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Research article

Assessment of bisphenol A in bottled drinking water and its environmental health risk implications

Sudarmaji[1,*], Retno Adriyani[1], Corie Indria Prasasti[1], Ratna Dwi Puji Astuti[1], Nurlia Sila[2] and Mohamad Azhar Mohd Noor[3]

[1] Department of Environmental Health, Faculty of Public Health, Universitas Airlangga, Surabaya 60115, Indonesia
[2] Department of Environmental Health, Faculty of Public Health, Universitas Hasanuddin, Makassar 90245, Indonesia
[3] Department of Environmental Health and Occupational Studies, Universiti Teknologi MARA, Shah Alam 40450, Selangor, Malaysia

* **Correspondence:** Email: sudarmaji@fkm.unair.ac.id; Tel: +6285730797888.

Abstract: Bisphenol A (BPA) is an industrial chemical commonly used as a monomer or additive in the production of polycarbonate plastics, epoxy resins, and other polymeric materials. BPA contamination is primarily associated with plastic bottled water containers. BPA has been associated with a range of adverse health effects. This study aims to investigate the impact of BPA exposure on public health in relation to the consumption of bottled drinking water. The research was conducted in Tambak Wedi Village, Surabaya, from July to October 2024. A total of 96 respondents participated in this cross-sectional study, which included laboratory analysis of bottled water samples and a human health risk assessment. Among ten brands of bottled water consumed by respondents, Brand A exhibited the highest BPA concentration (maximum 0.099 mg/L), while Brand G showed the lowest (maximum 0.082 mg/L). BPA exposure through bottled water consumption was not found to be significantly associated with carcinogenicity, reproductive system disorders, or endocrine disruption. However, a significant association was observed with immunosuppressive disorders (p-value=0.008; r-value=0,151), with very weak positive correlation strength. The noncarcinogenic and carcinogenic health risks of BPA across all bottled water brands were within acceptable safety limits. Collaborative efforts from governmental bodies, industry stakeholders, and consumers are essential to minimize the potential health risks associated with BPA exposure.

Keywords: Bisphenol A; bottled drinking water; health; environmental health risk analysis

1. Introduction

Bisphenol A (BPA) is a plastic material that is classified as plasticizers, used for the manufacture of plastic type polycarbonate (PC), and has been identified to contaminate food and beverages [1]. Numerous drink containers, compact discs, plastic cutlery, impact-resistant safety gear, and automobile parts are all made of that kind of plastic. Epoxy resin is synthesised using BPA as a monomer. Dental sealants, food can protection coatings, and other items use BPA epoxy resin [2]. Regulation No. HK 03.1.23.07.11.6664, issued by the Head of the National Agency for Drug and Food Control, sets the maximum BPA level at 0.3 ppm for infant bottles and 0.6 ppm for beverage bottles and other eating-drinking utensils [3]. Similarly, 0.5 μg/kg BW per day is the tolerance daily intake (TDI) value for BPA, per EFSA [4]. BPA is widely found in the environment and can be found in food containers, drink bottles, thermal paper, toys, and medical equipment. It can also leach or wash into the soil or water source. Bisphenol A (BPA) can migrate from various types of food packaging into the products inside, including plastic, metal (e.g., can linings), glass, ceramic, rubber, and paper. This migration is generally triggered by factors such as heating, high temperatures, exposure to sunlight, and prolonged exposure [5]. There is research that shows the influence of BPA levels on exposure to sunlight, which reveals that bottled water samples stored in rooms with exposure to sunlight are proven to contain BPA compared to samples without exposure to sunlight [4]. Through migration events, the BPA concentration in drinking water packaging may cause problems for the water. When water in polycarbonate plastics is heated to high temperatures, bisphenol-A can migrate to the water [6].

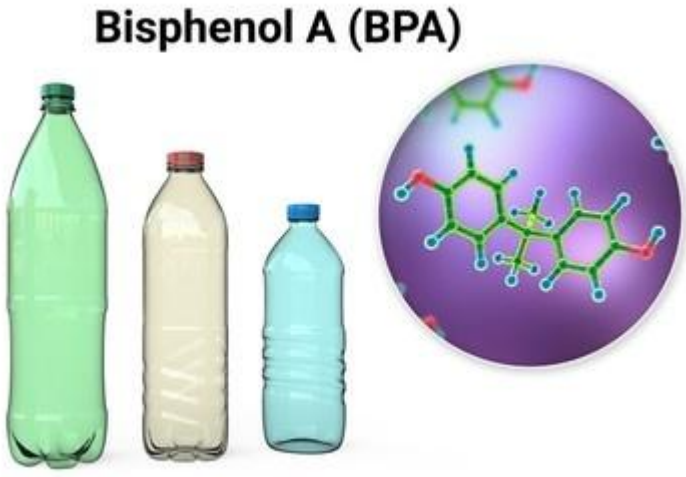

Figure 1. Plastic bottles as a common source of BPA exposure and its molecular structure.

Based on studies conducted in several countries, human exposure to BPA is quite widespread. Canadian statistical data conducted in 2007–2009 found that about 91% of Canadians aged 6 to 79 years had BPA detected in their urine [7]. BPA has the ability to change multiple bodily processes and can be a potent endocrine disruptor. Research demonstrates that BPA has numerous detrimental consequences on health, including on the immune system, neuroendocrine systems, and reproductive systems [8]. BPA exposure can be caused by food, which is the main route of exposure for the majority of individuals. In addition, BPA exposure can also come from dust, air, and other sources, but food and drink are the main ways people are exposed to BPA [9]. BPA exposure can occur through the

integumentary system (skin and eye contact), respiratory system (inhalation), vertical transmission (maternal-fetal), and digestive system (consumption).

One of the beverage markets with the quickest rate of growth in the world is bottled drinking water, which is predicted to overtake soft drinks as the largest beverage category by volume [10]. Even in nations where tap or well water is still generally safe, bottled drinking water is nevertheless widely consumed. In 2010, there were at least 473 companies in Indonesia that sold 1000 different kinds of bottled water, and there were another 800 companies that sold bottled water [10,11]. The consumption of bottled water in Indonesia is known to be 1,408,148,000 liters in 1997 and continues to increase to 3,643,138,000 liters in 2000 [10]. In 2023, the percentage of households in Indonesia whose main source of drinking water is bottled/refillable water is around 40.64%. This percentage is higher compared to other water sources, such as drilled/pump wells (17.07%), protected wells (15.26%), springs (12.17%), plumbing (8.92%), surface water/rainwater (3.53%), and unprotected wells (2.41%) [12]. The high consumption of bottled water in the community has a high potential for BPA exposure in the community.

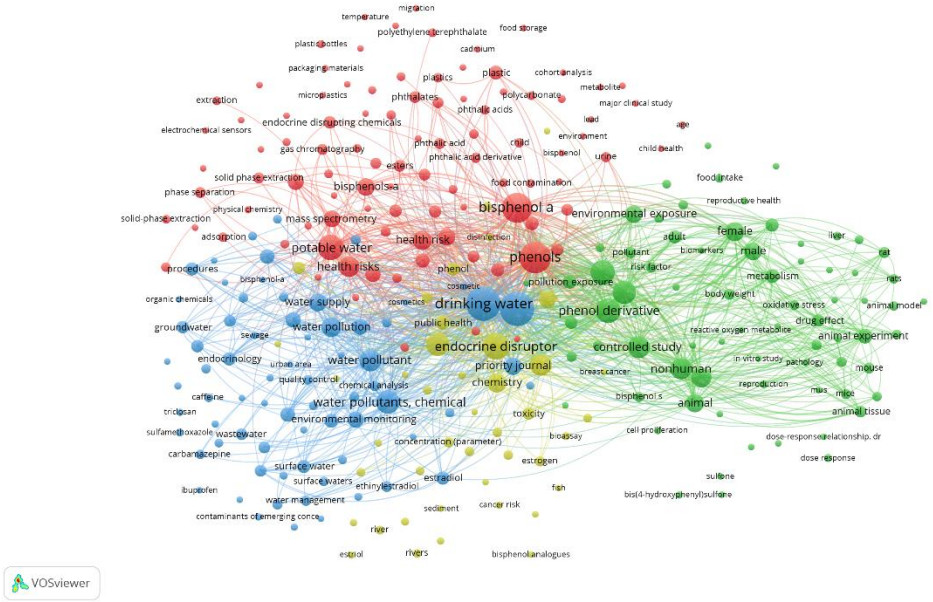

Figure 2. Bibliometric network visualization of research on BPA and environmental health risk using VOSviewer.

Despite growing global attention on BPA contamination in bottled drinking water, bibliometric analysis reveals that most studies remain concentrated on chemical characterization, plastic packaging materials, and animal-based toxicological models. One study documented how BPA migrated from plastic containers into drinking water under various temperature and storage conditions. This study was purely analytical and chemical in nature, validating that BPA was released, but rarely linking it directly to human health outcomes [13]. Another study focused on plastic packaging materials, comparing the rates at which BPA migrated from different types of plastic bottles [6,14]. Extensive studies have been conducted in rodents and aquatic organisms to understand the mechanisms of BPA toxicity, but the results are difficult to extrapolate directly to humans with complete confidence [15]. Clusters of research are heavily dominated by keywords, such as polycarbonate, plastic bottles, animal experiment, and metabolism, with limited integration into human population-based studies, especially

within developing country contexts. Notably, terms like drinking water, health risk, and public health appear, yet their connection to region-specific exposure scenarios, such as coastal communities in Indonesia, remains underexplored. This highlights a clear research gap in linking BPA exposure from bottled water consumption to environmental health risks in vulnerable human populations. The present study addresses this gap by assessing BPA concentrations in bottled water and evaluating the associated health risks among coastal residents in Surabaya, Indonesia. Residents in coastal areas who still lack adequate drinking water sources will have more potential to consume bottled drinking water to meet their needs. Therefore, this research will focus on the population in the coastal area in the city of Surabaya. Chronic exposure to BPA is known to cause various health problems, such as cardiovascular disease, neurological disorders, and reproductive disorders in humans [16]. BPA exposure in general amounts to humans may have negative effects on the brain, behavior, and prostate gland in fetuses, babies, and children, according to the National Toxicology Program of the U.S. Department of Health and Human Services.[17]. For this reason, monitoring the concentration of BPA in bottled water and its relation to public health risks needs to be carried out. Based on the literature review that has been conducted, research related to the content of BPA in bottled water and its impact on human health in Indonesia has not been done much. According to the literature analysis, there hasn't been much research done in Indonesia on the amount of BPA in bottled water and how it affects human health. Thus, this study aims to determine the amount of BPA present in the bottled water that Surabaya City residents frequently drink and determine the health hazards that residents face as a result of consuming bottled water that contains BPA.

2. Materials and methods

2.1. Study area and design

This study is a type of analytical observational research with a cross-sectional study design. This research will be carried out in Tambak Wedi Village, Surabaya City for four months starting from July to October 2024. The study will include sampling 10 types of bottled water that are favorite or often consumed by the public as biomonitoring of BPA concentrations in humans. The BPA concentration test carried out at the GIS (Saraswati Indo Genetech) laboratory in Surabaya will also use a questionnaire to find out consumption patterns or exposures, anthropometry, and health symptoms experienced by the residents of Surabaya City. The size of the human sample taken was 96 people with an age of >20 years. The calculation of the sample size is carried out using the Lemeshow formula.

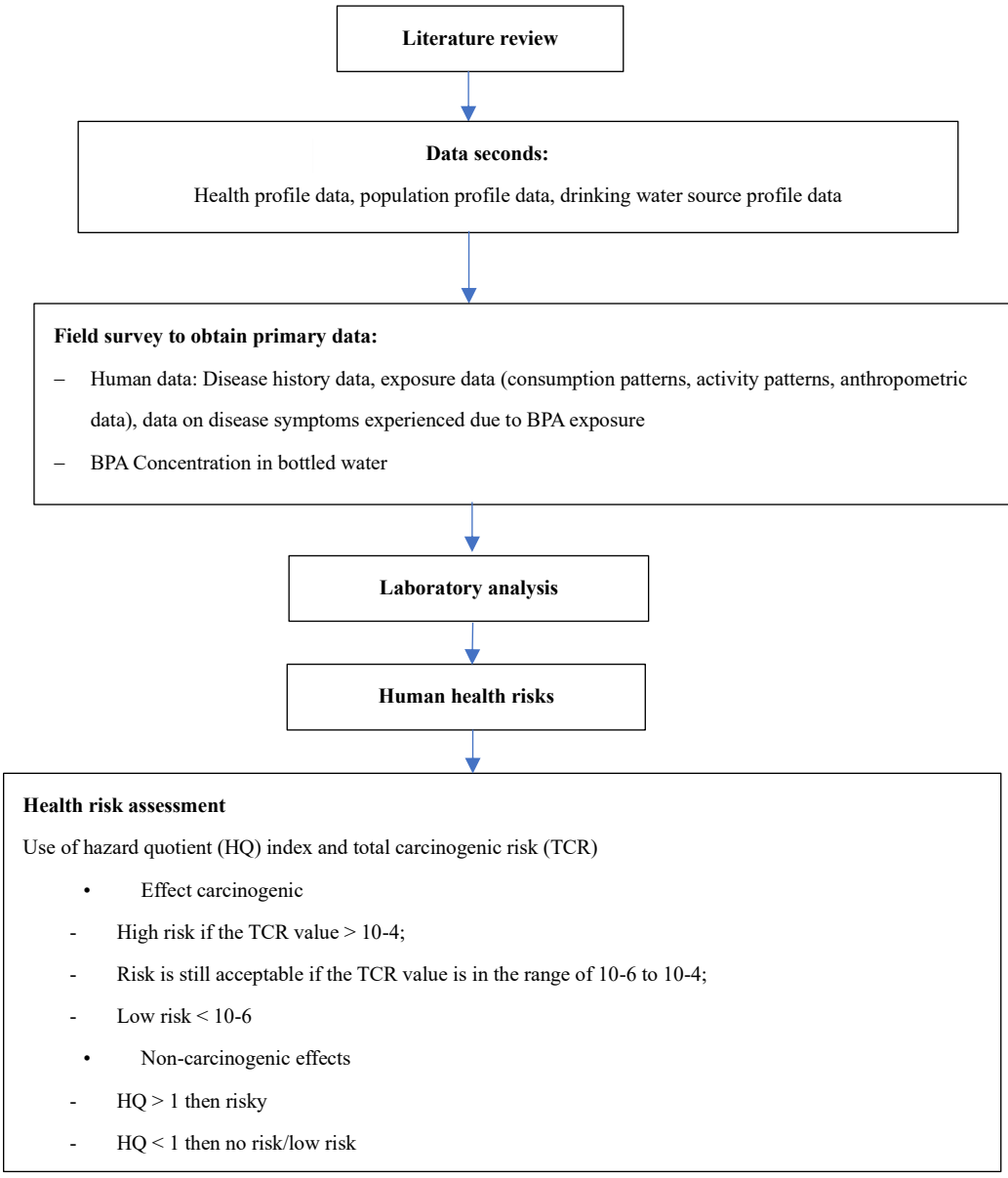

Figure 3. Stages and methods carried out during the research.

2.2. Water sample analysis

Ten types of bottled water that are often consumed and marketed in the market were used to collect water samples. The approach suggested by the EPA (528, 3535A, and 8041) can provide a basis for examining water samples used to determine the amount of phenolic compounds. [18]. Pretreatment in the form of solid-phase extraction is required in order to analyze the BPA concentration in water [18–22]. The AQUA Loader 3 (GL Science, Japan) and Oasis HLB SPE cartridges (225 mg, Waters, USA) are used to extract 1,000 milliliters of ultra-pure water or bottled water at a flow rate of 10 mL/min. Internal standards (IS) was added to the water sample at a concentration of 50 ng/L prior to extraction. Ten milliliters of ultra-pure water and six milliliters of MeOH were used to condition the HLB Oasis cartridges in turn. The cartridge is vacuum-dried for two hours after the water sample is loaded. Next, three milliliters of ethyl acetate and three milliliters of MeOH are used to gradually elute the target component from the cartridge. After being drained under a nitrogen stream, the eluate is

prepared for derivation as explained below. Following derivation, the sample is once more dried under a nitrogen stream before being redissolved in one milliliter of ethyl acetate. 1000 is the thickening factor. For quality control, blank control is performed using extremely clean water, and each bottled water sample or empty control is performed three times.

2.3. Derivatization of water samples

After the typical bisphenol analogue or by-product has been drained above, 50 microliters of DMF and 50 μL of BSTFA + 1% TMCS are added one after the other. The tubes are sealed tightly, combined, and heated for one hour at 80°C in a temperature-adjustable oven. Following derivation, the tubes are allowed to naturally cool to ambient temperature before being gently sprayed with nitrogen to dry them. After thoroughly mixing the tube and adding 1 mL of EtAc, the EtAc solution is moved to a 2 mL yellow vial for GC-MS analysis. Gas chromatography-mass spectrometry (GC-MS) was used to analyze the overall BPA levels in bottled water.

2.4. Environmental health risk analysis

After the concentration of BPA in the sample is known, the calculation of public health risk analysis can be carried out. In this study, estimates were made for health risks in the form of noncarcinogenic health risks and carcinogenic health risks. The formula for risk estimation is as follows [23,24]:

a. Noncarcinogenic health risks

$$HQ = \frac{C_w \times IR_w \times EF \times ED}{RfD \times AT \times BW} \tag{1}$$

b. Carcinogenic health risks

$$CR = \frac{C_w \times IR_w \times EF \times ED \times CSF}{AT \times BW} \tag{2}$$

In this case, HQ stands for hazard quotient (without units), Cw for concentration of BPA in water sample (mg/L), IR for ingestion rate of sample water (L/day), EF for frequency of exposure (days/year), ED for duration of exposure (years), BW for body weight (kg), AT for average exposure time (days), and RFD for reference dose of BPA in water (0.05 mg/kg/day) [25]. Although CSF is a slope factor for cancer, the toxicity test value for BPA in rats with prostate neoplasms indicates that the CSF value is 0.001 mg/kg/day [26].

2.5. Estrogenic activity-associated risk evaluation

BPA exposure can cause estrogen disruption, so we can evaluate the risk with the following formula [21]:

$$EEQ = \sum EP_i \times C_i \tag{3}$$

Where EP_i and Ci is the estrogenic potential of the individual bisphenols and the concentration of bisphenols in the sample (ng/L). The unit of EEQ is ng E_2/L. For BPA, the EP values are 1.92 E-3, 1E-4, and 8E-5 [21].

3. Results

3.1 Sample data results

Table 1. Consumption patterns and exposure of BPA.

No.	Consumption patterns and exposure of +BPA	Average
1	Total drinking water consumption	2 liters/day
2	Drinking water consumption frequency	365 days/year
3	Duration of drinking water consumption	31 years
4	Weight	71 kg

Respondents in this study involved 96 people with majority female gender (76%) in the age range of 21–80 years, with the majority aged between 31–40 years (31,3%). Based on Table 1., it can be known related to consumption patterns and exposure to BPA in research respondents. Where the average amount of bottled water consumption is 2 liters/day, for the frequency of consumption for 365 days/year and the duration of consumption time is 31 years for adults, with an average weight of 71 kg.

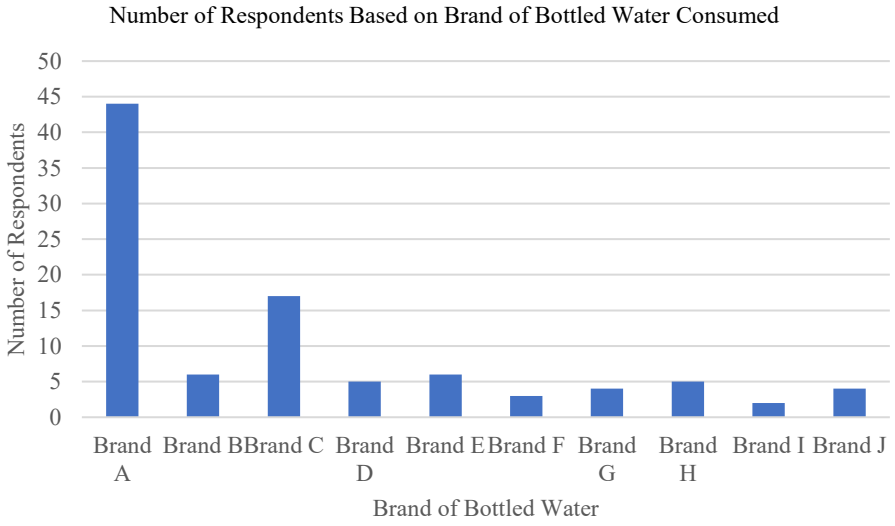

Figure 4. Number of respondents based on bottled water brand consumed.

In Figure 4. The type and number of bottled water (bottled drinking water) brands consumed by respondents were displayed. The majority of respondents consumed brand A bottled water and the brand of bottled water that was least consumed by respondents was brand I.

Table 2 shows that, with a maximum value of 0.099 µg/L and a minimum of 0.090 µg/L, Brand A has the highest BPA concentration in bottled drinking water samples. At a minimum of 0.080 µg/L and a maximum of 0.082 µg/L, Brand G is the brand of bottled water with the lowest concentration. The BPA concentration measurement results for the minimum, average, and maximum values in bottled drinking water samples are all within the safe range.

Table 2. BPA concentration of bottled samples based on bottled water brand.

No	Sample type of bottled water (500 ml/brand)	BPA concentration of bottled water sample (μg/L) (safe value= 0,6 bpj, mcg/kg (BPOM))		
		Minimum	Mean	Maximum
1	Brand A	0.090	0.095	0.099
2	Brand B	0.089	0.091	0.092
3	Brand C	0.082	0.087	0.092
4	Brand D	0.089	0.090	0.091
5	Brand E	0.081	0.085	0.093
6	Brand F	0.092	0.093	0.093
7	Brand G	0.080	0.081	0.082
8	Brand H	0.090	0.092	0.093
9	Brand I	0.094	0.094	0.094
10	Brand J	0.087	0.088	0.089

3.2. Environmental health risk analysis results

Table 3 of the study shows that respondents' health problems, such as endocrine system disorders, reproductive system disorders, carcinogenicity, and immunosuppressive diseases, are unaffected by the use of bottled drinking water, regardless of Brand A, B, or C. The Chi-square test findings showed that none of the variables had a significant association. This is probably due to the fact that drinking water's BPA concentration is still below acceptable bounds (< 0.6 mg/kg). Because the BPA concentration in urine was not measured for this study, the research questionnaire results also did not indicate any signs of disorders brought on by BPA exposure. Consequently, it is impossible to assess the level of toxicity brought on by BPA exposure. Daily exposure to BPA can still considerably raise the risk to human health, though. Table 3 lists the health effects of frequent exposure to BPA. Table 3 shows that BPA exposure through bottled water consumption was not found to be significantly associated with carcinogenicity, reproductive system disorders, or endocrine disruption. However, a significant association was observed with immunosuppressive disorders (p-value = 0.008; r-value=0.151), with very weak positive correlation strength.

Based on the findings of the study, the concentration of BPA in water samples was computed with least, average, and maximal concentration values in the environmental health risk analysis results. According to Table 4's findings, bisphenol A's carcinogenic and noncarcinogenic health risks are "safe" at the lowest, average, and maximum amounts. Additionally, the EEQ (Estrogenic activity-associated risk evaluation) results for the ten brands of bottled water are safe.

Table 3. Health symptoms experienced by respondents.

No	Health symptoms		Bottled water brand																		Total (N=96)		*p-value (r-value)*
			Brand A		Brand B		Brand C		Brand D		Brand E		Brand F		Brand G		Brand H		Brand I		Brand J				
			n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	N	%	
Endocrine system disorders																									
1	History of type 2 diabetes	No	38	46.9	5	6.2	13	16	4	4.9	5	6.2	3	3.7	3	3.7	4	4.9	2	2.5	4	4.9	81	100	0.971 (r=0.009)
	mellitus	Yes	6	40	1	6.7	4	26.7	1	6.7	1	6.7	0	0	1	6.7	1	6.7	0	0	0	0	15	100	
2	History of hypertension	No	32	50.8	2	3.2	9	14.3	3	4.8	3	4.8	3	4.8	2	3.2	5	7.9	1	1.6	3	4.8	63	100	0.257 (r=0.043)
		Yes	12	36.4	4	12.1	8	24.2	2	6.1	3	9.1	0	0	2	6.1	0	0	1	3	1	3	33	100	
3	History of hyperthyroid/	No	39	47.6	6	7.3	15	18.3	3	3.7	6	7.3	2	2.4	3	3.7	4	4.9	2	2.4	2	2.4	82	100	0.2 (r=0.148)
	hypothyroidism	Yes	5	35.7	0	0	2	14.3	2	14.3	0	0	1	7.1	1	7.1	1	7.1	0	0	2	14.3	14	100	
Reproductive system disorders																									
1	Experiencing pain during	No	26	40	4	6.2	12	18.5	4	6.2	5	7.7	2	3.1	4	6.2	4	6.2	2	3.1	2	3.1	65	100	0.822 (r=-0.175)
	menstruation	Yes	18	58.1	2	6.5	5	16.1	1	3.2	1	3.2	1	3.2	0	0	1	3.2	0	0	2	6.5	31	100	
2	Having irregular periods	No	28	45.9	2	3.3	14	23	3	4.9	2	3.3	2	3.3	4	6.6	4	6.6	1	1.6	1	1.6	61	100	0.129 (r=0.012)
		Yes	16	45.7	4	11.4	3	8.6	2	5.7	4	11.4	1	2.9	0	0	1	2.9	1	2.9	3	8.6	35	100	
3	Having fertility problems. such	No	36	45.6	3	3.8	16	20.3	2	2.5	6	7.6	3	3.8	3	3.8	5	6.3	2	2.5	3	3.8	79	100	0.084 (r=-0.057)
	as difficulty conceiving	Yes	8	47.1	3	17.6	1	5.9	3	17.6	0	0	0	0	1	5.9	0	0	0	0	1	5.9	17	100	
4	Riwayat PCOS (polycystic	No	44	45.8	6	6.3	17	17.7	5	5.2	6	6.3	3	3.1	4	4.2	5	5.2	2	2.1	4	4.2	96	100	-
	ovarian syndrome)	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5	Pain during marital relations	No	40	46	5	5.7	15	17.2	4	4.6	6	6.9	3	3.4	4	4.6	5	5.7	2	2.3	3	3.4	87	100	0.812 (r=-0.022)
		Yes	4	44.4	1	11.1	2	22.2	1	11.1	0	0	0	0	0	0	0	0	0	0	1	11.1	9	100	
Carcinogenicity																									
1	Having lumps on certain limbs	No	36	45.6	5	6.3	15	19	4	5.1	5	6.3	3	3.8	4	5.1	4	5.1	1	1.3	2	2.5	79	100	0.683 (r=0.036)
		Yes	8	47.1	1	5.9	2	11.8	1	5.9	1	5.9	0	0	0	0	1	5.9	1	5.9	2	11.8	17	100	
2	Experiencing drastic	No	37	45.7	5	6.2	14	17.3	5	6.2	5	6.2	2	2.5	3	3.7	4	4.9	2	2.5	4	4.9	81	100	0.961 (r=-0.020)
	weight loss	Yes	7	46.7	1	6.7	3	20	0	0	1	6.7	1	6.7	1	6.7	1	6.7	0	0	0	0	15	100	
3	Having a prolonged	No	40	47.6	5	6	16	19	5	6	4	4.8	3	3.6	3	3.6	4	4.8	1	1.2	3	3.6	84	100	0.236 (r=0.148)
	chronic cough	Yes	4	33.3	1	8.3	1	8.3	0	0	2	16.7	0	0	1	8.3	1	8.3	1	8.3	1	8.3	26	100	

No	Health symptoms		Bottled water brand																		Total (N=96)		*p-value (r-value)*
			Brand A		Brand B		Brand C		Brand D		Brand E		Brand F		Brand G		Brand H		Brand I		Brand J				
			n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	N	%	
4	Often feeling pale, weak,	No	28	44.4	4	6.3	12	19	3	4.8	3	4.8	2	3.2	4	6.3	3	4.8	2	3.2	2	3.2	63	100	0.909 (-0.033)
	and tired easily	Yes	16	48.5	2	6.1	5	15.2	2	6.1	3	9.1	1	3	0	0	2	6.1	0	0	2	6.1	33	100	
5	Having a fever that keeps	No	43	46.7	6	6.5	16	17.4	5	5.4	5	5.4	3	3.3	3	3.3	5	5.4	2	2.2	4	4.3	92	100	0.338 (r=0.092)
	recurrent	Yes	1	25	0	0	1	25	0	0	1	25	0	0	1	25	0	0	0	0	0	0	4	100	
Immunosuppressive Disorders																									
1	History of hypersensitivity	No	39	51.3	6	7.9	9	11.8	2	2.6	5	6.6	1	1.3	4	5.3	5	6.6	2	2.6	3	3.9	76	100	0.008 (r=0.151)
	or allergies	Yes	5	25	0	0	8	40	3	15	1	5	2	10	0	0	0	0	0	0	1	5	20	100	

Table 4. Health Risk Calculation Results from BPA Exposure in AMDK Samples.

Parameters		Bottled Water Brand									
		A	B	C	D	E	F	G	H	I	J
Noncarcinogenic (HQ≤1, Aman)	Minimum	5.070E-5	5.014E-5	4.620E-5	5.014E-5	4.563E-5	5.183E-5	4.507E-5	5.070E-5	5.296E-5	4.901E-5
	Mean	5.352E-5	5.127E-5	4.901E-5	5.070E-5	4.789E-5	5.239E-5	4.563E-5	5.183E-5	5.296E-5	4.958E-5
	Maximum	5.577E-5	5.183E-5	5.183E-5	5.127E-5	5.239E-5	5.239E-5	4.620E-5	5.239E-5	5.296E-5	5.014E-5
Carcinogenic (CR≤E-4, Aman)	Minimum	1.123E-9	1.110E-9	1.023E-9	1.110E-9	1.010E-9	1.148E-9	9.980E-10	1.123E-9	1.173E-9	1.085E-9
	Mean	1.185E-9	1.135E-9	1.085E-9	1.123E-9	1.060E-9	1.160E-9	1.010E-9	1.148E-9	1.173E-9	1.098E-9
	Maximum	1.235E-9	1.148E-9	1.148E-9	1.135E-9	1.160E-9	1.160E-9	1.023E-9	1.160E-9	1.173E-9	1.110E-9
EEQ (*Estrogenic activity-associated risk evaluation)*	Minimum	2.08E-1	2.06E-1	1.89E-1	2.06E-1	1.87E-1	2.13E-1	1.85E-1	2.08E-1	2.17E-1	2.01E-1
	Mean	2.19E-1	2.10E-1	2.01E-1	2.08E-1	1.96E-1	2.15E-1	1.87E-1	2.13E-1	2.17E-1	2.03E-1
	Maximum	2.29E-1	2.13E-1	2.13E-1	2.10E-1	2.15E-1	2.15E-1	1.89E-1	2.15E-1	2.17E-1	2.06E-1

4. Discussion

4.1. BPA in bottled drinking water

According to the study's findings, the lowest, average, and maximum BPA quantities measured in samples of bottled drinking water are all within the safe range. The detected drinking water's BPA concentration was less than 0.1, which is still below the BPOM-recommended safe threshold of 0.6 ppm and the EFSA-recommended tolerance daily intake (TDI) value of 0.5 μg/kg body weight per day. Prior research has documented BPA levels in drinking water as high as 0.42 μg/L, and consuming mineral water in bottles can also expose one to endocrine disruptors [27]. Because the sampling was done on packaged water at room temperature rather than boiling water temperatures (100°C), the BPA concentration in this study is comparatively low. BPA contamination from gallon jugs might leak into mineral water due to high water temperatures. Since they remain below the safe limit, the findings of the analysis of environmental health risk calculations that are carcinogenic and non-carcinogenic point to a safe level. Polycarbonate materials with code number 7 (others) are frequently used to make food packaging, such as containers or drink bottles. Packaging for food and beverages bearing code number 7 is frequently composed of polycarbonate, which contains bisphenol A (BPA). Because BPA-based packaging offers benefits including being clear, heat-resistant, lightweight, and shatter-resistant, it is utilised in polycarbonate plastics for food and drink [28]. Small amounts of BPA will inevitably be released into the environment during the production, transportation, processing, and waste disposal processes due to the growth in BPA production and use over time. According to numerous studies, BPA can dissolve in packaging items such metal food cans, plastic water bottles, baby bottles, and food containers before transferring to food and drinks, potentially exposing people to the chemical [26]. The study's analysis of AMDK bottled water revealed that brand A had the highest level when compared to the other two brands. AMDK Brand A's packaging had the code number 7 (others), meaning it included BPA-containing polycarbonate plastic. The public prefers BPA-containing product packaging because it offers a firm texture and transparency, such as jugs, bottles, glasses, mugs, water tanks, and so on. Reusable gallons are typically those that contain BPA. Single-use quarts, on the other hand, contain PET, which is BPA-free. PET (polythene terephthalate), which is used in single-use gallons, s free of BPA. Nonetheless, refillable gallons are frequently used in daily life [29].

4.2. Public health risks due to exposure to BPA in bottled drinking water

This study demonstrates that the health problems of the research participants were unaffected by the drinking of water from any of the brands of bottled water that were studied. Because the sampling was done on packaged water at room temperature rather than boiling water temperatures (100°C), the BPA levels in this study is comparatively low. High water temperatures have the potential to release BPA exposure into the mineral water from the gallon package. Since the carcinogenic and non-carcinogenic environmental health risk analysis results are still below the safe level, they are categorised as safe. A transfer method is used to move BPA from gallon containers used for drinking water into mineral water. The rate at which BPA moves from polycarbonate packaging to mineral water when it is exposed to boiling water (100°C) is 55 times more than when it is exposed to water at 20°C. Additionally, continuous (repeated) gallon use may enhance the transfer of BPA into beverages. This is because the walls of the container are more permeable, which makes it easier for water to stick to the gallon walls. This impacts the amount of BPA that customers are exposed to in the water they drink [29]. According to the study, when a volunteer drank warm water from the same container for a

week, the tests revealed that the amount of BPA in their urine had increased by 69%. BPA leaches and mixes with the mineral water as a result of the packaging's frequent use and exposure to high temperatures [30].

When BPA is released from food products and settles in the environment, it can enter the body through the mouth, skin, and lungs. This study used environmental health risk analysis from oral exposure to quantify BPA exposure. The primary method of food exposure is through oral exposure, which includes consuming fresh food from contaminated areas, eating freshwater fish or seafood that has been contaminated with BPA, eating food that has been stored in cans or plastic containers, and drinking water that has been tainted. Although inhalation and cutaneous exposures typically make up less than 5% of total exposure pathways, they nevertheless have a major impact on the workforce [26]. Although studies on the effects of BPA exposure, including those from drinking water, are still being conducted, there is currently insufficient data to conclusively link drinking water exposure to serious health problems. Research indicates that exposure levels from drinking water are often modest and below safe limits, despite the fact that BPA can leak from some containers into water. Research is still being done, though, as some studies suggest possible health risks, particularly at greater exposure levels. According to studies, BPA is a common contaminant in tap water, surface water, and mineral water bottles. Nonetheless, drinking water exposure to BPA is extremely low (i.e., less than 0.01% of the daily permissible intake).

Neuroendocrine abnormalities brought on by high levels of BPA exposure in the body can result in metabolic problems. A dangerous endocrine-disrupting chemical (EDC), BPA inhibits or modifies hormone production as well as enzyme synthesis, secretion, release, and transport. By substituting transporter proteins for endogenous hormones, BPA suppresses system activity [7]. The amounts of both bound and free hormones in the plasma are changed by this modification. Additionally, this chemical alters neuroendocrine function, which results in organ physiological abnormalities. Studies have indicated that BPA causes men's serum testosterone levels to drop and women's serum estradiol levels to rise. Additionally, BPA interferes with the reproductive system's normal development and function. According to recent research, BPA is associated with lower levels of blood cortisol and higher levels of progesterone, testosterone (T), estradiol (E2), and luteinizing hormone (LH) [31]. There have also been reports of a substantial correlation between BPA and elevated serum levels of total testosterone (TT). Researchers found that variations in the thickness of the uterine wall and BPA levels were related to age [32]. Furthermore, serum BPA concentrations were higher in PCOS patients than in healthy women and patients of colour. Additionally, researchers found that BPA may contribute to PCOS and unfavourable pregnancy outcomes such miscarriage and early birth [33]. Long-term BPA exposure in men is associated with poor sperm quality, sexual dysfunction, and reproductive issues. The features of variations and decreased velocity rates are described by the amplitude of lateral head displacement (ALH), wobble (WOB), linearity (LIN), mean angular displacement (MAD), sperm concentration, and the relationship with BPA. Male reproductive function abnormalities are caused by this arrangement [34].

BPA seems to be connected to the sharp rise in the incidence of certain cancer forms. This covers malignancies of the breast, ovaries, uterus, prostate, and testicles. The mechanistic carcinogenic action of BPA is described by increased estrogenic activity, according to findings from a variety of in vivo investigations conducted on animals (e.g., mice, rats). Investigations on BPA's role in carcinogenesis activation and cancer cell development are ongoing. Despite their poor affinity for one another, BPA binds to the ER to promote cellular responses [7]. In order to evaluate the association between BPA exposure and breast cancer risk in Korean women, 167 blood samples from patients with breast cancer and hospital controls between 1994 and 1997 were examined for BPA levels. They discovered a link

between BPA levels and variables linked to breast cancer, including nulliparity and age at first childbirth. Similarly, a research of postmenopausal women from Wisconsin (n = 264) found that elevated serum BPA concentrations correspond with increased breast density as measured by mammography, a breast cancer risk marker [26].

According to one study, BPA exposure has a direct correlation with inflammation, immunological response, and oxidative stress. Due to the development of both the innate and adaptive immune systems, BPA exposure is linked to the activation of mitochondrial damage and cellular apoptosis, which leads to systematic degradation and immune cell population turnover [35]. Autoimmunity can be induced by BPA via T-helper 1, 2, and 17. The immune response is regulated by the aryl hydrocarbon receptor (AhR), and T-helper 17 production is a crucial component of T-cells in a number of autoimmune disorders. In a similar vein, it controls pro- and anti-inflammatory cytokines and chemokines and decreases regulatory T cells (Treg). BPA exposure can both accelerate and slow the development of type 1 diabetes in both men and women (Xu et al., 2019). Research on pregnant women exposed to environmental factors (skin and inhalation) showed that the probability of elevated IL-33/TSLP was negatively correlated with the amount of BPA in the expectant mothers' urine (Ashley-Martin et al., 2015). Another study using human samples found that BPA can impair immune system function as measured by CMV antibody levels and the diagnosis of fever and allergies through oral and environmental exposure routes [36].

The label of processed food products does not disclose the presence of BPA. This is due to the fact that bisphenol-A is one of the raw ingredients used in food packaging rather than being a direct ingredient in processed foods. BPA, however, has the potential to move and contaminate the food item during the procedure. Although consumers are unable to detect the use of BPA in drinking water packaging, they can identify the use of BPA in polycarbonate plastic drinking water packaging by looking for the recycling code. Food packaging safety is indicated by the recycling code; polycarbonate plastic has recycling code number 7 (others). According to the Minister of Industry of the Republic of Indonesia (2010), the number 7 code denotes that different kinds of plastic are used as production raw materials. In the community, this can be utilised as a preventive measure, particularly for youngsters, babies, and pregnant women. Additionally, consumer education and training has to be carried out via publications, socialisation, and other channels. Business actors' involvement is particularly crucial since they have a duty to give truthful, transparent, and accurate information and to adhere to the criteria for the packaging of their manufactured food and drinking water. For the benefit of manufacturers and customers, the government must also establish rules, offer direction, and supervise the manufacturing of food and beverage packaging [38].

5. Conclusions

The process of migration may be the reason why BPA is released from mineral water packaging into the mineral water. Polycarbonate plastic can hydrolyze in response to high temperatures and lengthy exposure to sunshine, which permits BPA to seep into mineral water. There are no health concerns associated with both noncarcinogenic and carcinogenic BPA exposure levels. The health effects of BPA exposure include immunosuppressive disorders, carcinogenicity, reproductive system disorders, and endocrine system abnormalities. The usage of bottled water and the respondents' history of BPA-related illnesses, however, did not significantly correlate in this study. However, the government, business owners, and the community must continue to work to reduce BPA exposure. The toxicity results from BPA exposure, such as the amount of BPA in the urine of the population drinking BPA-containing water, have not yet been quantified Thus, there are still issues with this study.

Consequently, additional research can be planned to assess and compute it.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

No conflict of interest in this research.

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