulos et al. 2016
n = 30, pregnant ♀, Australia	10		0.3		< LOR–8.1	0.067 [d]/0.22–0.47 [e]	Heffernan et al. 2016
n = 50, Brazil (20 ♀, 30 ♂)	10				< LOQ–no data (no data)	0.01/0.04	Rocha et al. 2016
n = 21, USA		no data (0.41) [a]			no data (< LOD–11.04)	0.01–0.02/–	Thayer et al. 2016
n = 146, Germany (48 ♀, 98 ♂, 21–64 years)	86	0.18 (0.21) [b]	0.10 (0.10)	0.64 (0.49)	< LOQ–2.75 (< LOQ–7.43)	–/0.05	Jäger et al. 2017
n = 15, France (7 ♀, 8 ♂, 21–55 years)	96	0.72 (0.52) [a] 5.26 (2.34) [b]	0.67 (0.52)	12.6 (9.65)	< LOQ–229 (< LOQ–77.8)	–/0.1	Ndaw et al. 2018
n = 1396, pregnant ♀, Netherlands	52.7		0.36	1.08 [c]			Philips et al. 2018
n = 455, ♀, 3 months after delivery, Canada (32 ± 4.1 years)	64	0.17 (0.20) [a]	0.13 (0.17)	1.30 (1.31) 0.27 (0.38) [c]	< LOQ–72.1 (< LOQ–67.2)		Liu et al. 2018
n = 1812 (1810), USA (≥ 20 years)		0.441 (0.444) [a]	0.400 (0.389)	3.80 (3.49) 0.900 (0.839) [c]			CDC 2018

[a] GM: geometric mean; [b] AM: arithmetic mean; [c] 75th percentile; [d] MDL: method detection limit; [e] LOR: limit of reporting
BMI: body mass index; LOD: limit of detection; LOQ: limit of quantification

For the first time, Liao et al. (2012) reported about bisphenol S concentrations in urine samples obtained during the years 2010 and 2011 in the framework of an international research project comparison. Altogether 315 samples from seven Asian countries (China, India, Japan, Korea, Kuwait, Malaysia, Vietnam) and the USA (Albany, NY) were analysed. The random sample comprised 152 men and 150 women. Bisphenol S was found in 81% of all samples. The 95th percentile of the bisphenol S concentration in urine for the total random sample was 2.50 µg bisphenol S/l urine or 2.62 µg/g creatinine (median: 0.191 µg/l urine or 0.200 µg/g creatinine). The results from Japan (7.76 µg bisphenol S/l urine or 4.83 µg/g creatinine for the 95th percentile and 1.040 µg bisphenol S/l urine (0.827 µg/g creatinine) were clearly above the reference values for the samples from the other countries. In Japan, according to Liao et al. (2012), bisphenol S has been increasingly used as a substitute for bisphenol A in thermal paper since 2001, while in the USA an important thermal paper manufacturer had announced their intention in 2006 to substitute bisphenol S for bisphenol A. It is therefore striking that, despite relatively low median and 95th percentile values (0.263 µg

bisphenol S/l and 2.65 µg/l urine, respectively) in the 31 samples from the USA high individual values were found with obviously higher frequency (21 µg bisphenol S/l or 7.57 µg/g creatinine). In the 36 samples from Japan the median and the 95th percentile were 1.040 µg bisphenol S/l and 7.76 µg bisphenol S/l urine, respectively, the maximum value however was only 9.57 µg/l urine (14 µg/g creatinine).

Yang et al. (2014) analysed spontaneous urine samples of a total of 94 residents living near a manufacturing plant of bisphenol AF in China. The samples were collected in 2013. The authors found bisphenol S in about 40% of all samples, but quantification was possible only in about 20% of the samples. The geometric mean was 0.029 µg bisphenol S/l urine (0.028 µg/g creatinine) and thus in the range of the quantification limit of the method used (0.032 µg/l), the maximum was 2.511 µg bisphenol S/l urine (7.046 µg/g creatinine). The authors stated that their results were lower than the concentrations determined by Liao et al. (2012) in urine samples from China by a factor of 10 (geometric mean: 0.226 µg bisphenol S/l or 0.223 µg/g creatinine, n = 89). Yang et al. (2014) assumed that the environment- and life style-related background exposure, for example bisphenol S absorption from plastic products, varies strongly in various geographic regions in China.

In the process of developing and testing of methods, Zhou et al. (2014) analysed a total of 100 spontaneous urine samples of adult residents of Atlanta (GA, USA) obtained in the years 2009 to 2012. Bisphenol S was detected in 78% of all samples. The median was 0.13 µg/l urine, the maximum value 12.3 µg bisphenol S/l urine.

A study by Xue et al. (2015) with altogether 76 children (aged 2 to 14 years) from India, of which 49 were categorized as obese, revealed an arithmetic mean value of 0.25 µg bisphenol S/l (0.17 µg/g creatinine). The geometric mean was only 0.04 µg bisphenol S/l (0.03 µg/g creatinine). The obvious strongly left skewed distribution was attributed to the significant difference between obese and non-obese children (arithmetic mean 0.05 µg bisphenol S/l or 0.036 µg/g creatinine for the group of obese children versus 0.610 µg bisphenol S/l urine or 0.408 µg/g creatinine for children with normal body weights). The maximum value for urinary bisphenol S in this study was 12.2 µg/l urine or 8.08 µg/g creatinine.

Ye et al. (2015) described the results of a longitudinal study on bisphenol S concentrations in a total of 616 urine samples, which were collected in the years from 2000 to 2014 in Atlanta (GA, USA). Between 27 and 141 urine samples per year were selected and analysed. The authors found out that the median bisphenol S concentrations in this period increased from < 0.1 µg bisphenol S/l urine (2000–2007) over 0.1 µg/l urine (2009–2011) to 0.2 µg/l urine (2013–2014). The 95th percentiles increased accordingly from 0.3 µg bisphenol S/l urine (2000) to 1.8 µg/l urine (2014). This upward trend was confirmed by an increasing detection frequency (2000: 25%; 2014: 74%). In this study an opposite trend was found for urinary bisphenol A (2000: 95th percentile 7.4 µg bisphenol S/l urine, detected in 97% of the analysed samples; 2014: 95th percentile 1.7 µg/l urine, detected in 74% of the analysed samples). These observations support the assumption already made by Liao et al. (2012) that, due to regulation or voluntary measures, bisphenol A in consumer-relevant products has been increasingly substituted by alternative substances, for example by bisphenol S.

Zhang et al. (2016) analysed the bisphenol S concentrations in urine samples of 116 people living near e-waste recycling facilities in China and compared them with reference collectives (urban, rural) (year of examination 2014). The median value for bisphenol S concentrations in the samples of the people living near e-waste recycling facilities was 0.364 µg bisphenol S/l urine (0.500 µg/g creatinine), the maximum value was 1.38 µg bisphenol S/l urine (2.48 µg/g creatinine). Similar concentrations were found in the urine samples of the rural study group (n = 22): median 0.398 µg bisphenol S/l urine or 0.914 µg/g creatinine, maximum 1.07 µg bisphenol S/l urine (2.12 µg/g creatinine). The results for the urban reference group were higher than these (median: 0.835 µg bisphenol S/l urine or 1.68 µg/g creatinine, maximum: 1.57 µg/l urine or 4.21 µg/g creatinine). The authors assume that urban dwellers have more frequently contact with bisphenol S-containing products (packaged food, personal care articles, paper products).

In a study with a total of 30 pregnant Australian women, Heffernan et al. (2016) found bisphenol S only in three urine samples (10%). The maximum value was 8.1 µg bisphenol S/l urine. The limits of detection and quantification

of the LC-QTRAP-MS/MS procedure used by Heffernan et al. (2016) are comparatively high (0.067 µg bisphenol S/l urine and 0.22–0.47 µg/l, respectively).

Asimakopoulos et al. (2016) described the results of 130 persons from Jeddah, Saudi Arabia, who were examined in 2014. Bisphenol S could be detected in all samples (limit of detection 0.035 µg bisphenol S/l urine). The median was 4.92 µg bisphenol S/l urine (mean value: 13.3 µg/l) and the maximum was 630 µg bisphenol S/l urine. The results of the study by Asimakopoulos et al. (2016) are markedly above all background exposure data known to date. The authors assume a particularly widespread use of bisphenol S and a corresponding exposure of the population in Saudi Arabia and other countries with tropical climate, since bisphenol S is comparatively more heat and light stable than bisphenol A.

In the process of method development and application, Rocha et al. (2016) analysed urine samples from a total of 50 Brazilians. In spite of low limits of detection and quantification (0.01 µg bisphenol S/l urine and 0.04 µg/l, respectively), the authors found bisphenol S only in 10% of all samples. Data on median values or 95th percentiles are not given.

Thayer et al. (2016) reported about the analyses of bisphenol S in urine and serum samples of male and female cashiers in restaurants, grocery stores, pharmacies, clothing stores, book stores and home improvement centers in Raleigh, Durham and Chapel Hill (NC, USA). In this study, an internal reference group of 21 persons without known occupational contact with bisphenol S-containing materials or thermal paper cashier receipts was used. In this group the geometric mean for the urinary bisphenol S concentration was 0.41 µg/g creatinine, the maximum value was 11.04 µg/g creatinine.

In a study on the occupational exposure to bisphenol S in an industrial location in Germany, Jäger et al. (2017) analysed spot urine samples of a total of 142 persons of an internal reference collective in 2017. The detection and quantification limits of the LC-MS/MS procedure used were 0.01 µg bisphenol S/l urine and 0.05 µg/l urine, respectively. The authors found bisphenol S in 86% of all samples. The median was 0.10 µg bisphenol S/l urine (0.10 µg/g creatinine), the 95th percentile 0.64 µg bisphenol S/l urine or 0.49 µg bisphenol S/g creatinine (maximum: 2.75 µg/l urine or 7.43 µg/g creatinine). In the same study, urinary bisphenol A was determined. The results (95th percentile: 5.1 µg/l or 6.0 µg/g creatinine) were in good agreement with the reference value of 7 µg/l for urinary bisphenol A which the Human Biomonitoring Commission of the Federal Environment Agency has communicated for persons aged between 20 and 29 years (UBA 2012).

Within the framework of an investigation of bisphenol S exposure of cashiers in two supermarkets in France, Ndaw et al. (2018) analysed a total of 73 or 70 urine samples (volume-related or creatinine-related determination) of 15 employees of the respective supermarkets without known contact with thermal paper cashier receipts. The urine samples were collected before and after a shift and the following morning. Ndaw et al. (2018) found a median bisphenol S concentration in the urine of the reference group of 0.67 µg/l or 0.52 µg/g creatinine, the 95th percentile was 12.6 µg/l urine or 9.65 µg/g creatinine. In this study, very high maximum values for urinary bisphenol S were found (229 µg/l urine or 77.8 µg/g creatinine).

Philips et al. (2018) reported the results of a study in which bisphenol S was analysed in urine samples from 1396 pregnant women in the Netherlands. Sampling took place as early as in the years 2004–2005. The authors could determine bisphenol S in 52.7% of all urine samples, the median was 0.36 µg/l urine, the 75th percentile 1.08 µg bisphenol S/l urine. For the calculation of the statistical parameters, the results below the limit of quantification were not considered. Unlike in other studies, in which such samples are usually taken into account by using half the detection or quantification limits for calculation, higher concentrations for the relevant statistical descriptive parameters are thus obtained for methodological reasons in this study.

In a study with 455 Canadian women, who were examined three months after delivery, Liu et al. (2018) found a geometric mean value for the urinary bisphenol S of 0.17 µg/l or 0.20 µg/g creatinine. The 95th percentile was 1.30 µg/l urine or 1.31 µg/g creatinine (maximum: 72.1 µg bisphenol S/l urine or 67.2 µg/g creatinine), the detec-

tion frequency was 64%. During pregnancy, comparable bisphenol S concentrations had been found (detection frequency: 59%, median: 0.12 µg/l urine or 0.19 µg/g creatinine, 95th percentile: 1.16 µg bisphenol S/l urine or 1.58 µg/g creatinine, maximum: 243 µg bisphenol S/l urine or 192 µg/g creatinine).

In March 2018, the Centers for Disease Control and Prevention (CDC) published updated results from the fourth National Health and Nutrition Examination Study (NHANES) in the USA. In a study collective of altogether 1812 or 1810 persons older than 20 years a median value of 0.400 µg bisphenol S/l urine (0.389 µg/g creatinine) and a 95th percentile of 3.80 µg bisphenol S/l urine (3.49 µg/g creatinine) were determined (CDC 2018). Lehmler et al. (2018) summarized the results of the NHANES study: For a slightly smaller number of persons (n = 1808, older than 20 years) a median of 0.37 µg bisphenol S/l urine and a 75th percentile of 0.88 µg/l urine were calculated.

7 Evaluation

For the evaluation of a biological reference value (BAR), two fundamental findings of the studies published to date have to be taken into consideration, namely that the country of the investigation and the geographical origin of the examined collective have a major influence on the results of studies on the general background exposure. As bisphenol S is mainly used in plastics as well as in thermal papers and leather tanning agents, their use in the respective country is decisive for a possible exposure and burden. In addition, the results of Ye et al. (2015) and CDC (2018) point to a tendential increase in the background exposure to bisphenol S over time, at least in some industrialized countries. For this reason, it is meaningful, for the derivation of a provisional BAR, to use a current collective from the European Union or from a country with comparable regulatory requirements with regard to the use of bisphenol S and substitution of bisphenol A by bisphenol S.

This criterion is currently fulfilled only by the studies of Jäger et al. (2017), Liu et al. (2018) and CDC (2018) and, to a limited extent, by Ye et al. (2015) and Heffernan et al. (2016). In spontaneous urine samples of 146 persons from an internal reference collective (creatinine concentration 0.3–3.0 g/l) from Germany, the 95th percentile of the bisphenol S concentration after hydrolysis was 0.64 µg/l urine or 0.49 µg/g creatinine (Jäger et al. 2017). Liu et al. (2018) analysed 455 urine samples of Canadian women after pregnancy and found a 95th percentile for bisphenol S excretion of 1.30 µg/l urine or 1.31 µg/g creatinine. For a random sample of about 1800 persons from the USA, the NHANES data from 2013–2014 showed a 95th percentile of 3.80 µg bisphenol S/l urine or 3.49 µg/g creatinine. In contrast, a random sample from the USA on a markedly smaller scale (Ye et al. 2015) for the years 2013 and 2014 yielded markedly lower 95th percentiles of 1.3 µg bisphenol S/l urine (141 persons) and 1.8 µg/l urine (42 persons). Heffernan et al. (2016) investigated a random sample of Australian women post partum and found a median urinary bisphenol S concentration of 0.3 µg/l urine and a maximum of 8.1 µg/l urine. In summary, the NHANES results indicate a higher background exposure to bisphenol S in the USA compared with Germany and other industrialized countries.

From the study results of Jäger et al. (2017) and Liu et al. (2018) a background exposure (95th percentile) and thus a provisional

BAR of 1 µg bisphenol S (after hydrolysis)/l urine

can be derived. The provisional nature of the value is due to the comparatively low number of cases in the studies mentioned and to the fact that representative population-based studies for the population in Germany are not available.

8 Interpretation

The BAR relates to normally concentrated urine, in which the creatinine concentration should be in the range between 0.3 and 3 g/l urine. As a rule, where urine samples are outside the above limits, a repetition of the measurement in normally hydrated test persons is recommended (Bader and Ochsmann 2016).

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