Residual Butadiene in BD-derived polymers and resins – Summary of the evidence

A non-systematic literature search was carried out to identify references that report measurements of residual 1,3-Butadiene (1,3-BD) in Butadiene-derived polymers and resins or assessed the potential migration of residual 1,3-BD from such polymers and resins. The following paragraphs summarize theoretical considerations and references and table 1 contains the reported values found in the previous 20 years of literature, while Appendix 1 provides an annotated bibliography. Appendix 2 provides links to studies that have assessed migration of additives or monomers from butadiene-derived polymers or resins, but do not report any measured butadiene, which has consistently been identified as the monomer with the lowest presence in the resins (compared to the other components).

Residual 1,3-BD in BD-derived resins and polymers

Since 1,3-BD is part of the building blocks for many plastics and resins (i.e., Styrene-Butadiene Rubber (SBR), Acrylonitrile-butadiene-styrene (ABS), etc.), it is expected that residual monomers in plastic will always be present to a certain extent (Ministry of Environment and Food Denmark, 2019).

Since butadiene has a low boiling point (-4.5°C) and thus is gas at room temperature, it can be expected based on theoretical considerations that any bioavailable residues of this monomer will easily evaporate from the polymer or during the high moulding process temperatures unless the residues are encapsulated in the polymer.

A good example is the heating of the plastic for calendaring/extrusion or mixing, all the way to vulcanization of SBR. These processes will lead to the volatilization of part or all (in the case of vulcanization, as demonstrated by EPA, 2017) the residual BD in the resins. Through heating, the solubility of most substances increases which will counteract a possible degassing of monomers with low boiling point and/or high vapor pressure. From theoretical considerations based on reaction kinetics it can be expected that there will be a correlation between process type and removal of residual monomers. (Ministry of Environment and Food Denmark, 2019).

Table 1 summarizes the reported concentrations measured and reported in public literature. An example are vendor specifications for Styrene Butadiene Rubber Copolymer (Food) with a maximum concentration of 0.5 mg/kg of 1,3-BD in the gum.

Several unpublished studies were identified that assessed residual levels of BD monomer in materials. The results of an unpublished survey conducted in 2020 with the manufacturers of synthetic rubber in the USA indicate that BD monomer levels were below the limit of detection (Table 2a,b). Similarly, the International Institute of Styrene Butadiene Rubber Producers shared data on residual butadiene in these rubbers, as reported by the Association of Petrochemical Industry of Japan (IISRP, 2020)

An unpublished study from 2001 measured the levels of BD monomer in four different ABS plastic samples, yielding a single detection that occurred at the detection limit (1 mg/kg; Table 3). A more recent survey of two different ABS plastics that contained BD monomer levels with mean concentrations ranging from 0.68±0.71 to 2.1±1.5 mg/kg (Table 3).

Potential for migration of 1,3-BD from plastics or resins

Theoretical considerations

The solubility of monomers in the polymer and the affinity of the monomers (i.e. tendency to bond by electrostatic forces) for the polymer are in general so high that as a rule, the monomers are difficult to force out. The rule of thumb is that the monomer is the best solvent for a given polymer. Therefore, it cannot be expected that the residual monomers disappear completely with time, but stay in the matrix (i.e., limited to no bioavailability). However, this does not mean that the content of the residual monomers increases over time. Like for all chemical processes, a phase equilibrium will occur. (Ministry of Environment and Food Denmark, 2019).

The migration rate of organic chemical substances is size dependent. Small molecules, (e.g. monomers and residual solvents), with low boiling points, will migrate fast. In fact, some monomers e.g. formaldehyde, vinyl chloride, ethylene and butadiene have a tendency to migrate quickly even at ambient temperatures (Hahladakis et al (2018), Hansen et al, (2013)). Migration potential is impacted by a wide range of parameters, such as initial concentration of the monomer in the plastic, the thickness of the plastic material, the crystallinity of the plastic and the surface structure of the plastic have all a complex influence on the rate of migration (Hansen et al., 2013). Residual monomers in plastic will be in a phase equilibrium with the atmosphere and the plastic in which they are dissolved (Ministry of Environment and Food Denmark, 2019).   It is important to note that addition of additives to plastic will influence the diffusion coefficient and thus the amount which migrates from the plastic as well as the migration rate (Genualdi et al., 2014). From a purely theoretical point of view, it must therefore be expected that the migration from solid plastic products, such as ABS will be very slow. (Ministry of Environment and Food Denmark, 2019).

Seen from a theoretical point of view, the following conditions regarding residual monomers in plastic and migration of residual monomers from plastic apply:

• The actual production process of the polymer is significant for the content of residual monomers. It is possible to reduce the content of residual monomers in the polymer by controlling the process conditions and use subsequent processes which may reduce the monomer content but there will always be a certain amount of residual monomer left in the polymer.

• The production method of articles (for instance injection moulding versus blown film) may be important for the content of residual monomers in the polymer.

• The migration of residual monomers from the polymer follows in theory Fick's Law, i.e. the migration depends on among other things the type of plastic (initial concentration), time, temperature, thickness of material and exposure for example for liquids.

• The migration will decrease with time as the concentration of the monomer in the plastic decreases and as an equilibrium between monomer content in the plastic and monomer content in the migration medium will occur.

• The migration may be expected to be largest to the medium/liquid in which the monomer is easily soluble (not the case for 1,3-BD, as it has low water solubility)

Summary of data regarding migration from plastic

Based on the low water solubility of 1,3-BD, it is expected that migration to aqueous agents will be low, while there is potential that higher migration is predicted for fatty food tests (since ethanol would be a likely simulant).   Nevertheless, the few studies identified that report detections of 1,3-BD in oil, margarine, potato salad, cottage cheese, and yogurt describe concentrations ranging from <0.2 to 9 ng/g (ppb) ATSDR Tox Profile for 1,3-Butadiene (2012)

Table 1 also summarizes the little information about migration of the residual monomer butadiene that was found. Whether this is due to the fact that the content of the residual monomer butadiene is normally identified in small amounts (mostly < 1.7 mg/kg, maximum measurement 5.3 mg/kg) is unknown. However, this is the argument which Abe et al. (2013) state for not measuring the migration of butadiene from the toys they examined. Only data from one of the European toy producers (TIE,

2018) show that all the measurements (20 in total) are below the detection limit. (Ministry of Environment and Food Denmark, 2019).

In an unpublished study, the migration of BD monomer from four samples of ABS plastic was assessed using three different food simulants (3% acetic acid, 10% ethanol, olive oil). Migration was assessed using the following test conditions: 2 hours at 70 degrees C, 2 days at 40 degrees C, and 10 days at 20 degrees C. For all samples and test conditions except for 1, the levels of BD monomer were below the limit of detection (10 ug/kg simulant; Table 4). A single detection was report for one sample (ABS 4) and test condition and simulant (2 days, 40 degrees C, in olive oil) just slightly above the detection limit (12 ug/kg simulant).

Table 1. Summary of Published Literature on the Residual Content and Migration of 1,3-BD Monomer from Polymer Materials

Reference	Year	Material	Residual content (ug/g)	Migration to water (ng/ml)	Migration to air (ug/m³)	Migration to food (ug/g)
Determination of Residual 1,3-Butadiene in Synthetic Resins containing Butadiene	1981	PBD	ND (< 1 ppm)	--	--	--
		ABS	ND (< 1 ppm)	--	--	--
Single ion monitoring of butadiene in plastics and foods by coupled mass spectrometry-automatic headspace gas chromatography	1984	ABS	<0.005 - 0.31			ND (< 0.0002) in margarine
Analysis of Acrylonitrile, 1,3-Butadiene, and Related Compounds in Acrylonitrile-Butadiene-Styrene Copolymers for Kitchen Utensils and Children's Toys by Headspace Gas Chromatography/Mass Spectrometry	2010	ABS	0.06–1.58	--	--	--
		AS	ND	--	--	--
		PS	0.01 - 0.08	--	--	--
Migration study of 1,3-butadiene in eye-drop solutions	2012	?	--	0 - 0.52 (after 12 months at 40C)	--	--
Analysis of trace residual 1,3-butadiene in poly(acrylonitrile-co-butadiene-co-styrene)	2012	ABS	0.002 - 0.003	--	--	--
Volatile Substances in Polymer Toys Made from Butadiene and Styrene	2013	ABS	0.04 - 5.3 (mean 0.78)	3 - 40	--	--
		thermoplastic elast.	<0.1	ND	--	--
		rubber toys (SBR)	< 0.1	ND	--	--
Survey of volatile substances in kitchen utensils made from acrylonitrile–butadiene–styrene and acrylonitrile–styrene resin in Japan	2014	ABS	0.06 - 1.7	ND	--	--
		AS	ND	ND	--	--
Toy Industries of Europe (TIE) (as reported in Survey of monomers in toy materials	2018	ABS	<0.01 - 5 (mean 0.29)	<0.01		
Survey and investigation of migration of monomers in toy materials	2019	ABS	0.23 - 1.55	<0.01	--	--
		SBC	<0.1 - 0.2	<0.01	--	--
Synthetic Turf Field Recycled Tire Crumb Rubber Research Under the Federal Research Action Plan. Final Report Part 1 – Tire Crumb Rubber Characterization Volume 1	2019	SBR recycled	--	--	--	--
		SBR turf field	--	--	--	--
Determination of 1,3-Butadiene Migrated from Butadiene-Based Polymers to Air and Water Using Sorbent Tubes and Purge-and-Trap	2021	ABS	--	ND	ND	--
		SBR	--	0.044±0.003	0.91±0.09	--
Styrene Butadiene Rubber Copolymer (Food)	2023	SBR	0.5 (maximum spec)	--	--	--

Table 2a. Unpublished Data on Residual BD Monomer in SBR (IISRP, 2020)

Product	Residual BD	Unit	Method, remarks
ESBR	<50	ppb	Head Space-Gas Chromatography /Mass Spectrometry Method
SSBR	<20	ppb	GC/MS Method
SBS	ND	ppb	GC/MS Method and EPA Method 8260
BR	<20	ppb	GC/MS Method
SEBS	ND	ppb	GC/MS Method

Table 2b. Unpublished Data from the Association of Petrochemical Industry of Japan (IISRP, 2020)

	Product Category	Product Detail (Commercial Name, sub-category, etc.)	Evaluation of Analysis		
			Residual BD	unit (ppm/%)	Method, Detection limit, Remarks
1	ESBR		N.D.	ppm	ISO17052 compatible, Lower limit of Detection:50ppm
2	SSBR		N.D.	ppm	ISO17052 compatible, Lower limit of Detection:50ppm
3	SSBR		N.D.	ppm	GC/MS Method Quantitation Limit: 1ppm
4	SSBR		N.D.	ppm	GC-FID Method Quantitation Limit: 10ppm
5	NBR		N.D.	ppm	ISO17052 compatible, Lower limit of Detection:50ppm
6	BR		N.D.	ppm	ISO17052 compatible or GC/MS Method, Lower limit of Detection:1ppm
7	SBS		N.D.	ppb	ISO17052 compatible, Quantitation Limit:4ppb
8	SEBS		N.D.	ppb	ISO17052 compatible, Quantitation Limit:10ppb
9	SEBS		N.D.	ppb	GC/MS Method Quantitation Limit: 1ppm

Table 3. Unpublished Data on Residual BD Monomer in ABS Plastic

				Residual BD (mg/kg)			
Year of analysis	Sample	Analytical Method	DF	Minimum	Maximum	Mean	SD
2001	ABS 1	GCMS	0/1	--	--	<1	--
2001	ABS 2	GCMS	0/1	--	--	<1	--
2001	ABS 3	GCMS	0/1	--	--	<1	--
2001	ABS 4	GCMS	1/1	--	--	1	--
2020-2023	ABS 5	Not specified	53/56	0.2	3.15	0.68	0.71
2020-2023	ABS 6	Not specified	595/595	0.1	10.4	2.1	1.5

Table 4. Unpublished Data for Migration of BD Monomer from ABS Plastic

Sample (residual BD, mg/kg)	Simulant	Test Exposure (repeat use)	BD migration (ug/kg simulant)		
			2 hours, 70 °C	2 days, 40 °C	10 days, 20 °C
ABS 1 (<1 mg/kg)	3% acetic acid	1st	ND*	ND	--
	10% ethanol		ND	ND	--
	olive oil		ND	ND	--
	3% acetic acid	3rd	ND	ND	--
	10% ethanol		ND	ND	--
	olive oil		ND	ND	--
ABS 2 (<1 mg/kg)	3% acetic acid	1st	--	--	ND
	10% ethanol		--	--	ND
	olive oil		--	--	ND
ABS 3 (<1 mg/kg)	3% acetic acid	1st	ND	ND	--
	10% ethanol		ND	ND	--
	olive oil		ND	ND	--
	3% acetic acid	3rd	ND	ND	--
	10% ethanol		ND	ND	--
	olive oil		ND	ND	--
ABS 4 (1 mg/kg)	3% acetic acid	1st	ND	ND	--
	10% ethanol		ND	ND	--
	olive oil		ND	12	--
	3% acetic acid	3rd	ND	ND	--
	10% ethanol		ND	ND	--
	olive oil		ND	ND	--

*GCMS Detection limit = 10 ug/kg simulant

Appendix 1:
Annotated summary of references reporting residual content or migration of BD from polymers

Old references already summarized in ATSDR Tox Profile for 1,3-Butadiene (2012)
1,3-Butadiene is used to manufacture synthetic rubber and plastics that are frequently used for food packaging. Because residual 1,3-butadiene may be present in the polymers used to make the containers, both the packaging and the food contained therein have been analyzed. In one study, 1,3-butadiene at a concentration of 8–9 ng/g (ppb) was detected in three of three brands of olive oil packaged in 1,3-butadiene rubber-modified acrylonitrile-acrylic bottles (McNeal and Breder 1987). Analysis of the bottles themselves found 1,3-butadiene residues as high as 6,600 ng/g (ppb). Soft-plastic packaging tubs used as containers for potato salad, cottage cheese, and yogurt had residual 1,3-butadiene levels in the range of 21–1,700 ng/g (ppb). However, no 1,3-butadiene was detected in any of the food packed in these containers (detection limit 1 ppb). Chewing gum made with a 1,3-butadiene rubber base did not show residual traces of this diene (McNeal and Breder 1987). Soft-plastic margarine tubs from five major name brands in the United Kingdom contained 1,3-butadiene residues ranging from 5 to 310 μg/kg (ppb), but none of the monomer was detected in the margarine samples themselves (detection limit 0.2 μg/kg) (Startin and Gilbert 1984). The authors concluded that migration of the 1,3-butadiene monomer from plastic packaging to food is unlikely to present a problem. Residual levels of 1,3-butadiene in food containers are closely regulated by the Food and Drug Administration. Pellizzari et al. (1995) measured 0.1 mg of 1,3-butadiene in rapeseed oil emissions during 20 minutes of heating the oil in a wok at 260 °C. The presence of 1,3-butadiene was attributed to the pyrolytic decomposition of unsaturated fatty acids in the oil.

Determination of Residual 1,3-Butadiene in Synthetic Resins containing Butadiene (Tan and Okada, 1981)
Samples of household wrapping film, ABS sheets, and kitchen utensils such as chopsticks, Ladles, graters, and lunch trays were analyzed for residual monomers. The reported concentrations of 1,3-BD were consistently below limit of detection (1 ppm)

Single ion monitoring of butadiene in plastics and foods by coupled mass spectrometry-automatic headspace gas chromatography (Startin and Gilbert, 1984)
The authors analyzed tubs of margarine and their contents to determine the potential migration of butadiene from ABS into foodstuff. Levels of butadiene in the ABS Plastics ranged from < 0.005 to 0.31 mg/kg and for the soft margarines were not detectable at a detection limit of 0.0002 mg/kg. The authors conclude that the absence of butadiene in the margarine suggests that this monomer is unlikely to present a problem through migration into foods.

Human exposures to monomers resulting from consumer contact with polymers (Leber, 2001)
A survey of all food-contact sources of butadiene monomer indicates negligible risks to consumers. The many worse-case assumptions that are used in surveys and analyses that estimate monomer exposures derived from polymers in contact with food provide assurances that these consumer products do not contribute in a significant manner to human health concerns.

Summary Risk Assessment Report (European Union JRC, 2002)
The only available measured data for the presence of monomer in indoor air suggest that indoor levels are generally below 2.2 μg/m3 (equivalent to 0.001 ppm), giving rise to an estimated daily dose of 5E-4

mg/kg/day for an adult or 7E-4 mg/kg/day for a toddler. The predicted reasonable worst-case oral dose of 1,3-butadiene as a result of leaching from packaging into foodstuffs is about 2.1E-4 mg/kg/day for an adult and 1.2E-3 mg/kg/day for a toddler. The combined exposure from indoor air and leaching from packaging into foodstuffs amounts to a predicted reasonable worst-case dose of 7E-4 mg/kg/day for an adult and 1.9E-3 mg/kg/day for a toddler.

Analysis of Acrylonitrile, 1,3-Butadiene, and Related Compounds in Acrylonitrile-Butadiene-Styrene Copolymers for Kitchen Utensils and Children's Toys by Headspace Gas Chromatography/Mass Spectrometry (Ohno, 2010)
Twenty-two samples made from ABS copolymer (13 kitchen utensils and nine children's toys). AS copolymers (5 kitchen utensils), PS (3 kitchen utensils and 2 food containers), and seven NBR gloves
In ABS copolymers, 1,3-BD was detected at 0.06–1.58 ug/g in all samples. The levels in children's toys were confirmed to be identical to those in kitchen utensils. 1,3-BD was not detected in AS copolymers,. In PS samples, 1,3-BD was detected at low levels compared with the ABS copolymers (levels were 0.01 and 0.08 ug/g).

Analysis of trace residual 1,3-butadiene in poly(acrylonitrile-co-butadiene-co-styrene) (Choi and Kim, 2012)

Residual 1,3-butadiene extracted from ABS pellets with toluene and N,N-dimethylacetamide was analyzed using GC-FID. ABS with the acrylonitrile, 1,3-butadiene, and styrene contents of 25, 17, and 58 wt%, respectively was used. The solvent extraction with toluene and N,N-dimethylacetamide was found to be much more efficient than the direct thermal desorption. The concentrations of 1,3- butadiene extracted with toluene and N,N-dimethylacetamide were about 3 and 2 ppb, respectively.

Migration study of 1,3-butadiene in eye-drop solutions (Pistos, 2012)
After 12 months of storage, all eight eye-drop solutions were negative for the migration of 1,3-BD after storage at 2–8°C. At room temperature, 1,3-BD appears to initiate the migration into one of the eye-drop solutions after 7 months of storage and increases almost linearly up to 12 months. At the same formulation, the migration seemed to be affected significantly by the temperature at 40°C after 4 months of storage and seemed to follow a linear increase up to 8 months.

Volatile Substances in Polymer Toys Made from Butadiene and Styrene (Abe, 2013)
The authors reported residual levels and migration behavior of volatile substances for acrylonitrile-butadiene-styrene copolymer (ABS) toys, thermoplastic elastomer toys, and rubber toys made from 1,3-butadiene and styrene found on the Japanese market. They analyzed 73 toy samples comprising 59 ABS toys, 12 thermoplastic elastomer toys, and 2 styrene-butadiene rubber toys.
The maximum residual level of 1,3-butadiene was 5.3 µg/g, which is much lower than the EU limit of 0.1%. Furthermore, some volatile substances migrated from ABS toys into water in amounts of 3 - 40 ng/mL. Thermoplastic elastomer toys and rubber toys contained these volatile substances at significantly lower levels than ABS toys.
They selected the toys with the highest concentration of residual VOCs to test migration into water (as surrogate of saliva). The authors did not detect any migration of 1,3-BD.

Survey of volatile substances in kitchen utensils made from acrylonitrile–butadiene–styrene and acrylonitrile–styrene resin in Japan.(Abe, 2014)
They looked at residual (not migrated) concentrations of 1,3-BD and other substances in 30 kitchen utensils made from acrylonitrile–butadiene–styrene resin (ABS) and acrylonitrile–styrene resin (AS) such

as slicers, picks, cups, and lunch boxes. The residual levels of 1,3-butadiene ranged from 0.06 to 1.7ug/g in ABS, where only three of 15 ABS samples exceeded the regulatory limit for this compound as established by the European Union (1 ug/g = 1 ppm). The residual levels of 1,3-butadiene in 15 of the AS sables were below the limit of quantitation (0.025 ug/g).

Monomers - Proposed requirements for Appendix C of the Toy Safety Directive (ANEC - The European consumer voice in standardization, 2018)
Corroborates the limit of 1 mg/Kg residual 1,3-BD as acceptable for toys and consumer uses. This limit is also applied to foodstuff (EFSA)

Toy Industries of Europe (2018) (as reported in Survey and investigation of migration of monomers in toy materials)
This report summarizes analyses of the content of residual monomers in ABS material used for toys (examined via the standards in the EN 1313018 series). The content of 1,3-BD was measured to:
- 9 samples did not contain butadiene (detection limit 0.01 mg/kg)
- 7 samples contained between 0.06 and 0.76 mg butadiene/kg (average value 0.29 mg/kg)
- 5 samples contained between 1 and 5 mg/kg

They also examined migration (via the standards in EN 13130 series, i.e. migration to 10 % ethanol solution and 3 % acetic acid solution – in both cases for 24 hours at 40 °C). The content of butadiene in the ABS was between 0.07 and 3.1 mg/kg. The result was that no migration of any of the monomers in any of the samples was identified (the detection limit was 0.01 mg/l).

Survey and investigation of migration of monomers in toy materials (Ministry of Environment and Food of Denmark, 2019)
10 products of ABS (analyzed for content of acrylonitrile, butadiene and styrene)
5 products of PS (analyzed for content of styrene)
2 products of SEBS (analyzed for content of styrene)
2 products of SBC (analyzed for content of butadiene and styrene)

Monomer	Material	Content measured in toys in this project (mg/kg)	Other measurements in toys (mg/kg)	Other measurements in other products (mg/kg)
Vinyl chloride	PVC	< 0.1	< 0.1	< 1 (raw material)
Acrylonitrile	ABS	8 - 64	< 0.01 - 55	0.15 - 50 (FCM)
Butadiene	ABS	0.23 - 1.55	< 0.01 - 5	0.06 - 1.7 (FCM)
	SBC	< 0.1 - 0.2	*No data*	*No data*
	SBS	*Not analysed*	< 0.1	*No data*
Styrene	ABS	595 - 1350	1.3 - 2600	Max. 3042 (FCM)
	PS	230 - 490	Max. 800	345 - 1000
	SBC	< 0.2 - 8	*No data*	*No data*
	SEBS	< 0.2	< 0.05 - 1.1	*No data*
	SBR/SBS	< 0.1	*No data*	*No data*

For ABS 1,3-BD is identified at the lowest levels and is generally below 1 mg/kg but with two products with a content above 1 mg/kg (with a content of 1.05 mg/kg and 1.55 mg/kg). On average, the content of butadiene is 0.57 mg/kg in the 10 examined products. This corresponds to results from the literature

which states levels from 0.06 to 1.7 mg/kg – however, with a single survey of toys with a content of up to 5.3 mg/kg.
Migration analyses were carried out on two products of ABS and two products of PS with the highest levels of acrylonitrile, butadiene and styrene respectively. The result was that no migration from any of the monomers (acrylonitrile, butadiene and styrene) were identified, either to artificial sweat, 20 % ethanol, artificial saliva, demineralised water or stomach acid from either ABS or PS in any of the in total four examined toy materials.

Synthetic Turf Field Recycled Tire Crumb Rubber Research Under the Federal Research Action Plan. Final Report Part 1 – Tire Crumb Rubber Characterization Volume 1 (and Volume 2) (EPA 2019)
VOC measurements at 25 °C : For tire crumb rubber from tire recycling plants, 1,3 butadiene was not detected in any of the 27 samples. For tire rubber infill from synthetic turf, 1,3-butadiene measurements were above quantifiable limits in only 5 of the 38 samples and the emission factors were low for these few samples (≤1.0 ng/g/h).
VOC Emissions at 60 °C : Similar to tests at 25 °C measurements, 1,3-butadiene was above quantifiable limits in4 of 37 samples, and the emission factors were low (≤ 1.3 ng/g/h).

Determination of 1,3-Butadiene Migrated from Butadiene-Based Polymers to Air and Water Using Sorbent Tubes and Purge-and-Trap (Anara Omarova et al, 2021)
The study is centered around the validation of the method. There is not enough information about the sample they took from a SBR shoe and ABS toys to make any inferences (number of samples, content of BD in sample, size of sample, etc.). Extraction in water was done for 24 h at 104 °F (extreme condition), while extraction in air was done at room temperature.
The 1,3-butadiene was not detected in migration air and water from ABS toys but was found in both air and water after incubation with SBR-based sample. The concentrations of 1,3-butadiene migrated from SBR samples were 0.91±0.09 μg m^{-3} in air and 0.044±0.003 μg L^{-1} in water.

Comments by Juan Ramon Salinas, Managing Director and Chief Executive Officer, International Institute of Synthetic Rubber Producers Inc. EPA-HQ-OPPT-2018-0451-0027 (IISRP, 2020)
The submitted information comprises a slide deck that provides a mass balance of inputs and outputs of 1,3-BD in both the Emulsion and Solution Processes for producing synthetic rubber products, information on the residual 1,3-BD levels in synthetic rubbers, and information on occupational exposure to 1,3-BD during the manufacture of synthetic rubber. It also includes a substantial number of safety data sheets for various common grades of synthetic rubber products.

Appendix 2:
Studies evaluating migration of VOCs from plastic products/ polymers, but no reference to detection of Butadiene (not clear if not quantified or not measured)

Temperature driven variations in VOC emissions from plastic products and their fate indoors: A chamber experiment and modelling study (Beel, 2023)

Influence of polymer additives on gas-phase emissions from 3D printer filaments (Potter, 2021. EPA study)

Monitoring the BTEX Volatiles during 3D Printing with Acrylonitrile Butadiene Styrene (ABS) Using Electronic Nose and Proton Transfer Reaction Mass Spectrometry (Wojnowski, 2020)

Identification of plastic toys contaminated with volatile organic compounds using QCM gas sensor array (Oleneva, 2020)

Particle and volatile organic compound emissions from a 3D printer filament extruder (Byrley, 2020 EPA study)

Emissions of VOCs From Polymer-Based Consumer Products: From Emission Data of Real Samples to the Assessment of Inhalation Exposure (Even, 2019)

VOC Emissions and Formation Mechanisms from Carbon Nanotube Composites during 3D Printing (Potter, 2019. EPA study)

The emissions of monoaromatic hydrocarbons from small polymeric toys placed in chocolate food products (Marc, 2015)

Environmental-sanitary risk analysis procedure applied to artificial turf sports fields (Ruffino et al, 2013)

Contamination in food from packaging material (Lau and Wong, 2000)

Air Emissions from Carpet Manufacturing Processes (Mulholland, ??)

Modeling emissions of VOCs from new carpets (Little, 1994)