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Research Article

Bisphenol a Exposure and Risk From Plastic-Packaged Drinking Water in Buea, Cameroon

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Abstract

The widespread use of plastic packaging for drinking water raises concerns about bisphenol A (BPA) exposure. BPA, an endocrine-disrupting chemical, can leach into water from polymers such as polycarbonate plastics and epoxy resins, particularly when containers are exposed to heat, UV radiation, or undergo aging; posing potential health risks(1). Despite the growing reliance on packaged drinking water in Cameroon, data on BPA contamination and related health risks remain scarce. This study assessed BPA concentrations in plastic-bottled and sachet water sold in Buea, Cameroon, and associated consumer exposure and health risk. A descriptive cross-sectional survey was conducted in Buea. Water samples from nine bottled brands and eight sachet brands were collected over two months from markets, supermarkets and street stalls. BPA concentrations were determined using ELISA. Estimated daily intake (EDI) and hazard index (HI) were calculated assuming a daily consumption of 2 L and an adult body weight of 60 kg. Results were compared with the European Union maximum limit (2.5 µg/L) and the EFSA tolerable daily intake (0.2 ng/kg bw/day). BPA was detected in all samples; bottled water showed mean BPA levels of 0.078 (range: 0.00001-0.340) µg/L, while sachet water exhibited significantly higher levels at 343.8 (range: 0.034-2,670.3) µg/L. Sachet water had significantly higher BPA concentrations than bottled water, with some sachet brands exceeding the EU maximum limit by over 130-fold. EDI values were 0.0026 ng/kg bw/d for bottled water and 11.46 ng/kg bw/d for sachet water, with HI scores of 0.013 and 57.3, respectively. EDI from sachet water consumption surpassed the EFSA tolerable daily intake by more than 1,700-fold. HI values for sachet water exceeded 1, indicating a potential health risk. Bottled water generally showed lower BPA concentrations and EDI below risk thresholds. This study reveals widespread BPA contamination in packaged drinking water in Buea, with sachet water posing a higher potential risk to consumers. The findings underscore the need for stricter regulatory monitoring, improved quality control in sachet water production, public education on safe storage practices, and promotion of BPA-free packaging to safeguard public health.

INTRODUCTION

The widespread reliance on plastic packaging for drinking water has led to increasing concern over human exposure to bisphenol A (BPA). As an endocrine-disrupting chemical, BPA can leach from materials such as polycarbonate plastics and epoxy resins, especially when containers are subjected to heat, ultraviolet radiation, or prolonged use, potentially resulting in adverse health effects [1]. The global use of plastic packaging in the food and beverage sector has increased markedly over the past few decades [2-4] because of its low production cost, durability, and versatility. Plastics are widely employed to package liquids, solids, and fresh produce, facilitating storage, transportation, and marketing. In addition, plastic packaging often enhances the visual appeal of products, which can increase consumer preference [5].

In Cameroon, as in many other low- and middle-income countries, a large proportion of food and beverages; especially drinking water is sold in plastic packaging, such as bottles and sachets. Most of these packages are manufactured from polyethylene terephthalate (PET, resin code 1) or polypropylene (PP, resin code 5), which typically do not contain bisphenol A (BPA) [2, 6-8]. In contrast, polycarbonate plastics, which fall under the heterogeneous resin code 7, are a well-documented source of BPA, as they can leach this endocrine disruptor into packaged products [9, 10].

BPA is a well-recognized endocrine-disrupting chemical that mimics estrogen and interferes with hormonal regulation. Human exposure to BPA has been associated with reproductive dysfunction [11], increased risk of breast and prostate cancers, developmental disorders, asthma, and metabolic disturbances such as obesity and diabetes. BPA can cross the placental barrier, exposing the fetus during pregnancy, and chronic exposure has been linked to cardiovascular, hepatic, and renal diseases [12-15].

The risk of exposure is heightened by storage and handling practices. In many Cameroonian markets and street-vending sites, bottled and sachet water is frequently stored and displayed under direct sunlight or at high ambient temperatures. These conditions can accelerate the leaching of BPA from plastic packaging into the water. In tropical regions such as Cameroon, where high temperatures and prolonged storage are common, this increases the potential exposure of consumers, including vulnerable populations such as children, pregnant women, and the elderly [5, 16].

Previous studies in various countries, Saudi Arabia, Iran, China, Poland, Nigeria have documented the presence of BPA in packaged drinking water under various storage conditions, sometimes at levels approaching or exceeding recommended safety thresholds [8, 17-22]. In response, many countries and regional bodies have introduced regulations or guidelines restricting BPA content in food-contact materials, such as the European Food Safety Authority, the World Health Organization (WHO) and the Environmental Protection Agency (EPA) [23, 24].However, in Cameroon and several neighboring countries, data on contamination levels remain scarce and enforcement of regulations is limited [25, 26].

Despite the widespread consumption of plastic-packaged drinking water in Cameroon, little is known about the actual occurrence and levels of BPA in these products [27, 28]. This lack of local data limits effective risk assessment and evidence-based policymaking. To address this gap, the present study was conducted in the Buea municipality, in the South-West Region of Cameroon, with the objective of determining the levels of BPA in drinking water packaged in plastic bottles and sachets sold in local markets.

METHODOLOGY

Study Site

This study was conducted in Buea Township is a major urban center and the capital of the Southwest Region of Cameroon. Buea is situated on the southern slopes of Mount Cameroon, the highest mountain in West and Central Africa. The local climate is highly relevant to the study of BPA leaching. While the city experiences a temperate climate due to its high elevation, it is characterized by significant daily and seasonal fluctuations in temperature and solar radiation. Maximum daytime temperatures can regularly reach 25-30°C, with intense, direct sunlight due to the equatorial latitude [29, 30]. These conditions: elevated temperature and high UV radiation exposure are known to accelerate the degradation of plastic polymers and the leaching of BPA [8, 17-22]; therefore, Buea presents a relevant and realistic scenario for assessing BPA contamination under conditions of typical consumer storage and handling The target population for this study was business people in the Buea municipality who operate public businesses where plastic-bottled and sachet water are regularly sold and stored, often in these ambient conditions [31].

Study Design and Sample Collection

A cross-sectional sampling design was employed to assess the presence of bisphenol A (BPA) in plastic packaged drinking water available the Buea municipality, South-West Region of Cameroon. Sampling was designed to capture a representative snapshot of the market. A stratified random sampling approach was used to select retail outlets. The sampling frame was stratified by outlet type: street vendors, local shops, and supermarkets. Within each stratum, outlets were selected randomly using a "random walk" pattern in different zones of Buea, selecting every third vendor encountered to minimize selection bias. A total of nine unique brands of bottled water and eight unique brands of sachet water samples were identified and sampled. To account for within-brand variability, three independent samples per brand were purchased from three different sellers. This resulted in a total of 27 bottled water samples and 24 sachet water samples. Commonly available brands were targeted to reflect typical consumer exposure.

Bottled water samples were purchased in common volumes of 0.5 L and 1 L, while sachet water samples were collected as batches of three 0.33 L units, totaling approximately 1 L per brand. Sampling was carried out over a two-month period (January and February, 2023), with collections made at different intervals to capture potential batch-to-batch variation. All samples were maintained in their original packaging at ambient temperature during transport to simulate to simulate typical consumer handling conditions prior to analysis. Each brand was assigned a unique code to maintain anonymity during laboratory analysis; sachet-water brands were coded: O, Q, T, M, N, S, R and P and bottled-water brands were coded: E, A, B, I, F, D, C, G, and H . The collected samples were carefully packed and transported to the Laboratory of Pharmacology and Toxicology at the Department of Biochemistry, Faculty of Science, University of Yaounde 1 for analysis.

Determination of BPA by ELISA

The ELISA tests based on the competitive ELISA test procedure were carried out following the manufacturer's recommendations. Briefly, a 200 µL aliquot of sample dilution buffer was dispensed into a blank (BL) well, while 100 µL of sample dilution buffer was dispensed into the maximum binding (Bo) wells using a micropipette. Subsequently, 100 µL of each standard was dispensed onto the appropriately labeled wells on the plate. The diluted bisphenol A - Horse Reddish Peroxidase (HRP) conjugate was loaded into the Bo wells, standard wells, and sample wells, except for the blank well, where the HRP conjugate was omitted. Following a 2-hour incubation period at room temperature, the plate was washed three times with 400 µL of wash buffer dispensed into each well. Excess moisture on the plate was then removed using a paper towel. Next, 200 µL of TMB (3,3 5',5 Tetramethylbenzidine) substrate was added to all wells, including the blank well, and the plate was re-incubated for an additional 30 minutes at room temperature. Finally, 50 µL of 2-N sulfuric acid was added to each well to complete the procedure.

BPA Exposure Assessment

Oral exposure to BPA from drinking water stored in plastic bottles and or sachets was obtained by the estimated daily intake formula previously described by [32]. $EDI = \frac{C_{BPA} \times IR}{BW}$

Where:

EDI: is the estimated daily intake through ingestion (µg/kg/day), C_{BPA}: is the concentration of BPA (µg/L) released from the plastic package (bottle or sachet) into the water. IR: is the water ingestion rate (mL/day), and BW: is body weight (kg).

In this study, the EDI of BPA for the healthy adult population shall assume a daily 2 L water intake and an estimated 60 kg body weight a healthy adult [33]. Likewise, the hazard index (HI), is a tool generally employed to understand health risk from chemicals. HI is calculated by dividing the EDI by the Tolerable Daily Intake (TDI) or the reference dose (RfD). A HI score of above 1.0 indicates increased likelihood of a toxicological response to the exposed chemical (i.e., adverse health effects are possible). For BPA, the HI calculation exploited the EDI calculated using the above equation, and the TDI fixed by EFSA as 0.2 ng/kg bw/d (34). HI = EDI / TDI or RfD.

RESULTS

Quantification of BPA was evaluated by measuring the OD value decrease with increasing concentration of BPA. A representative image of the ELISA plate is presented in Figure 1, providing visual confirmation of the colorimetric results for both calibration standards and tested samples. Thereafter a 6-point calibration curve was constructed to indicate the relationship between concentration of BPA and inhibitory rate. Figure 2 shows the plot of B/B0% as a function of the logarithm of BPA concentration.

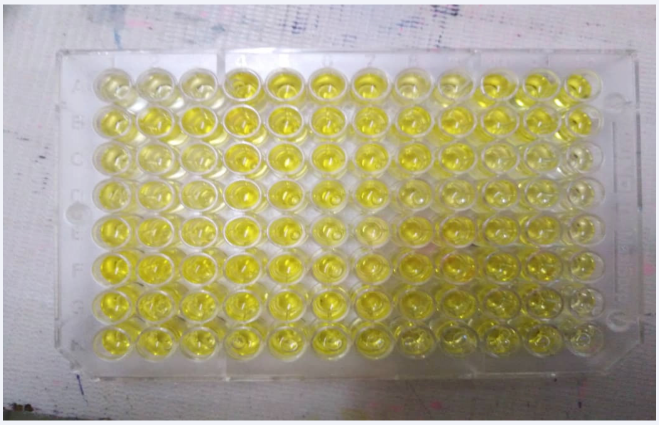

Figure 1 Visual conformation of the ELISA assay's outcome

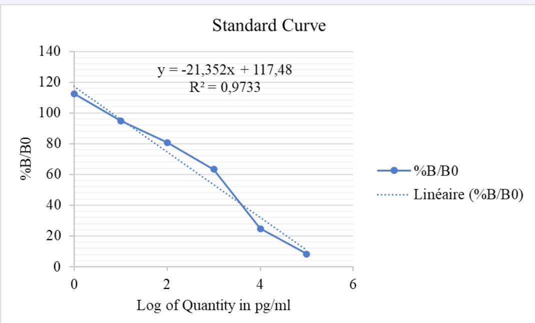

Figure 2 Standard plot of Bisphenol A standards as prescribed by the manufacturer of the ELISA Kit (Boster Biological Technology)

A total of nine brands of bottled drinking water were analyzed, with BPA detected in 100% of the bottled water samples. The highest BPA concentration was found in G at 0.340 µg/L (i.e., 304.2 pg/mL), while the lowest BPA concentration was found in B at 0.00001 µg/L (i.e., 0.01 pg/mL). The mean BPA level across all bottled water samples was 0.078 µg/L (78.13 pg/mL), with a range of 0.00001 – 0.304 µg/L (i.e., 0.01 - 340.18 pg/mL) (Figure 3.A).

A total of 8 brands of sachet water were analyzed. BPA was detected in 100% of these samples. The T brand had the highest BPA concentration of 2,607.29 µg/L (i.e., 2,670,290 pg/mL), while the brand with the lowest concentration was M with 0.034 µg/L (i.e., 33.67 pg/mL) (Figure 3.B). The mean BPA level across all sachet water samples was 343.8 µg/L (i.e., 343,800 pg/mL), with a range of 0.034 – 2,607.29 µg/L (i.e., 33.67 - 2,670,289.70 pg/mL)

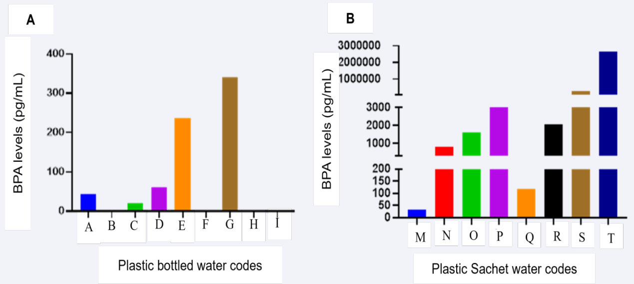

Figure 3 Mean Bisphenol A levels in the studied plastic bottle (A) and sachet (B) water samples.

Based on an assumed daily water consumption of 2 L and an average adult body weight of 60 kg, the estimated daily intake (EDI) of BPA for adults consuming bottle packaged drinking water mean was 0.078 ng/kg bw/day and 343.8 ng/kg bw/day for those consuming sachets packaged drinking water. The corresponding hazard index (HI) values were 0.013 from bottled water and 57.3 for sachet water. However, sachet water exhibited HI values above 1.

DISCUSSION

This study provides one of the first assessments of BPA contamination in packaged drinking water sold in Buea, Cameroon. Both plastic-bottled water and sachet water are widely available in public spaces, including markets, supermarkets, restaurants, bus stations, and schools. Many residents perceive water from these packaged products as cleaner and safer than tap water. However, this study highlights the presence of BPA in both bottled and sachet water, indicating that consumer perceptions

Table 1: The Estimated Daily Intake (EDI) and estimated hazard index of BPA amongst consumers of plastic bottled water and sachet water.

	Mean (Max) BPA level (µg/L)	ML (µg/L)	EDI mean (max)	EFSA's TDI (ng/kg b.wt)	HI mean (max)
Bottled water	0.078 (0.304)	2.5	0.0026 (0.010)	0.2	0.013 (0.05)
Sachet water	343.8 (2,607.29)	2.5	11.46 (89.91)	0.2	57.3 (449.55)

ML: Maximum limit of BPA in drinking water intended for human consumption as fixed by the European Commission [35].

HI: Hazard Index calculated as EDI/TDI fixed by European Food Safety Authority [34] as 0.2 ng/kg body weight per day. samples of safety may not fully reflect chemical contamination risks. Results presented in Table 1 show a significant variation in BPA concentrations across different water brands. Among plastic-bottled water samples (brands A–I), the highest concentrations of BPA were observed in brands G and E, while brands B and I exhibited the lowest levels. A more pronounced trend was evident in sachet water brands (M–T), with the highest concentrations detected in T, S, P, and O, and the lowest levels in M and Q. These elevated levels are likely attributable to two key factors. First, sachet packaging readily leaches BPA when exposed to high temperatures [36], a common scenario given the frequent observation of bags stored in direct sunlight. Secondly, and more critically, the intrinsic composition of the plastic sachets varies between manufacturers, and it is well-established that many of these plastics are manufactured from polycarbonates or epoxy resins containing bisphenol A [9, 10]. Consequently, the specific formulation used by different brands would contain varying amounts of BPA precursors or possess different structural stability, leading to the observed disparities in leaching potential. This explains why brand T exhibited a particularly high concentration compared to other sachet waters, pointing directly to the composition of its specific plastic package. Overall, sachet water samples exhibited higher BPA concentrations than bottled water, suggesting that consumers of sachet water may be at greater risk of exposure.

When selecting and consuming safe drinking water, it is advisable to adhere to guidelines from reputable sources such as the World Health Organization (WHO) and the Environmental Protection Agency (EPA) [23, 24]. The concentration of BPA in packaged water is influenced by a combination of factors. The notably higher levels in sachet water are primarily due to the packaging material itself being a source of BPA. Sachets used for packaging are made from plastics, such as polycarbonates epoxy resins, and therefore can contain BPA [36, 37]. This inherent contamination risk is exacerbated by two key factors: prolonged exposure to high temperatures during storage and distribution, which accelerates leaching [8, 17-22], and minimal manufacturing oversight within the informal sachet water sector [38]. . These factors are consistent with the variability observed in Table 1 and 2, where sachet water shows both higher mean BPA concentrations and wider ranges compared to bottled water [2, 12]. This distinction may be attributed to the more stringent and legally controlled measures governing the production of plastic-bottled water compared to sachet water. Additionally, sachet water production is more likely carried out by individuals or small groups with fewer legal controls [38]. Paradoxically, despite the potential health risks associated with higher BPA levels, sachet water remains a more popular choice among the masses due to its affordability, availability, and convenience [39]. Furthermore, economic hardships might be a drive for several unemployed individuals to begin uncontrolled sachet water business, potentially leading to inaccurate claims on water quality labels to attract consumers and generate income for survival [40].

Our findings align with other studies in tropical regions, where high temperatures increase BPA leaching. For instance, a study in Saudi Arabia reported higher BPA in bottles stored outdoors, while indoor-stored bottles had lower levels [17]. In contrast, our bottled water samples had relatively lower BPA, likely due to shorter sun exposure and different climatic conditions.

In a nigerian study, sachet water samples had BPA concentrations ranging from 0.001 to 3.007 mg/L, higher than some bottled water samples with BPA between 0.001 and 0.139 mg/L, which is higher than our current study where bottle water samples ranged between 0.01 - 340.18 pg/mL and sachets water between 33.67 - 2,670,289.70 pg/mL [41]. Our results are also consistent with a previous Cameroonian study focusing on Occurrence of bisphenols and contribution of edibles liquids conditioned in plastic packaging to the dietary exposure in Cameroon which reported mean values of 2.2 ± 0.2 µg L−1 in two brand of sachet water samples [28].

High-temperature exposures of plastic water vessels can influence the migration of BPA from the plastic into the water content [20]. Considering consumer exposure to BPA from water stored in plastic vessels, our findings indicate that consumers, regardless of the studied water brand, source, or type, are exposed to BPA in their drinking water.

Using Table 1, estimated daily intake (EDI) and hazard index (HI) were calculated assuming 2 L/day consumption and 60 kg body weight. For the bottled water, the EDI and HI values were generally below EFSA thresholds, suggesting low potential risk. Meanwhile, for the sachet water, the mean BPA concentrations and EDI exceeded the EFSA TDI of 0.2 ng/kg bw/day and EU maximum limit of 2.5 µg/L by 137.5 and 1719 times, respectively [42]. HI values were greater than 1, indicating potential health concern for consumers [32, 43].

CONCLUSION

This study provides one of the first systematic assessments of BPA contamination in packaged drinking water in Buea, Cameroon; a setting where bottled and sachet water are widely consumed and often perceived as safer than tap water. By demonstrating that both sources contain detectable BPA, with sachet water showing particularly high levels, the study underscores a potential, often overlooked, route of human exposure in a population increasingly reliant on packaged water for daily hydration. The finding that sachet water exceeded both the EU maximum limit for BPA in drinking water and the EFSA tolerable daily intake highlights urgent public health concern. These results call for stricter regulatory oversight of plastic packaging materials, improved quality control of sachet water production, and public education on safe storage practices to reduce heat-induced BPA leaching. Beyond immediate consumer safety, this work contributes baseline data for Cameroon, filling a critical knowledge gap and providing a foundation for further monitoring, risk assessment, and policy development. Continued research on BPA migration under local climatic and storage conditions, as well as the exploration of BPA-free packaging alternatives, will be essential to protect public health in communities dependent on packaged water.

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