

Influence of Storage Conditions on Bisphenol A in Polycarbonate Carboys of Water

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ABSTRACT

In this study, the migration of BPA from polycarbonate carboys (19 L) from a widely used producer in Turkey (W1-W10, n= 10) into drinking water stored at different temperatures (20, 25 and 31 °C, mean) over seven weeks was investigated using LC-MS/MS. Additionally, physical parameters (pH and conductivity), cations by ICP-MS and anions were measured by ion chromatography system (ICS). The highest BPA levels of the W1-W10 coded samples (n=10) were 2.05±0.04, 2.65±0.06, 2.24±0.03, 2.70±0.01, 0.75±0.04, 0.84±0.02, 1.02±0.09, 1.05±0.01, 3.15±0.03 and 2.75±0.02 µg/L. Across the water samples, an increase in the BPA values was detected (P<0.01), depending on the time of exposure. Depending on the storage conditions taken within the scope of the research, the results changed with the samples and some differences in the BPA levels (P<0.01) were detected. The BPA contents of all of the samples were determined to be below the EU ADI limit. For this reason, it can be said that there is no risk to human health from BPA migration in the drinking water in PC water bottles.

Keywords: BPA; drinking water; polycarbonate bottle

1. Introduction

Bottled water has become popular, as it is perceived as source of clean water. Recent studies demonstrated that polycarbonate (PC) plastic bottles can release harmful chemicals such as bisphenol A (BPA) into water. Therefore, the safety of bottled water has become a controversial issue (Fan et al., 2014).

BPA (4, 4'-dihydroxy-2, 2-diphenylpropane; CAS# 80- 05-7) is commonly used in the manufacturing process for polycarbonate plastics and epoxy resins (Bourgin et al., 2013). It is an important raw material and monomer used extensively in the production of a hard, clear plastic known as polycarbonate (Lu et al., 2014). It is also used for the production of epoxy resins and as a non-polymer additive in plastics such as polyvinyl chloride (PVC) and water pipes (Chen et al., 2013; Lee et al., 2013; Santhi et al., 2012). Polycarbonate is used in reusable plastics, food packages and cans (baby bottles, drinking water bottles, etc.) (Selvaraj et al., 2014). BPA is ubiquitous in our lives because it can be inadvertently released into the environment to contaminate rivers and ground water during the manufacture of these products. Moreover, BPA can also migrate into food and drinking water from a wide variety of materials in contact with food; in particular those derived from polycarbonates and epoxy resins, such as infant feeding bottles, tableware, storage containers and food can linings (Deng, 2014). According to studies conducted in the USA, Germany, Japan and the Netherlands, BPA concentrations ranged from being undetectable to 1 µg/L in river water (Chen et al., 2013).

BPA has been reported to leach from plastics and epoxy coatings into a wide variety of foods and beverages, resulting in the detection of BPA in various human tissues and fluids (Lane et al., 2014). It is an emerging endocrine-disrupting compound (Lee et al., 2013). Exposure to this endocrine disruptor in humans is comes mainly through food (Santhi et al., 2012). BPA is a xenoestrogen, and animal studies have shown it they cause negative effects on the prostate, immune system, mammary glands, reproduction, brain development and functioning, metabolism, and it has also lead to migraine symptoms (Lane et al., 2014; Vandenberg et al., 2012; Vermeer et al. 2014).

The study of BPA in water, especially when it's used for human consumption, is important (Santhi et al., 2012). Human studies have examined elevated levels of BPA with regards to reproduction, neurobehavioral development and metabolic diseases (e.g., obesity, diabetes, heart disease, thyroid and liver function) (Lane et al., 2014; Rochester 2013). In recent years, BPA has received a more attention due to its extensive industrial use and potential estrogenic activity (Bourgin et al., 2013). Although BPA is rapidly bio transformed and excreted in the urine, levels of unconjugated BPA detected in bio monitoring studies suggest that the human population is at risk of internal exposure (Santhi et al., 2012). Similarly to BPA and oestrogens, pesticides have been reported to exhibit endocrine-disrupting properties in a number of laboratory and field studies (Rodriguez-Mozaz et al., 2004).

Various methods have already been proposed to assay BPA. HPLC (Jiang et al., 2006; Ikegami et al. 2004), liquid chromatography coupled with electrochemical methods, ultra-violet and fluorescence detection (Inoue et al., 2000), LC-MS (Kawaguchi et al., 2005), gas chromatography (Shin et al., 2001), gas chromatography-mass spectrometry (GC-MS) (Li et al., 2001) and capillary electrophoresis (Mei et al., 2011) are the most commonly used methods for BPA analysis (Wu et al., 2015). These methods are accurate, precise and robust for the analysis of BPA (Deng et al., 2014). LC-MS is often preferred to GC-MS as it does not need any derivatization step prior to chromatographic separation. However, one remaining major drawback of the LC-MS methodology

is that the charge competition observed in the electrospray ionization leads to questionable results, especially where complex biological matrices, such as foodstuffs, are concerned (Deceuninck et al., 2014).

In Turkey, the water bottles (19 L) widely made from PC material are used to package drinking water for consumption. Until this water is consumed, it is kept in the places that can receive direct sunlight or be away from sunlight. The detention time and lifetime of BPA differs according to the population and consumption levels at home or in the workplace. In this study, polycarbonate bottled water belonging to the brands widely consumed in Turkey (n= 10) was kept at three different conditions for seven weeks. The aim was to determine the change in the anion and cation levels depending on the conditions and retention time, as well as the change in BPA, using physical properties (pH and conductivity). The retention time of the drinking water was determined accounting for the use conditions at home and in businesses.

2. Materials and Methods

2.1. Sampling

The most well-known and widely consumed products from ten bottle producers (W1 – W10) in Turkey were used in this study. Samples (n= 30) of polycarbonate carboy bottles (19 L) of water were obtained in 2012 from local markets in Ankara (Turkey). Only one lot from each product was obtained, all of which were bottled in 2012.

2.2. Storage of samples

Samples of each product were stored at three different conditions for seven weeks prior to analysis; (a) in a room, placed such that they would be in direct sun light (31 ± 1 °C), (b) in the centre of a room (25 ± 1 °C) and (c) in a dark room (20 ± 1 °C).

2.3. Standards and reagents

The cation standards for aluminium, antimon, arsenic, barium, boron, cadmium, calcium, chrome, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silisium, sodium and zinc were purchased from Vhg Labs (Manchester, NH, United States). The anion standards for fluorine, chlorine, bromine, nitrate, nitrite and sulphate were purchased from High Purity StandardsTM (Charlestone, SC, United States). The standard for BPA (2,2-Bis-4-hydroxyphenyl propane) was purchased from Dr EhrenstorferGmbH (Wessel, Germany). The standard for ERM (European Reference Material) CA 022a was purchased from LGC Standards (Teddington, United Kingdom). 100 µg/mL of the BPA standard stock solution as prepared using methanol.

All reagents, solvents and chemicals were of analytical or HPLC grade and were obtained from either Sigma (St Louis, MO, United States) or Merck (Darmstadt, Germany).

2.4. Physical parameters

2.4.1. pH and Conductivity

A pH meter (WTW Inolab pH730, Germany), fitted with an electrode previously calibrated to buffer solutions of pH 4 and pH 7, was used to determine the PH values. The electrode was immersed in the sample in a beaker with magnetic stirrer to homogenize the sample. After stabilizing the display on the dial of the pH meter, we determined the pH. All data were expressed as the mean value of three replicates conducted on different samples of the same carboy from each producer.

The conductivity was measured with an electrical conductivity meter (WTW Inolab Cond730, Germany), which directly determines conductivity of the sample in $\mu\text{S}/\text{cm}$. The conductivity values for each sample were measured in triplicate.

2.5.LC-MS/MS

The LC-MS/MS method used for this study was adapted from the methods used by Li et al. (2010) and Morales et al. (2010). A 6410A Triple Quadrupole LC-MS/MS from Agilent Technologies (Waldbronn, Germany) equipped with an Agilent LV 1200 series autosampler, binary pump and thermostatted column compartment was used. The LC separation was performed on a 100 mm x 3 mm ID 2.7 μm Poroshell 120SB C18 column (Agilent, Santa Clara, CA, United States) at 35°C. Using this method, the total ion chromatograms (TICs) of the samples were obtained. All samples were injected into the LC-MS/MS system in triplicate. Validation of the LC-MS/MS method was performed by studying the linearity, detection and quantification limits. The external standard of the BPA at different concentrations was used under the conditions of the method described in the LC-MS/MS conditions. For validation, the BPA standard was injected into the LC-MS/MS system at five concentration levels ranging from 0.50 to 10.0 $\mu\text{g}/\text{L}$ and LOD (0.50 $\mu\text{g}/\text{L}$) and LOQ (0.17 $\mu\text{g}/\text{L}$) for BPA were determined.

Prior to injection into the LC-MS/MS system, vigorously shaken water samples from each carboy were passed through a 0.45 μm PTFE syringe filter (Chromacol, United Kingdom) to remove any solid particles that might interfere in the analysis or damage the equipment.

2.6. Determination of cations by ICP-MS

ICP-MS determinations of the cations were performed using an Agilent 7700 (Agilent, United States). Operational conditions were optimized based upon the daily performance. The LOD and LOQ values were ranged 0.01-0.30 and 0.04 - 1.4 $\mu\text{g}/\text{L}$, respectively.

The calibration curves ranged from: 5 - 200 $\mu\text{g}/\text{L}$ for Al, Fe, Mn, Cr, Cu, Ba and Zn; 0.10 - 10.0 mg/L for B, Na, Mg, K, Ca and Si; and 0.10 - 10.0 $\mu\text{g}/\text{L}$ for Ni, As, Cd, Se, Sb, Hg and Pb. The internal standard mix (10 mg/L each Li, Sc, Ge, Y, In, Tb, Bi in 5.00% HNO_3) was injected in line. Samples that exceed the upper calibration limit were diluted to be in the proper calibration curve range.

Calibration solutions were prepared in ultrapure water (10.0%, v/v) and acidified with twice-distilled HNO_3 . Additionally, water samples (50.0 mL) were mixed with HNO_3 (1.00 mL) and HCl (0.25 mL) to be stored at 4 °C. The LOD and LOQ were calculated based on the standard deviation of the calibration blanks: three times the standard for the LOD (ten times for the LOQ), divided by the slope of the calibration curve.

2.7. Determination of anions by ICS

Determination of the anion content by the Ion Chromatography System (ICS) used in this study was based on the method described in TS-EN-ISO 1034-1 (Anonymous, 2010). An ICS3000 from Thermo Scientific (Sunnyvale, California, United States) equipped with pump, generator, detector and autosampler was used.

A mixture of the fluorine, chlorine, bromine, nitrate, nitrite and sulphate standards was analysed by the ICS at five concentration levels from 1.00 to 5.00 mg/L. LOQ (0.004-13 $\mu\text{g}/\text{L}$) and LOD (0.001-0.04 $\mu\text{g}/\text{L}$) values for anions were determined.

2.8. Statistical analysis

Quantitative data are expressed as the mean. The results of the analyses were analysed using the Tukey's test (SPSS 15.0, SPSS Inc., Chicago, IL, United States). Values at $P < 0.01$ were considered significant.

3. Results and Discussion

3.1 Physical properties of water samples

The pH in aqueous media plays a major role in the stability of epoxy derivatives such as bisphenol F (BPF) diglycidyl ether and BPA diglycidyl ether because of the presence of hydroxyl groups in their structures (Oca et al., 2014).

The pH and conductivity of the water samples kept at the three different conditions were measured at seven-day intervals during the seven-week testing period (Tables 1 and 2). In all of the water samples, the average pH values were found to vary between 7.64 and 9.28. The conductivity range was 16.4-487.0 $\mu\text{S}/\text{cm}$. It was observed that the conductivity values differed between all of the samples ($P < 0.01$). The range of the pH values can be considered wide, which was an advantageous quality for this study. Looking at the entire storage period, an inverse relationship between the temperature and time versus the pH values was found for many of the samples. However, the number of samples that showed this relationship in terms of the conductivity values was less. ($P < 0.01$). The fact that pH has an important effect on the stability of packaging materials and the migration of some toxic components must be considered. Additionally, given the wide range of pH values observed in the samples, it is thought to be important to examine the change in pH of water samples in controlled conditions and its effect on packaging stability in terms of food security and consumer health.

Table 1 pH of water samples

Sample		1. Week		2. Week		3. Week		4. Week		5. Week		6. Week		7. Week	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
W1	31°C ^B	7.56	0.01	7.35	0.00	7.82	0.00	7.53	0.00	7.53	0.00	7.88	0.00	7.86	0.00
	25°C ^A	7.56	0.01	7.59	0.01	7.34	0.01	7.42	0.01	7.67	0.01	7.93	0.01	7.86	0.01
	20°C ^B	7.51	0.01	7.49	0.00	7.45	0.00	7.38	0.01	7.38	0.00	7.48	0.00	7.46	0.00
	Mean	7.54 ^{c,1}	0.00	7.48 ^{b,1}	0.00	7.54 ^{bcd,1}	0.00	7.44 ^{bc,1}	0.00	7.53 ^{bcd,1}	0.00	7.76 ^{b,2}	0.00	7.73 ^{cd,2}	0.00
W2	31°C ^B	7.61	0.01	7.69	0.00	7.98	0.01	8.89	0.00	9.41	0.00	9.23	0.00	9.17	0.00
	25°C ^A	7.75	0.01	7.64	0.01	7.85	0.00	7.55	0.01	7.78	0.01	7.89	0.00	7.86	0.01
	20°C ^A	7.65	0.00	7.72	0.01	7.66	0.01	7.65	0.00	7.58	0.00	7.68	0.01	7.71	0.00
	Mean	7.67 ^{c,1}	0.00	7.68 ^{bc,1}	0.00	7.83 ^{cde,12}	0.00	8.03 ^{d,12}	0.00	8.26 ^{e,2}	0.00	8.27 ^{c,2}	0.00	8.25 ^{d,2}	0.00
W3	31°C ^B	7.65	0.01	7.70	0.00	7.94	0.00	7.89	0.01	8.42	0.01	8.27	0.00	8.18	0.01
	25°C ^A	7.65	0.00	7.57	0.05	7.59	0.01	7.48	0.00	7.72	0.00	7.81	0.01	7.81	0.00
	20°C ^A	7.55	0.01	7.58	0.00	7.64	0.00	7.56	0.01	7.56	0.00	7.65	0.00	7.72	0.00
	Mean	7.62 ^{c,1}	0.01	7.62 ^{bc,1}	0.02	7.72 ^{cde,12}	0.00	7.64 ^{cd,1}	0.00	7.90 ^{de,2}	0.00	7.91 ^{bc,2}	0.00	7.90 ^{d,2}	0.00
W4	31°C ^B	7.96	0.01	8.05	0.00	8.24	0.01	8.58	0.00	9.15	0.00	8.83	0.00	8.95	0.00
	25°C ^A	7.85	0.01	7.83	0.00	7.91	0.01	7.72	0.01	7.94	0.01	7.94	0.01	7.94	0.00
	20°C ^A	7.68	0.00	7.74	0.01	7.82	0.00	7.76	0.00	7.76	0.00	7.76	0.01	7.68	0.00
	Mean	7.83 ^{cd,1}	0.00	7.87 ^{c,1}	0.00	7.99 ^{e,12}	0.00	8.02 ^{d,12}	0.00	8.28 ^{e,2}	0.00	8.17 ^{bc,12}	0.00	8.19 ^{d,12}	0.00
W5	31°C ^C	9.28	0.00	9.13	0.00	9.35	0.00	9.22	0.00	9.38	0.00	9.29	0.00	9.33	0.00
	25°C ^A	9.28	0.00	9.17	0.01	9.26	0.01	9.22	0.01	9.22	0.00	9.22	0.01	9.25	0.01
	20°C ^B	9.28	0.01	9.11	0.01	9.17	0.00	9.01	0.00	8.89	0.00	9.07	0.00	9.05	0.01
	Mean	9.28 ^{e,3}	0.00	9.14 ^{d,1}	0.00	9.26 ^{f,23}	0.00	9.15 ^{e,1}	0.00	9.16 ¹²	0.00	9.19 ^{d,123}	0.00	9.21 ^{e,123}	0.00

All of the experiments were performed in triplicate. All of the data represent the means ± SD. For each parameter, the means are followed by the same letter or number are not significantly different (P<0.01). Small letters are used for water sample x to identify that the pH value interaction is in the same week of the storage period. Numbers are used for storage period x to show that the pH value interaction is in the same water sample. Capital letters are used for storage condition x to show the pH value over the entire storage period of each sample in the same water sample.

Table 1 (continued)

Sample	1. Week		2. Week		3. Week		4. Week		5. Week		6. Week		7. Week		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
W6	31°C ^C	8.12	0.00	8.13	0.00	8.54	0.00	8.53	0.00	8.71	0.01	8.52	0.00	8.87	0.00
	25°C ^A	6.57	0.01	6.41	0.02	6.38	0.01	6.20	0.01	6.38	0.01	6.29	0.01	6.32	0.00
	20°C ^B	6.22	0.00	5.77	0.01	5.82	0.00	5.60	0.00	5.65	0.00	5.77	0.00	5.99	0.00
	Mean	6.97 ^{b,1}	0.00	6.77 ^{a,1}	0.00	6.91 ^{ab,1}	0.00	6.78 ^{ab,1}	0.00	6.91 ^{ab,1}	0.00	6.86 ^{a,1}	0.00	7.06 ^{bc,1}	0.00
W7	31°C ^B	6.55	0.00	6.64	0.00	7.04	0.00	7.29	0.01	7.11	0.00	6.86	0.01	6.87	0.01
	25°C ^B	6.87	0.01	6.75	0.01	6.75	0.01	6.33	0.00	6.42	0.00	6.35	0.00	6.43	0.00
	20°C ^A	6.80	0.00	6.78	0.01	7.12	0.00	6.42	0.00	6.91	0.00	6.75	0.00	6.75	0.00
	Mean	6.74 ^{a,12}	0.00	6.72 ^{a,12}	0.00	6.97 ^{a,2}	0.00	6.68 ^{a,1}	0.00	6.81 ^{a,12}	0.00	6.65 ^{a,1}	0.00	6.68 ^{a,1}	0.00
W8	31°C ^{AB}	8.03	0.00	7.94	0.00	8.07	0.00	7.80	0.01	7.79	0.00	8.01	0.01	7.81	0.00
	25°C ^B	7.99	0.01	7.91	0.00	7.78	0.01	7.66	0.00	7.79	0.01	8.08	0.00	8.03	0.01
	20°C ^A	8.03	0.01	7.96	0.00	7.95	0.00	7.77	0.00	7.97	0.00	8.13	0.01	8.11	0.00
	Mean	8.01 ^{d,34}	0.00	7.94 ^{c,3}	0.00	7.93 ^{cde,3}	0.00	7.74 ^{cd,1}	0.00	7.85 ^{cde,2}	0.00	8.07 ^{bc,4}	0.00	7.98 ^{d,3}	0.00
W9	31°C ^A	7.92	0.01	7.87	0.03	8.10	0.00	7.83	0.00	7.80	0.00	8.14	0.00	7.99	0.00
	25°C ^A	8.03	0.00	8.06	0.00	7.89	0.01	7.88	0.01	7.94	0.00	8.02	0.00	8.04	0.00
	20°C ^A	7.98	0.01	7.85	0.00	7.94	0.00	7.67	0.00	7.82	0.01	8.09	0.01	8.08	0.01
	Mean	7.97 ^{d,23}	0.00	7.93 ^{c,2}	0.01	7.98 ^{de,23}	0.00	7.79 ^{cd,1}	0.00	7.85 ^{cde,1}	0.00	8.08 ^{bc,4}	0.00	8.04 ^{d,34}	0.00
W10	31°C ^B	7.03	0.00	6.96	0.01	7.89	0.00	7.86	0.00	7.59	0.00	7.13	0.00	7.62	0.00
	25°C ^{AB}	7.03	0.00	6.89	0.01	7.39	0.01	7.28	0.01	6.91	0.01	6.56	0.01	6.68	0.01
	20°C ^A	7.12	0.01	6.92	0.01	7.21	0.01	7.23	0.00	7.18	0.00	6.89	0.00	7.01	0.00
	Mean	7.06 ^{b,12}	0.00	6.92 ^{a,1}	0.00	7.49 ^{bc,3}	0.00	7.46 ^{bc,3}	0.00	7.23 ^{abc,23}	0.00	6.86 ^{a,1}	0.00	7.10 ^{ab,12}	0.00

All of the experiments were performed in triplicate. All of the data represent the means \pm SD. For each parameter, the means are followed by the same letter or number are not significantly different ($P < 0.01$). Small letters are used for water sample x to identify that the pH value interaction is in the same week of the storage period. Numbers are used for storage period x to show that the pH value interaction is in the same water sample. Capital letters are used for storage condition x to show the pH value over the entire storage period of each sample in the same water sample.

Table 2. Conductivities of water sample ($\mu\text{S}/\text{cm}$)

Sample		1. Week	2. Week	3. Week	4. Week	5. Week	6. Week	7. Week
A	31°C ^A	127.4 ± 0.00	126.0 ± 0.00	126.0 ± 0.00	127.1 ± 0.00	126.8 ± 0.00	127.9 ± 0.00	127.0 ± 0.00
	25°C ^A	127.4 ± 0.00	126.9 ± 0.00	127.1 ± 0.00	126.5 ± 0.00	129.2 ± 0.00	126.7 ± 0.00	127.5 ± 0.00
	20°C ^A	126.2 ± 0.00	125.9 ± 0.00	126.1 ± 0.00	127.1 ± 0.00	127.1 ± 0.00	126.5 ± 0.00	127.1 ± 0.00
	Mean	127.0 ^{c,2} ± 0.00	126.3 ^{c,1} ± 0.00	126.4 ^{c,1} ± 0.00	126.9 ^{c,2} ± 0.00	127.7 ^{c,4} ± 0.00	127.0 ^{c,2} ± 0.00	127.2 ^{c,3} ± 0.00
B	31°C ^A	147.0 ± 0.00	151.2 ± 0.00	148.6 ± 0.00	153.5 ± 0.00	146.0 ± 0.00	146.5 ± 0.00	146.6 ± 0.00
	25°C ^B	151.4 ± 0.00	151.3 ± 0.00	150.9 ± 0.00	151.0 ± 0.00	151.1 ± 0.00	151.8 ± 0.00	152.1 ± 0.00
	20°C ^C	153.4 ± 0.00	151.8 ± 0.00	146.9 ± 0.00	156.2 ± 0.00	156.6 ± 0.00	154.5 ± 0.00	154.3 ± 0.00
	Mean	150.6 ^{d,2} ± 0.00	151.4 ^{d,3} ± 0.00	148.8 ^{d,1} ± 0.00	153.6 ^{d,4} ± 0.00	151.2 ^{d,3} ± 0.00	150.9 ^{d,23} ± 0.00	151.0 ^{d,23} ± 0.00
C	31°C ^B	170.8 ± 0.00	170.5 ± 0.00	169.4 ± 0.00	169.0 ± 0.00	167.5 ± 0.00	169.9 ± 0.00	168.7 ± 0.00
	25°C ^B	170.8 ± 0.00	173.0 ± 0.00	171.3 ± 0.00	169.3 ± 0.00	170.2 ± 0.00	170.5 ± 0.00	170.2 ± 0.00
	20°C ^A	166.0 ± 0.00	175.2 ± 0.00	173.2 ± 0.00	172.0 ± 0.00	172.0 ± 0.00	168.5 ± 0.00	169.4 ± 0.00
	Mean	169.2 ^{e,1} ± 0.00	172.9 ^{e,6} ± 0.00	171.3 ^{e,5} ± 0.00	170.1 ^{e,4} ± 0.00	169.9 ^{e,34} ± 0.00	169.6 ^{e,23} ± 0.00	169.4 ^{e,12} ± 0.00
D	31°C ^B	401.0 ± 0.00	405.0 ± 0.00	403.0 ± 0.00	404.0 ± 0.00	404.0 ± 0.00	409.0 ± 0.00	406.0 ± 0.00
	25°C ^A	300.0 ± 0.00	300.0 ± 0.00	302.0 ± 0.00	300.0 ± 0.00	300.0 ± 0.00	302.0 ± 0.00	302.0 ± 0.00
	20°C ^A	304.0 ± 0.00	302.0 ± 0.00	312.0 ± 0.00	308.0 ± 0.00	308.0 ± 0.00	308.0 ± 0.00	308.0 ± 0.00
	Mean	335.0 ^{f,1} ± 0.00	335.7 ^{f,1} ± 0.00	339.0 ^{f,1} ± 0.00	337.3 ^{f,1} ± 0.00	337.3 ^{f,1} ± 0.00	339.7 ^{f,1} ± 0.00	338.7 ^{f,1} ± 0.00
E	31°C ^A	487.0 ± 0.00	485.0 ± 0.00	483.0 ± 0.00	489.0 ± 0.00	485.0 ± 0.00	491.0 ± 0.00	487.0 ± 0.00
	25°C ^A	487.0 ± 0.00	485.0 ± 0.00	488.0 ± 0.00	485.0 ± 0.00	485.0 ± 0.00	485.0 ± 0.00	487.0 ± 0.00
	20°C ^A	487.0 ± 0.00	487.0 ± 0.00	489.0 ± 0.00	488.0 ± 0.00	487.0 ± 0.00	488.0 ± 0.00	488.0 ± 0.00
	Mean	487.0 ^{h,3} ± 0.00	485.7 ^{h,1} ± 0.00	486.7 ^{h,2} ± 0.00	487.3 ^{h,4} ± 0.00	485.7 ^{h,1} ± 0.00	488.0 ^{h,5} ± 0.00	487.3 ^{h,4} ± 0.00
F	31°C ^C	522.0 ± 0.00	520.0 ± 0.00	516.0 ± 0.00	524.0 ± 0.00	519.0 ± 0.00	524.0 ± 0.00	524.0 ± 0.00
	25°C ^B	446.0 ± 0.00	446.0 ± 0.00	446.0 ± 0.00	444.0 ± 0.00	445.0 ± 0.00	446.0 ± 0.00	446.0 ± 0.00
	20°C ^A	426.0 ± 0.00	414.0 ± 0.00	415.0 ± 0.00	416.0 ± 0.00	415.0 ± 0.00	410.0 ± 0.00	414.0 ± 0.00
	Mean	464.7 ^{g,1} ± 0.00	460.0 ^{g,1} ± 0.00	459.0 ^{g,1} ± 0.00	461.3 ^{g,1} ± 0.00	459.7 ^{g,1} ± 0.00	460.0 ^{g,1} ± 0.00	461.3 ^{g,1} ± 0.00
G	31°C ^A	87.8 ± 0.00	87.8 ± 0.00	87.9 ± 0.00	87.7 ± 0.00	88.0 ± 0.00	87.8 ± 0.00	88.5 ± 0.00
	25°C ^A	88.2 ± 0.00	87.6 ± 0.00	87.6 ± 0.00	86.2 ± 0.00	85.4 ± 0.00	87.1 ± 0.00	86.5 ± 0.00
	20°C ^A	87.8 ± 0.00	88.3 ± 0.00	88.1 ± 0.00	89.0 ± 0.00	88.2 ± 0.00	87.6 ± 0.00	87.4 ± 0.00
	Mean	87.9 ^{b,4} ± 0.00	87.9 ^{b,4} ± 0.00	87.9 ^{b,34} ± 0.00	87.6 ^{b,23} ± 0.00	87.2 ^{b,1} ± 0.00	87.5 ^{b,2} ± 0.00	87.5 ^{b,2} ± 0.00
H	31°C ^A	126.0 ± 0.00	126.6 ± 0.00	126.4 ± 0.00	126.6 ± 0.00	126.3 ± 0.00	127.0 ± 0.00	128.0 ± 0.00
	25°C ^A	125.8 ± 0.00	127.7 ± 0.00	125.6 ± 0.00	125.8 ± 0.00	125.9 ± 0.00	126.2 ± 0.00	126.1 ± 0.00
	20°C ^A	126.0 ± 0.00	125.8 ± 0.00	126.1 ± 0.00	126.1 ± 0.00	125.6 ± 0.00	123.5 ± 0.00	126.5 ± 0.00
	Mean	125.9 ^{c,2} ± 0.00	126.7 ^{c,4} ± 0.00	126.0 ^{c,23} ± 0.00	126.2 ^{c,3} ± 0.00	125.9 ^{c,2} ± 0.00	125.6 ^{c,1} ± 0.00	126.9 ^{c,4} ± 0.00
I	31°C ^A	174.0 ± 0.00	172.2 ± 0.00	171.5 ± 0.00	172.6 ± 0.00	172.1 ± 0.00	173.8 ± 0.00	173.0 ± 0.00
	25°C ^A	174.0 ± 0.00	174.0 ± 0.00	174.0 ± 0.00	176.0 ± 0.00	174.0 ± 0.00	176.0 ± 0.00	173.6 ± 0.00
	29°C ^A	174.0 ± 0.00	173.6 ± 0.00	174.6 ± 0.00	172.5 ± 0.00	173.0 ± 0.00	174.2 ± 0.00	174.2 ± 0.00
	Mean	174.0 ^{e,4} ± 0.00	173.3 ^{e,2} ± 0.00	173.4 ^{e,2} ± 0.00	173.7 ^{e,3} ± 0.00	173.0 ^{e,1} ± 0.00	174.7 ^{e,5} ± 0.00	173.6 ^{e,3} ± 0.00
K	31°C ^A	15.8 ± 0.00	15.4 ± 0.00	16.4 ± 0.00	15.7 ± 0.00	15.4 ± 0.00	15.5 ± 0.00	15.4 ± 0.00
	25°C ^B	16.5 ± 0.00	17.0 ± 0.00	16.1 ± 0.00	16.0 ± 0.00	16.0 ± 0.00	15.8 ± 0.00	17.0 ± 0.00
	20°C ^C	17.0 ± 0.00	17.2 ± 0.00	16.8 ± 0.00	16.4 ± 0.00	16.8 ± 0.00	16.1 ± 0.00	16.8 ± 0.00
	Mean	16.4 ^{a,23} ± 0.00	16.5 ^{a,3} ± 0.00	16.4 ^{a,23} ± 0.00	16.0 ^{a,1} ± 0.00	16.1 ^{a,12} ± 0.00	15.8 ^{a,1} ± 0.00	16.4 ^{a,23} ± 0.00

All of the experiments were performed in triplicate. All of the data represent the means \pm SD. For each parameter, the means are followed by the same letter or number are not significantly different ($P < 0.01$). Small letters are used for water sample x to represent the conductivity value interaction in the same week of the storage period. Numbers are used for storage period x to represent the conductivity value interaction in the same water sample. Capital letters are used for storage condition x to represent the conductivity value over the entire storage period for each sample in the same water sample.

Table 3 Cation contents of water samples

Cation	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Al ($\mu\text{g/L}$)	$3.78^c \pm 0.02$	$10.4^b \pm 0.40$	$2.86^c \pm 0.06$	$3.46^c \pm 0.25$	$11.4^b \pm 0.40$	$2.48^c \pm 0.25$	$2.73^c \pm 0.06$	$19.0^a \pm 0.25$	$2.67^c \pm 0.06$	$7.30^{bc} \pm 0.00$
Sb ($\mu\text{g/L}$)	$<0.30^b$	$<0.30^b$	$<0.30^b$	$0.44^a \pm 0.10$	$<0.30^b$	$<0.30^b$	$<0.30^b$	$<0.30^b$	$<0.30^b$	$<0.30^b$
As ($\mu\text{g/L}$)	$0.80^e \pm 0.00$	$0.50^f \pm 0.02$	$8.30^c \pm 0.20$	$8.03^c \pm 0.05$	$25.0^a \pm 0.20$	$9.50^b \pm 0.30$	$<0.30^g$	$4.40^d \pm 0.46$	$0.50^f \pm 0.02$	$<0.30^g$
Ba ($\mu\text{g/L}$)	$7.07^c \pm 0.06$	$4.15^f \pm 0.31$	$3.17^g \pm 0.06$	$6.67^d \pm 0.15$	$1.62^j \pm 0.20$	$5.41^e \pm 0.20$	$25.6^a \pm 0.25$	$<0.90^k$	$18.0^b \pm 0.20$	$2.00^h \pm 0.00$
B (mg/L)	$<0.02^f$	$0.20^{bc} \pm$	$0.02^e \pm 0.00$	$0.10^{de} \pm 0.00$	$2.24^a \pm 0.13$	$0.08^{de} \pm 0.00$	$0.18^{cd} \pm 0.05$	$0.28^b \pm 0.01$	$0.02^e \pm 0.00$	$<0.02^f$
Cd ($\mu\text{g/L}$)	$<0.25^a$	$<0.25^a$	$<0.25^a$	$<0.25^a$	$<0.25^a$	$<0.25^a$	$<0.25^a$	$<0.25^a$	$<0.25^a$	$<0.25^a$
Ca (mg/L)	$25.9^b \pm 0.31$	$15.3^d \pm 0.30$	$15.9^c \pm 0.14$	$4.27^h \pm 0.06$	$1.32^j \pm 0.20$	$6.68^f \pm 0.35$	$5.61^g \pm 0.20$	$14.3^e \pm 0.10$	$28.1^a \pm 0.50$	$1.18^j \pm 0.15$
Cr ($\mu\text{g/L}$)	$<1.00^a$	$<1.00^a$	$<1.00^a$	$<1.00^a$	$<1.00^a$	$<1.00^a$	$<1.00^a$	$<1.00^a$	$<1.00^a$	$<1.00^a$
Cu ($\mu\text{g/L}$)	$1.80^c \pm 0.04$	$<1.00^f$	$<1.00^f$	$1.77^c \pm 0.05$	$1.41^d \pm 0.20$	$2.37^b \pm 0.15$	$1.00^e \pm 0.00$	$1.50^{cd} \pm 0.10$	$7.00^a \pm 0.20$	$1.00^e \pm 0.00$
Fe ($\mu\text{g/L}$)	$8.51^d \pm 0.30$	$8.77^d \pm 0.15$	$4.01^g \pm 0.20$	$4.59^f \pm 0.42$	$6.70^e \pm 0.20$	$14.4^a \pm 0.30$	$3.22^h \pm 0.30$	$11.1^c \pm 1.00$	$12.0^b \pm 0.40$	$3.67^{gh} \pm 0.16$
Pb ($\mu\text{g/L}$)	$1.13^a \pm 0.06$	$<0.45^c$	$<0.45^c$	$<0.45^c$	$<0.45^c$	$<0.45^c$	0.60 ± 0.00	$<0.45^c$	$<0.45^c$	$<0.45^c$
Mg (mg/L)	$3.10^b \pm 0.10$	$7.22^b \pm 0.40$	$7.61^a \pm 0.40$	$1.00^d \pm 0.04$	$1.00^d \pm 0.00$	$1.00^d \pm 0.00$	$1.70^c \pm 0.00$	$2.10^c \pm 0.11$	$3.67^b \pm 0.06$	$<0.90^e$
Mn (mg/L)	$0.57^c \pm 0.06$	$<0.50^d$	$<0.50^d$	$<0.50^d$	$0.80^b \pm 0.005$	$0.77^b \pm 0.00$	$17.0^a \pm 0.60$	$<0.50^d$	$<0.50^d$	$<0.50^d$
Hg ($\mu\text{g/L}$)	$<0.40^b$	$<0.40^b$	$<0.40^b$	$<0.40^b$	$<0.40^b$	$0.50^a \pm 0.10$	$<0.40^b$	$<0.40^b$	$<0.40^b$	$<0.40^b$
Ni ($\mu\text{g/L}$)	$1.94^b \pm 1.00$	$<0.40^c$	$<0.40^c$	$<0.40^c$	$<0.40^c$	$<0.40^c$	$7.21^a \pm 0.30$	$<0.40^c$	$<0.40^c$	$<0.40^c$
K (mg/L)	$<0.90^f$	$1.80^e \pm 0.10$	$6.00^a \pm 0.10$	$2.83^c \pm 0.06$	$<0.90^f$	$3.17^b \pm 0.16$	$1.90^d \pm 0.00$	$<0.90^f$	$<0.90^f$	$<0.90^f$
Se ($\mu\text{g/L}$)	$0.39^d \pm 0.01$	$<0.30^e$	$<0.30^e$	$<0.30^e$	$2.52^a \pm 0.30$	$0.40^d \pm 0.00$	$0.90^b \pm 0.00$	$0.81^c \pm 0.44$	$0.40^d \pm 0.00$	$<0.30^e$
Si (mg/L)	$3.64^h \pm 0.12$	$19.0^d \pm 0.10$	$33.0^a \pm 1.00$	$21.5^c \pm 0.07$	$11.1^e \pm 1.00$	$31.0^b \pm 0.45$	$11.0^e \pm 0.20$	$6.39^f \pm 0.46$	$5.37^g \pm 0.15$	$3.07^j \pm 0.05$
Na (mg/L)	$2.30^g \pm 0.10$	$8.07^e \pm 0.06$	$9.07^e \pm 0.07$	$64.7^c \pm 1.50$	$112^a \pm 2.01$	$88.0^b \pm 0.43$	$8.31^e \pm 0.30$	$11.6^d \pm 0.10$	$5.77^f \pm 0.17$	$1.57^g \pm 0.06$
Zn ($\mu\text{g/L}$)	$13.0^d \pm 0.15$	$11.7^e \pm 0.15$	$5.42^g \pm 0.40$	$25.8^b \pm 2.52$	$2.60^h \pm 0.10$	$9.07^f \pm 0.16$	$5.10^g \pm 0.00$	$13.3^d \pm 0.12$	$19.0^c \pm 0.25$	$35.9^a \pm 0.12$

The experiments were performed in triplicate. All of the data are reported as the mean \pm SD. For each cation, the means followed by the same letter are not significantly different ($P < 0.01$).

Table 4. Anion contents of water samples (mg/L)

Anion	Sample									
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
F	<0.04 ^d	0.08 ^d \pm 0.00	<0.04 ^d	0.37 ^b \pm 0.002	3.57 ^a \pm 0.06	<0.04 ^d	<0.04 ^d	0.32 ^b \pm 0.10	0.20 ^c \pm 0.00	0.20 ^c \pm 0.00
Cl	18.9 ^a \pm 1.00	1.16 ^g \pm 0.06	<0.17 ^h	5.76 ^d \pm 0.06	9.33 ^e \pm 0.12	10.2 ^c \pm 0.20	13.2 ^b \pm 0.15	1.60 ^f \pm 0.10	1.50 ^{fg} \pm 0.00	1.50 ^{fg} \pm 0.00
Br	<0.05 ^a	<0.05 ^a	<0.05 ^a	<0.05 ^a	<0.05 ^a	<0.05 ^a	<0.05 ^a	<0.05 ^a	<0.05 ^a	<0.05 ^a
NO ₃	3.31 ^c \pm 1.00	1.77 ^d \pm 0.06	<0.13 \pm 0.00	5.70 ^b \pm 0.10	0.48 ^e \pm 0.03	9.46 ^a \pm 0.15	<0.13	0.81 ^e \pm 0.10	1.77 ^d \pm 0.06	1.77 ^d \pm 0.05
NO ₂	<0.05 ^b	<0.05 ^b	<0.05 ^b	<0.05 ^b	<0.05 ^b	0.08 ^a \pm 0.00	<0.05 ^b	<0.05 ^b	<0.05 ^b	<0.05 ^b
SO ₄	6.44 ^{ef} \pm 0.15	5.41 ^f \pm 0.30	<0.13 ^g	16.3 ^c \pm 0.15	40.8 ^a \pm 2.52	20.6 ^b \pm 0.16	7.00 ^e \pm 0.00	10.0 ^d \pm 0.50	9.27 ^d \pm 0.17	9.27 ^d \pm 0.14

The experiments were performed in triplicate. All of the data are reported as the mean \pm SD. For each anion, the means followed by the same letter are not significantly different ($P < 0.01$).

Table 5 Bisphenol A (BPA) contents of water samples ($\mu\text{g/L}$)

Sample		1. Week	2. Week	3. Week	4. Week	5. Week	6. Week	7. Week
W1	31°C ^C	<0.50	<0.50	<0.50	<0.50	0.51 ± 0.05	0.68 ± 0.05	0.81 ± 0.01
	25°C ^A	<0.50	<0.50	<0.50	0.53 ± 0.01	<0.50	0.50 ± 0.00	2.05 ± 0.04
	20°C ^B	<0.50	<0.50	<0.50	0.51 ± 0.01	0.62 ± 0.01	0.75 ± 0.03	1.78 ± 0.06
	Mean	<0.50 ^{e,3}	<0.50 ^{d,3}	<0.50 ^{e,3}	0.51 ^{e,3} ± 0.00	0.55 ^{c,3} ± 0.02	0.66 ^{d,2} ± 0.03	1.73 ^{d,1} ± 0.03
W2	31°C ^A	<0.50	<0.50	0.50 ± 0.01	1.04 ± 0.05	1.25 ± 0.01	2.12 ± 0.01	2.65 ± 0.06
	25°C ^B	<0.50	0.65 ± 0.03	0.71 ± 0.02	0.78 ± 0.03	0.85 ± 0.02	0.95 ± 0.03	2.09 ± 0.05
	20°C ^B	<0.50	0.50 ± 0.01	0.58 ± 0.01	0.82 ± 0.02	0.86 ± 0.02	1.02 ± 0.02	2.03 ± 0.03
	Mean	<0.50 ^{e,6}	0.56 ^{c,5,6} ± 0.01	0.61 ^{d,5} ± 0.01	0.89 ^{e,4} ± 0.02	1.02 ^{b,3} ± 0.00	1.57 ^{b,2} ± 0.00	2.29 ^{b,1} ± 0.05
W3	31°C ^B	<0.50	<0.50	<0.50	<0.50	0.50 ± 0.00	0.56 ± 0.04	1.25 ± 0.07
	25°C ^A	<0.50	<0.50	0.87 ± 0.02	1.25 ± 0.03	2.16 ± 0.05	1.31 ± 0.01	1.84 ± 0.03
	20°C ^A	<0.50	0.51 ± 0.01	0.72 ± 0.01	1.17 ± 0.04	2.24 ± 0.03	1.17 ± 0.02	1.67 ± 0.08
	Mean	<0.50 ^{e,5}	<0.50 ^{d,5}	0.73 ^{b,4} ± 0.01	1.09 ^{b,3} ± 0.04	2.03 ^{a,1} ± 0.03	1.12 ^{c,3} ± 0.01	1.62 ^{d,2} ± 0.01
W4	31°C ^B	<0.50	<0.50	<0.50	0.63 ± 0.01	<0.50	<0.50	0.50 ± 0.00
	25°C ^A	<0.50	<0.50	0.62 ± 0.01	0.58 ± 0.01	0.50 ± 0.01	1.21 ± 0.01	2.68 ± 0.07
	20°C ^A	<0.50	<0.50	0.66 ± 0.01	0.72 ± 0.00	0.65 ± 0.03	1.37 ± 0.04	2.70 ± 0.01
	Mean	<0.50 ^{e,4}	<0.50 ^{d,4}	0.60 ^{d,3,4} ± 0.01	0.65 ^{c,3} ± 0.01	0.56 ^{c,3,4} ± 0.01	1.16 ^{c,2} ± 0.02	2.51 ^{c,1} ± 0.02
W5	31°C ^B	0.60 ± 0.02	0.56 ± 0.02	0.68 ± 0.01	<0.50	<0.50	0.51 ± 0.01	<0.50
	25°C ^B	0.51 ± 0.01	0.51 ± 0.01	0.62 ± 0.01	<0.50	0.53 ± 0.01	0.62 ± 0.01	0.68 ± 0.06
	20°C ^A	0.64 ± 0.03	0.72 ± 0.04	0.68 ± 0.04	<0.50	<0.50	0.54 ± 0.01	0.75 ± 0.04
	Mean	0.59 ^{d,2} ± 0.01	0.61 ^{b,2} ± 0.01	0.66 ^{c,1} ± 0.02	<0.50 ^{e,4}	0.51 ^{c,4} ± 0.01	0.56 ^{d,3} ± 0.01	0.66 ^{e,1} ± 0.01
W6	31°C ^B	<0.50 ^{e,3}	0.50 ± 0.00	0.75 ± 0.03	<0.50	<0.50	<0.50	<0.50
	25°C ^C	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.62 ± 0.02
	20°C ^A	<0.50	<0.50	<0.50	<0.50	0.51 ± 0.01	0.54 ± 0.02	0.84 ± 0.02
	Mean	<0.50	<0.50 ^{d,3}	0.61 ^{d,2} ± 0.03	<0.50 ^{e,3}	0.50 ^{c,3} ± 0.01	0.51 ^{e,3} ± 0.02	0.68 ^{g,1} ± 0.02
W7	31°C ^A	<0.50	<0.50	<0.50	0.64 ± 0.02	<0.50	0.58 ± 0.01	1.02 ± 0.09
	25°C ^B	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.83 ± 0.01
	20°C ^B	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.90 ± 0.05
	Mean	<0.50 ^{e,4}	<0.50 ^{d,4}	<0.50 ^{e,4}	0.56 ^{e,2} ± 0.02	<0.50 ^{e,4}	0.53 ^{e,3} ± 0.01	0.92 ^{e,1} ± 0.01
W8	31°C ^A	<0.50	<0.50	0.56 ± 0.01	<0.50	0.60 ± 0.02	<0.50	1.05 ± 0.01
	25°C ^B	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.50 ± 0.00
	20°C ^B	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	Mean	<0.50 ^{e,2}	<0.50 ^{d,2}	0.52 ^{e,2} ± 0.03	<0.50 ^{e,2}	0.54 ^{c,2} ± 0.02	<0.50 ^{e,2}	0.78 ^{f,1} ± 0.01
W9	31°C ^B	0.50 ± 0.01	0.87 ± 0.03	1.38 ± 0.01	0.54 ± 0.02	0.70 ± 0.02	<0.50	3.15 ± 0.03
	25°C ^A	0.51 ± 0.01	0.50 ± 0.01	1.07 ± 0.01	1.52 ± 0.04	2.14 ± 0.02	2.37 ± 0.01	2.78 ± 0.03
	20°C ^A	0.54 ± 0.02	0.69 ± 0.02	1.13 ± 0.03	1.43 ± 0.04	2.24 ± 0.01	2.46 ± 0.04	2.94 ± 0.06
	Mean	0.52 ^{b,7} ± 0.01	0.72 ^{a,6} ± 0.00	1.21 ^{a,5} ± 0.01	1.33 ^{a,4} ± 0.03	1.98 ^{a,3} ± 0.00	2.23 ^{a,2} ± 0.02	2.96 ^{a,1} ± 0.04
W10	31°C ^B	<0.50	0.50 ± 0.01	0.62 ± 0.02	0.70 ± 0.02	0.92 ± 0.01	1.17 ± 0.02	2.75 ± 0.02
	25°C ^{AB}	<0.50	0.50 ± 0.00	0.62 ± 0.01	1.09 ± 0.02	2.13 ± 0.04	1.71 ± 0.03	2.05 ± 0.05
	20°C ^A	<0.50	0.50 ± 0.01	0.58 ± 0.01	1.15 ± 0.03	2.36 ± 0.01	1.74 ± 0.02	2.12 ± 0.01
	Mean	<0.50 ^{e,6}	0.50 ^{d,6} ± 0.00	0.61 ^{d,5} ± 0.00	1.02 ^{b,4} ± 0.02	2.02 ^{a,2} ± 0.02	1.58 ^{b,3} ± 0.00	2.35 ^{b,1} ± 0.01

All of the experiments were performed in triplicate. All of the data represent the means ± SD. For each parameter, means followed by the same letter or number are not significantly different ($P < 0.01$). Small letters are used for water sample x to represent the BPA content interaction in the same week of the storage period. Numbers are used for storage period x to represent the BPA content interactions in the same water sample. Capital letters are used for storage condition x to represent the BPA content over the entire storage period of each sample in the same water sample.

3.2 Anion and cations

For this study, the cation (Table 3) and anion levels in the water samples were examined (Table 4). In all of the water samples, the levels of Br, Cd and Cr were found to be below the values of LOQ. The levels of NO₂, Sb, Mn and Ni could not be detected in most of the water samples. Of the samples observed in this study, the sample with the W5 code, containing six different cations and two different anions, was found to have the highest contaminant level ($P < 0.01$). The national legal regulation concerning drinking water is the “Regulation about the Water Intended for Human Conception” (Anonymous, 2006). The water sample with the W5 code was found to have As (max 10.0 µg/L), B (max 1.0 mg/L) and F (max 1.5 mg/L) above the regulated level. The detected amounts of As, B and F were 25.0 ± 0.20 µg/L, 2.24 ± 0.13 mg/L and 3.57 ± 0.06 mg/L, respectively. It is also noteworthy that the same sample (W5) had the highest average pH (9.28) and conductivity (487.0 µS/cm) levels. All of the other water samples did not pose any threat to the health of consumers in terms of anion and/or cation levels.

3.3 BPA

Several studies have reported BPA migration into food (Bemrah et al., 2014; Cunha et al., 2011; Geens et al., 2010; Grumetto et al., 2008; Pandelova et al., 2011). These investigations have shown that BPA can migrate from polycarbonate (PC) materials due to the diffusion and hydrolysis of polymers. Nevertheless, diffusion has a significantly lower effect on BPA migration from PC (Michalowicz, 2014). For this reason, analysis of the effect and strength of different storage conditions and packaging materials on BPA migration is important for food safety and technology concerns. In this study, BPA migration with varying temperatures and residence times in water kept in PC packaging was examined. The weekly test results from all of the monitored samples are shown in Table 5.

In the samples coded W1-W10 ($n=10$) the highest BPA levels were detected to be 2.05 ± 0.04 , 2.65 ± 0.06 , 2.24 ± 0.03 , 2.70 ± 0.01 , 0.75 ± 0.04 , 0.84 ± 0.02 , 1.02 ± 0.09 , 1.05 ± 0.01 , 3.15 ± 0.03 and 2.75 ± 0.02 µg/L, respectively. The water samples showed an increase in the detected BPA levels with time ($P < 0.01$). However, it was also seen that the magnitude of this increase changed from sample to sample. Additionally, the storage temperature and conditions tested for this study led to differences in the change in the BPA levels in the samples. For this reason, we could not reveal the effect of typical home and business storage conditions on the migration of BPA in PC bottles.

When evaluating the BPA limits in drinking water, scientific studies related to toxicological, international, regional (e.g., EU) and national (e.g., Turkey) regulations and standards must be given particular attention. Drinking water in Italy and Malaysia was reported to have BPA levels between 17 to 56 ng/L and 3.5 to 59.8 ng/L, respectively (Chen et al., 2013; Kang et al., 2006; Santhi et al., 2012). BPA can get to water sources used by humans or affect aquatic life in rivers and lakes (Kang et al., 2007). Stackelberg et al. (2004) previously reported BPA levels in drinking water as high as 0.42 µg/L. The consumption of bottled mineral water may also contribute to exposure to endocrine disruptors (Santhi et al., 2012).

The current tolerable daily intake (TDI) established by the EFSA for BPA of 4 µg/kg (body weight)/day in 2015 (Gundert et al., 2017). Considering the possibility for BPA migration from polycarbonates to food and water as well as the significant toxicity of this compound, some countries (e.g., the European Union, Canada and the US) have ceased the production of baby bottles made from BPA polymers (Michalowicz, 2014).

In all of the water samples in the scope of this study (n=10), at the end of the different storage times, all of the detected BPA levels were below 3.15 µg/L. If the 4µg/kg bw/day TDI limit is taken as a basis, the BPA levels of all of the water samples can be considered to be similar, and the levels seen at the storage temperatures and residence times that correspond to typical home and business conditions did not exceed the limits that lead to risks for human health.

The BPA levels detected in our study were determined to be very close values to the LOQ values in general. Weekly changes in BPA levels were observed, but the changes did not occur in a linear fashion. Additionally, a correlation between the direction and magnitude of the changes to the temperature and residence time could not be found for all of the samples (P<0.01). It is possible that a relationship between the half-life of BPA and the composition and physical features of the water exists in this situation. As such, while BPA could be migrating into the water in the PC packaging on one hand, while a certain amount of the BPA was completing its half-life on the other hand. The half-life of BPA in water is approximately three to five days, which is enough time to affect aquatic organisms (Kang and Kondo 2002). In a study conducted by Kang and Kondo (2005), river water samples were analysed in aerobic conditions for 60 days and the half-life for BPA was calculated to be four days at 25°C and three days at 35°C. The BPA level in river water was detected to fall under the detection limit by the seventh day (0.5 µg/L). However, as previously mentioned, other factors that could affect this half-time must be considered.

In general, it was detected that drinking water having a high level of hardness caused degradation in PC packages and increased the BPA levels of the drinking water (Brem and Grob, 2009). The main materials that affective the hardness level of water are Ca and Mg (Şener, 2006;Uzun 2006). Considering all the conditions and residence times in the scope of this study, the highest BPA levels detected were the ones belonging to the sample with the W9 code (3.15 ± 0.03 µg/L). The Ca level belonging to the sample with W9 code was detected to be at a higher level than in all of the other samples (28.1±0.50 mg/L) (P<0.01). For this reason, the results of this study were consistent previous studies that showed that a high hardness level increases BPA migration in PC packaging.

It was found that the BPA migration ratio from PC bottles to other solutions varied with the chemical properties of the materials (Michalowicz, 2014). The results published by Mercea (2009) showed that lower pH values of a solution were associated with an increase in BPA migration from PCs to water, whereas the presence of cations in a solution (at room temperature) did not significantly affect PC hydrolysis. It was also noted that BPA migrated more quickly from polycarbonate bottles (used as water containers) that were turned over every few years (3–7) and were exposed to increased temperatures (Michalowicz, 2014). The studies conducted indicate that high temperature and alkali environments (i.e., high pH level) causes degradation in polycarbonate plastics and that PC materials increase BPA migration (Sajiki and Yonekubo, 2004;Brem and Grob, 2009). However, in our study, despite the pH increases detected, especially in the samples of W2, W3 and W4, a statistically significant change in the BPA levels could not be detected (P<0.01). Additionally, no relationship between the samples within the scope of the study and the conductivity values belonging to these samples was found (P<0.01).

Storage time is a factor that affects BPA migration in PC bottles and can increase the levels of this substance in drinking water. However, after the BPA has migrated, consumption times when the BPA has reached a level that may cause a risk for human health must be considered. The risk can be decreased by altering the production of the packaging material, modifying the physical and chemical features of the water used in the packaging and by other methods. In all of the water

samples tested, the highest BPA level was found to be 3.15 µg/L. According to these results, maximum amount of BPA amount that would be consumed by an adult drinking 2 L of water a day would be 6.30 µg. This amount is well below the limits regulated by both the EU and Turkey, and the data obtained in our study reveal that there is no situation in Turkey that would risk human health due to BPA migration. However, the wide range of changes to the physical features of the water in this study is a reminder that standardization on this matter is a necessity. Again, the identification of dangerous water samples, particularly due to their cation and anion contents, may be accepted as an indicator of insufficiencies of the producers, audit institutions and organizations.

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