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Presence of Polychlorinated Biphenyls (PCBs) in Bottled Drinking Water in Mexico City

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Abstract This paper describes the concentrations of seven polychlorinated biphenyls (PCBs) in bottled drinking water samples that were collected over 1 year from Mexico City in two sizes (1.5 and 19 L), using gas chromatography with an electron capture detector. PCBs 28 (0.018–0.042 μg/L), 52 (0.006–0.015 μg/L) and 101 (0.001–0.039 μg/L) were the most commonly found and were present in the majority of the samples. However, total concentrations of PCBs in bottled drinking water (0.035–0.039 μg/L) were below the maximum permissible level of 0.50 μg/L stated in Mexican regulations and probably do not represent a hazard to human health. PCBs were detectable in all samples and we recommend a monitoring program be established to better understand the quality of drinking bottled water over time; this may help in producing solutions for reducing the presence of organic contaminants.

Keywords Bottled drinking water · Chlorinated compounds · Water contamination

Polychlorinated biphenyls (PCBs) were produced from 1930 and had numerous applications such as coolants and insulating fluids for transformers and capacitors, stabilizing additives in PVC coatings, pesticide extenders, cutting oils, flame retardants, hydraulic fluids, sealants, adhesives, wood floor finishes, paints and carbonless copy paper (Batterman et al. 2009). They consist of 209 congeners and have been designated as typical persistent organic pollutants (POPs) by the Stockholm Convention of May 22, 2001 (Yang et al. 2009). PCBs are industrial products (there are no known natural sources), they are semi-volatile, inert, resistant to both alkali and acid, thermally stable, largely insoluble in water, lipophilic, resistant to degradation, highly persistent, bioaccumulative and toxic (ATSDR 2000; WHO 2003). Their biphenyl structure with two linked benzene rings and 1–10 chlorine atoms supports 209 congeners theoretically although only 130 have been identified in commercial PCB products.

Half-life for PCBs from 10 days to decades have been reported depending on the congener (WHO 2003). PCBs have a tendency to bioaccumulate with fish, meats and dairy products containing the highest concentrations; food consumption has been and will continue to be the major exposure source in the general population (ATSDR 2000; Lake et al. 2005). PCB exposures have been linked to neuro-development effects in infants, cancer and immunotoxic effects. Despite restrictions and bans on PCBs production and use in most countries, numerous environmental sources and reservoirs of these contaminants remain such as soils and sediments, and atmospheric movement is the key transport and dispersal route (Huang et al. 2007).

PCBs enter the aquatic environment through a variety of sources that include direct deposition from the atmosphere, runoff from the land, and industrial and municipal wastewater discharge. Due to their low solubility in water and high octanol–water partition coefficients, PCBs quickly become associated with particulate matter once in aquatic environments, and ultimately accumulate in bottom sediments (Yang et al. 2009). PCB pollution has been identified and reported all over the world, even in the Antarctic and the Arctic zone.

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Consumers are worried about their health and well-being. They buy bottled drinking water (BDW) to feel good and to lose weight. Bottled water is considered a healthy alternative to other beverages. Changes in ways of life also explain the increase in BDW sales. Increasing urbanization, causing tap water quality to decline, also help explain increased use (Ferrier 2001). BDW is perceived as pure and safe although this is not necessarily true. The presence of organic compounds has been noted in water of questionable quality (Al-Mudhafa et al. 2009), some of which are hazardous to human health due to carcinogenic, mutagenic, and disruptive properties (Gibbons and Laha 1999). Recent investigations have demonstrated the presence of some organic contaminants in BDW such as volatile organic compounds (toluene, benzene and dichloromethane,), phthalates in USA; haloacetic acids (China); formaldehyde, acetaldehyde and acetone (Poland), di(2-ethyl-hexyl)phthalate (Sweden, Spain, Italy), di(2-ethyl-hexyl)adipate (Sweden), traces of 4-nonylphenol and diethylphthalate (Spain).

The goal of this study was an investigation of the presence of PCBs in bottled drinking water commercially available in Mexico City, considering a comparison between two commercial presentations of BDW.

Materials and Methods

Bottled drinking water samples (labeled DBW1–DBW6; 16 samples in total for each brand) from the south of Mexico City (the district of Coyoacan) were bought in supermarkets and stored at room temperature. The samples were in bottles of 1.5 L (DBW1 to DBW3) and 19 L (DBW4 to DBW6). This research took place during 1 year (November 2007 to November 2008), with samples taken each month until the final 2 months when two samplings were carried out.

A 500 mL aliquot of each bottled water sample was added to a separating funnel, followed extraction with 75 mL of ether-hexane (25%, v/v); a further 500 mL aliquot was extracted with 75 mL of hexane to complete 1 L of sample. The organic phase was dried over anhydrous sodium sulfate. The samples were evaporated in a rotary evaporator to 5 mL. Chromatographic columns were packed with florisil activated by heating at700°C for 12 h and deactivated with 1.25% of deionized water. The PCBs were eluted with a mixture of hexane-ether (9:1 and 8:2). The organic extract was concentrated in a rotary evaporator to 3 mL and transferred to a vial for GC analysis (USEPA 1981).

The method was optimized for the analysis of 7 PCBs by a GC (HP 6890 Series) with an EC detector (^{63}Ni). Analysis was carried out using a Hewlett Packard (HP) 5MS capillary column (crooslinked 5% phenyl methylpolysiloxane, 30 m long, 0.25 mm id and 0.25 μm film thickness). The GC was programmed as follows: 90°C (2 min), at 30°C min^{-1} to 180°C (0 min), at 1°C min^{-1} to 200°C (0 min), at 10°C min^{-1} to 300°C (6 min). The injection port and detector temperature were kept at 320°C and 2 μL of the sample was injected in splitless mode. The helium (carrier gas) and nitrogen were maintained at a flow of 6 and 60 mL min^{-1} respectively.

A PCBs special mixture containing PCBs 28, 52, 101, 118, 138, 153 and 180 was obtained from Chem Service Inc, West Chester, PA, USA. These compounds are considered environmental indicators (Vilanova et al. 2001).

The concentration calculations were made by an external standard approach. The calibration curve was made up of concentrations of 1, 5, 15, 30 and 60 ppb. The limits were defined by reference to the standard error of the slope and intercept of the curves as to lowest value that can be detected with a 95% confidence level. The values were in the order of 0.01–0.05 pg/L and 0.05–0.10 pg/L for detection limit (DL) and quantification limit (QL), respectively.

We used criteria described by CENAM (2005) for method performance where it evaluates specificity, linearity, repeatability, exactitude, limit of detection and limit of quantification.

The analytical quality control scheme included periodic analysis of solvent blanks, fortified blanks, electronic blanks and duplicate samples as a control for extraction and purification analysis. The accuracy of determination was routinely checked by injection of the middle point (15 ppb) of the calibration curve. The quality assurance and control experiment were performed in duplicate and relative standard deviations (RSD) were all below 15%.

Results and Discussion

The most common PCBs found in the BDW were PCBs 28, 52 and 101 while the others showed lower concentrations. In many regulations, PCBs are consider only as sum total of several compounds, although in some reports there are specific descriptions about individual compounds.

Table 1 shows concentrations of PCBs in terms of extent of chlorination; tri and pentachlorinated compounds were prominent; other PCBs were lower in concentration. The total sum of these compounds did not constitute a significant risk for the consumer but their presence indicates a pollution problem. Further these values show high variability during sampling.

Figure 1 shows the individual distributions of concentrations of PCBs in the drinking bottled water samples, and it can be seen that PCB 28 and 101 were the common dominant compounds. These concentrations describe variations over 1 year among brands and sizes of water bottle; for example, BDW1 to BDW 3 correspond to 1.5 L and

Table 1 Concentrations of PCBs in commercial bottled drinking bottled water ($n = 16$) for Mexico City

Chlorinated compound	Concentration (μg/L)					
	BDW1	BDW2	BDW3	BDW4	BDW5	BDW6
PCB 28 (Trichlorinated)	0.018 ± 0.029	0.018 ± 0.030	0.029 ± 0.056	0.011 ± 0.014	0.042 ± 0.069	0.027 ± 0.051
PCB 52 (Tetrachlorinated)	0.007 ± 0.006	0.007 ± 0.008	0.008 ± 0.010	0.007 ± 0.009	0.009 ± 0.015	0.008 ± 0.008
ΣPCB 101 and 118 (Pentachlorinated)	0.006 ± 0.007	0.039 ± 0.069	0.009 ± 0.009	0.015 ± 0.021	0.003 ± 0.003	0.002 ± 0.002
ΣPCB 138, 153 and 180 (Hexachlorinated)	0.006 ± 0.003	0.003 ± 0.003	0.005 ± 0.004	0.004 ± 0.002	0.004 ± 0.002	0.005 ± 0.003
Total sum of concentration	0.035	0.067	0.051	0.037	0.058	0.042

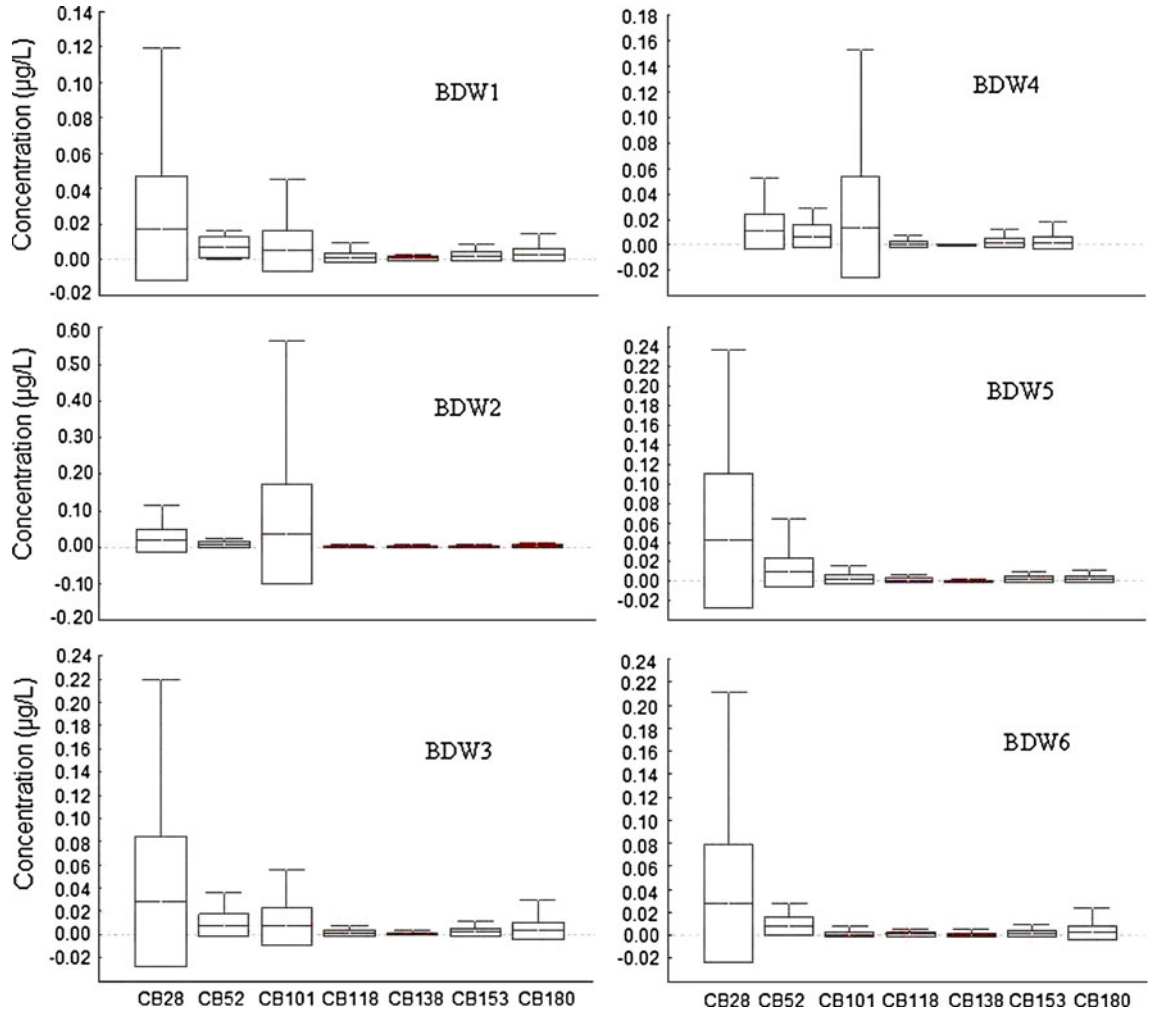

Fig. 1 Distribution of PCBs in presentations of 1.5 and 19 L for bottled drinking water from Mexico City

BDW4 to BDW6 to 19 L. Three commercial brands were analyzed with their corresponding presentations of 1.5 and 19 L where BDW1–BDW4, BDW2–BDW5 and BDW3–BDW6 represent different brands. We suspect that differences exist in the plastic material in the bottles and the chemical degradation that they suffer (so releasing PCBs to the bottled water) as the water for a particular brand is sourced from the same reservoir, not matter the different bottle sizes. The other possibility is cross contamination during handling (Pinto and Reali 2009), or possibly contamination inside bottling facilities such as vapors of chlorinated compounds during the handling of material, chlorination of water and control of infestation outbreaks.

Figure 2 shows the concentration variations in the three brands in the two presentations (1.5 and 19 L); PCBs 28, 52 and 101 were consistently present. Concentrations of some PCBs in April, May, June and September were high, particularly PCB 28 (0.12 μg/L-BDW1, 0.22 μg/L-BDW3

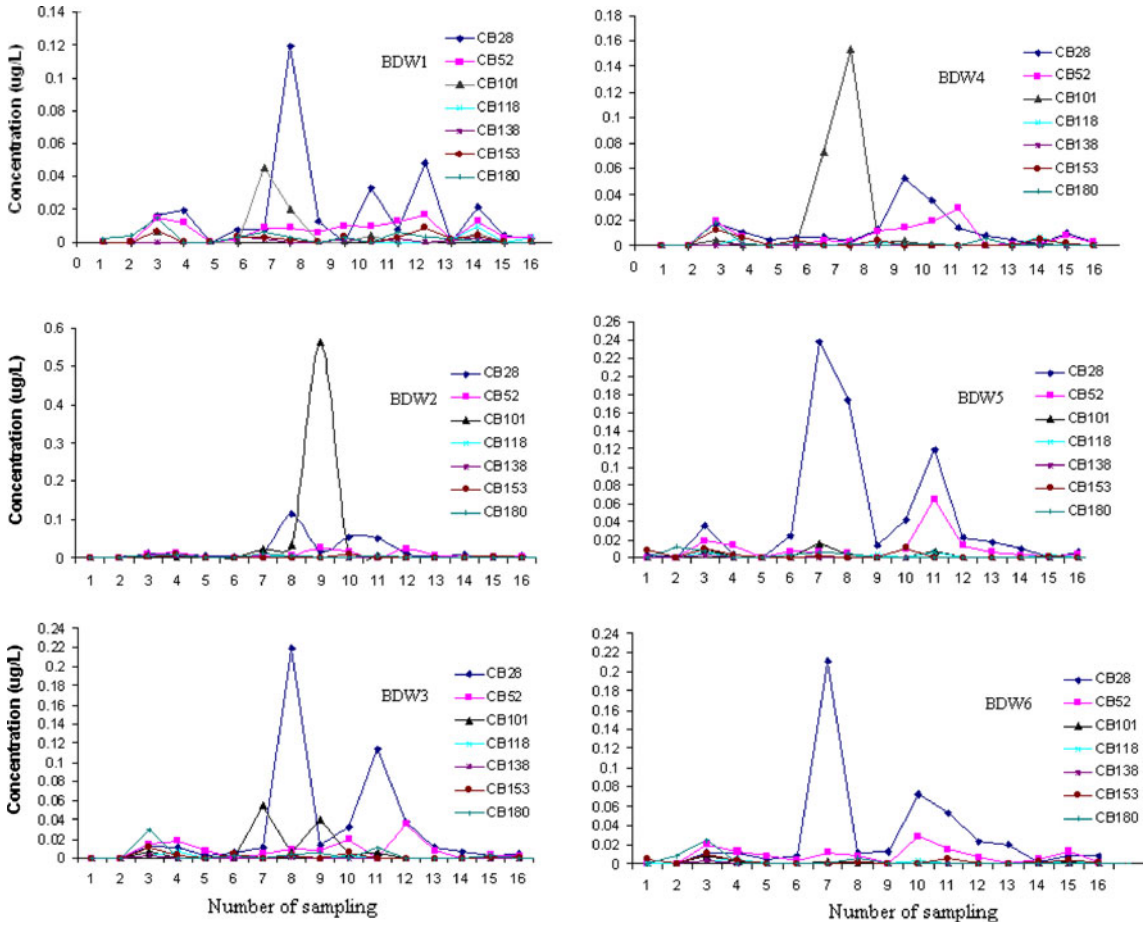

Fig. 2 Presence of individual concentrations of PCBs during sampling of DBW from Mexico City

and BDW6 and 0.24 μg/L BDW5) and PCB101 (0.58 μg/L BDW2 and 0.16 μg/L BDW4), while PCB 52 was a third compound with 0.1 μg/L in all presentations. Such concentrations probably are a consequence of contamination during packing of drinking water or contamination of the water reservoir.

The values reported in this study are comparable with data from water analysis in Italy using 1260 PCB mix and PCB 52 was a common compound found. In China, samples from the Yangzte River was analyzed where it is used for human consumption, and showed values of 0.6–1.4 pg/L, compared to our results were from 0.03 to 0.06 μg/L. Research from France by Chevreuil and Granier (1991) on drinking water measured concentrations of 0.024 and 0.250 μg/L, which did not exceed permissible limits.

According to the Mexican and European regulations for human consumption of water, total PCBs present in our samples do not represent a hazard for human health because they are lower than set out in the regulations (0.50 μg/L) PROY-NOM-SSA1-250-2007 (Senior and Ashurst 1998; SSA 2007).

Kimbrough et al. (2010) established that PCBs are present in BDW worldwide in very low concentrations (<1 μg/L), and they are usually associated with point sources that may have contaminated water from wells, rivers, and lakes. At such low concentrations, PCBs in drinking water are expected to provide little or no contribution to the human body burden.

The presence of xenobiotics in drinking bottled water represents a complex problem because contamination can occur in different phases of the production process, for example from the water of a contaminated reservoir through open burning, waste incineration, vaporization from contaminated surfaces and products containing PCBs, and improper disposal or leakage of oil from transformers and capacitors of industrial machinery (Chevreuil and Granier 1991; Bozlaker et al. 2008). It has been shown that the environmental gas-phase concentrations of PCBs are affected by seasonal temperature variations with movement to different environmental reservoirs such as air, soil and water. Some researchers have explained the importance of plastic as a source of contamination due to degradation by temperature and sunlight, as well as the raw materials (Símkoa et al. 1999; Leivadara et al. 2008; Pinto and Reali 2009).

It is important to monitor the quality of BDW with the intention of ensuring better health for people as these

compounds are persistent and many reservoirs around the world have serious problems of contamination (Chen et al. 2008). It has long been recognized that some PCB congeners are slowly biotransformed in animals, leading to their slow clearance from the body but also the formation of toxic metabolites during degradation in the body (James et al. 2008).

In general, the concentrations of PCBs in BDW from this study do not represent a health hazard according to PROY-NOM-SSA1-250-2007, but it is essential to continue monitoring the quality of bottled water in all commercial presentations. Further, with regard to the description of some elements such as salts content, the companies should make sure that the products are of good quality and packed in hygienic conditions, particularly in emerging and developing countries, and furthermore that they comply with storage regulations.

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