

04-228

Relationship between bisphenol A and microplastic-like particles in the waters of Cochabamba, Bolivia

PAUL d'ABZAC, Richard Roger Veizaga Barrientos, Ana Nicole Balderrama Vargas

Universidad Católica Boliviana San Pablo, Centro de Investigación en Ciencias Exactas e Ingenierías

Deficient waste management in Cochabamba (Bolivia) has led to environmental contamination by microplastic-like (MP-like) particles. Bisphenol A (BPA), an endocrine-disrupting monomer used in plastic composition, is released from the plastic matrix into the water through a process influenced by environmental variables. This study analyzed the relationship between both pollutants in seven water sources (surface, groundwater, and potable water) in Cochabamba. The physicochemical variables of the samples were determined, and MP-like particles and BPA were quantified using fluorescence microscopy and HPLC-UV/Vis, respectively. All water samples showed the presence of BPA (26.03 to 68.81 ppb) and MP-like particles (2,917 to 10,500 MP/L). Statistical analysis evidenced a strong positive correlation between the presence of microfragments and microfilaments and the concentration of BPA in the water. It was determined that pH is the parameter with the greatest influence on the presence of BPA. Furthermore, higher temperatures and conductivities were associated with lower BPA concentrations in the samples. In conclusion, the distribution and persistence of BPA are determined by direct interaction with MP-like particles and the physicochemical conditions of the medium.

Keywords: Microplastics; Microplastic-like particles; Bisphenol A; Environmental factors; Water sources

Relación entre el bisfenol A y las partículas microplastic-like en las aguas de Cochabamba, Bolivia

La deficiente gestión de residuos en Cochabamba (Bolivia) ha derivado en una contaminación ambiental por partículas microplastic-like (MP-like). El bisfenol A (BPA), monómero utilizado en la composición de plásticos, un disruptor endocrino, es liberado desde la matriz plástica hacia el agua, proceso influenciado por variables ambientales. Este estudio analizó la relación entre ambos contaminantes en siete fuentes de agua (superficiales, subterráneas y potables) de Cochabamba. Se determinaron las variables fisicoquímicas de las muestras y se cuantificaron los MP-like (microscopía de fluorescencia) y el BPA (HPLC-UV/Vis). Todas las muestras de agua presentaron presencia de BPA (26,03 a 68,81 ppb) y de MP-like (2.917 a 10.500 MP/L). El análisis estadístico de los resultados evidenció la estrecha relación positiva entre la presencia de microfragmentos y microfilamentos y la concentración de BPA en las aguas. Se determinó que el pH es el parámetro que tiene mayor influencia sobre la presencia de BPA en el agua. Además, temperaturas y conductividades más altas están relacionadas a concentraciones de BPA más bajas en las muestras. En conclusión, la distribución y persistencia del BPA están determinadas por la interacción directa con los MP-like y las condiciones fisicoquímicas del medio.

Palabras clave: Microplásticos; Partículas microplastic-like; Bisfenol A; factores ambientales; Fuentes de agua

This work was supported by the VLIR-UOS: Vlaamse Interuniversitaire Raad-Universitaire Ontwikkelingssamenwerking (Grant Number BO2017IUC034A105) and by the DGD: Directorate General for Development Cooperation and Humanitarian Aid.



©2026 by the authors. Licensee AEIPRO, Spain. This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Global society's reliance on plastic materials has intensified since the onset of large-scale commercial production in the 1950s (Hale et al., 2020). At a fundamental level, plastics are defined by the polymerization of repeating monomeric units into extensive chains (Heal, 2020). Among these synthetic precursors, Bisphenol A (BPA) remains one of the most ubiquitous, serving as a cornerstone in the manufacture of polycarbonate (PC) plastics and epoxy resins (Pjanic, 2017). These materials are integral to an expansive array of consumer and industrial applications, including food and beverage packaging, safety equipment, automotive components, and medical devices (American Chemistry Council, n.d.). However, the widespread utility of BPA is overshadowed by its classification as a potent endocrine-disrupting chemical (EDC). Cumulative evidence identifies BPA as a contaminant capable of significant hormonal interference, with numerous studies linking chronic exposure to adverse health outcomes in both humans and wildlife (Juan-García et al., 2015).

As an emerging organic pollutant, BPA's entry into the hydrological cycle poses a direct threat to public health. Anthropogenic activities facilitate its transport into groundwater, where concentrations typically fluctuate between 0.02 ppb and 0.74 ppb (Careghini et al., 2014; Dueñas-Moreno, 2022). In surface waters, levels vary from 0.25 ppb in marine environments to 0.41 ppb in inland systems (Sánchez et al., 2019). Of particular concern is the detection of BPA in drinking water at concentrations as high as 2.23 ppb (Gao et al., 2023), representing a severe risk under chronic exposure scenarios. Furthermore, the magnitude of this contamination is most evident in industrial and urban effluents, with reports of 107 ppb in landfill leachates and 17.3 ppb in wastewater (Sánchez et al., 2019), underscoring a critical threat to receiving environmental compartments.

The leaching of BPA from the plastic matrix is accelerated by diverse external stressors, including high temperatures, mechanical abrasion, irradiation, and exposure to varying pH levels or detergents (Khalili et al., 2023). In tandem with chemical leaching, abiotic weathering and biotic degradation trigger the fragmentation of macroplastics into microplastics (MPs), defined as particles ranging from 1 μm to 5 mm (Crawford & Quinn, 2017). These particles are not merely physical pollutants; they serve as sophisticated vectors for hazardous microorganisms and chemical pollutants (García, 2021; Bollaín & Vicente, 2019). As polymers decompose, their altered physical and chemical structures enhance their toxicity (UNEP, 2021). Monomers and adsorbed contaminants can be released upon ingestion, potentially entering the bloodstream and inducing liver and gastrointestinal toxicity (Morillo-Velarde, 2021; Whelshons et al., 2006).

Recent investigations have begun to characterize the complex relationship between BPA and microplastics in aquatic matrices, revealing that polymers act simultaneously as sinks and sources of the contaminant (Xuemin et al., 2019). While certain polymers like polyamide and polyurethane may adsorb BPA from the environment (acting as sinks), others, as polycarbonate, release it through desorption or structural degradation (acting as sources). Due to their high specific surface area and hydrophobicity, these particles exhibit a high affinity for BPA, facilitating its transport into living organisms (Wang et al., 2023). Under simulated gastrointestinal conditions, BPA desorption occurs rapidly, with significantly higher rates observed in polypropylene (PP), polystyrene (PS), and polyamide (PA). Notably, while gastric pH (1–3) appears to have a negligible effect, the transition to the alkaline conditions of intestinal juices (pH 6–8) markedly increases desorption, a process further modulated by salinity and temperature (Wang et al., 2023).

In the South American context, Bolivia has mirrored global trends with an exponential rise in plastic consumption, which reached approximately 171,239 tons in 2019 (WWF Bolivia, 2021a). 5% of this waste is diverted into open-air dumps or natural water bodies, triggering severe ecological damage (WWF Bolivia, 2021b). This crisis is acutely visible in Cochabamba, where the metropolitan area maintains a systemic reliance on the K'ara K'ara landfill. This facility has long exceeded its operational lifespan and currently faces a judicial mandate for closure by 2025. Consequently, environmental mitigation in the Rocha River

basin remains fundamentally inadequate, leaving urban plastic debris as the primary driver of downstream pollution (Comptroller General of the State, 2023).

The failures in local waste management have led to widespread contamination by particulate matter (PM) and microplastic-like (MP-like) particles across the valley, detected in both aquatic and atmospheric samples (Oporto et al., 2021). While research into the physical presence of these particles and their public health risks is burgeoning in Cochabamba, their chemical nexus with BPA remains an unexplored frontier. Given that these particles may act as protective reservoirs that inhibit the rapid degradation of BPA in water, it is imperative to investigate how BPA interacts with the specific characteristics of the MP-like particles found in Cochabamba's local waters. Thus, from a project engineering perspective, identifying emerging contaminants is a critical phase in the technical diagnostic and design of water treatment infrastructure and management. In high-altitude Andean watersheds, the lack of integrated waste management systems introduces significant chemical risks that must be addressed during the pre-feasibility stages of hydraulic projects to ensure long-term operational viability and compliance with international health standards.

2. Objective

The main objective of this research is to evaluate the interaction between BPA and MP-like particles in Cochabamba's water sources as a foundational technical diagnostic for environmental risk management and the engineering design of hydraulic infrastructure. This assessment is operationalized through a multi-stage approach. First, establishing a physicochemical baseline (pH, temperature, and conductivity) will facilitate the definition of design requirements and operating conditions for future treatment facilities. Then, quantifying BPA and MP-like concentrations will allow to delineate the chemical risk profile essential for water purification process engineering.

3. Methodology

3.1 Sampling and in-situ physicochemical measurements of the water samples

This research used water samples from various sources in Cochabamba, including rivers, lagoons, groundwater, and drinking water. These samples were collected at the end of the rainy season during the afternoon (2:00 PM–7:00 PM). Table 1 describes each sampling point.

Sampling was carried out according to the protocol adapted from the National Institute of Agricultural Technology (INTA) (2011): Sampling, transport, and preservation of water samples for multiple purposes. pH, temperature, and electrical conductivity (EC) were then measured in the field using a multiparameter field equipment (Hanna, model: HI 9829). pH was selected because previous studies have shown that pH can affect the chemical stability of BPA and its adsorption capacity on plastics, with some studies suggesting greater release under extreme acidity and others under basicity (Whelshons et al., 2006; Khalili et al., 2023). Similarly, temperature is a key factor because it can either increase or decrease the concentration of BPA in water: elevated temperatures increase the release of BPA from PC MP into the water, raising its concentration (Napierska, 2019), or temperature can increase the rate of degradation of BPA dissolved in water, reducing its concentration (Petrucci et al., 2023). Furthermore, EC, which measures the concentration of dissolved ions in water, was included in the analysis because, in media with high conductivity, ions could compete with BPA for adsorption sites on MP particles (Fuentes, 2024).

Table 1: Sampling point Characteristics

Sampling point	Water	Name of the water body	Latitude	Longitude	Activities in the area
M1	Surface water	Coña Coña lake	17°23'22,14" S	66°12'28,21" W	Urban
M2	Surface water	Alalay lake	17°24'42,32" S	66°8'31,35" W	Urban
M3	Surface water	Rocha River	17°24'38,08" S	66°10'33,32" W	Urban
M4	Surface water	Tamborada river	17°26'24,31" S	66°9'40,98" W	Agriculture
M5	Surface water	Angostura lake	17°31'44,83" S	66°5'6,62" W	Agriculture Tourism Fishing
M6	Groundwater	Groundwater in the center of the city	17°23'55,18" S	66°9'17,51" W	Urban
M7	Tap water	Tap water in the center of the city	17°23'56,75" S	66°9'17,73" W	Urban

3.2 Determination of bisphenol A concentration in water samples

First, a 500 ppm BPA stock solution was prepared in pure acetonitrile. Then, by dilution of the stock solution with the same solvent, five 10 mL BPA standards were prepared at concentrations of 0.2, 0.5, 1, 5, and 10 ppm.

A liquid chromatography system with the following characteristics was used:

- HPLC-Biobase Ichrom 5100 High Performance Liquid Chromatography
- Software: M5103 Manager
- O501 Column Oven
- O501 UV-Vis Detector
- 55101 Auto Sampler
- Waters C18 5 µm column (250 x 4.6 mm).

The configuration was based on the BPA quantification runs from the study by Aristiawan et al. (2015):

- Injection: 30 µL
- Isocratic elution
- Mobile phase flow rate: 2 mL/min
- Mobile phase ratio: water/acetonitrile 40/60 (Zoeller, 2023)
- Wavelength: 200 nm
- Conditioning: 30 min

3.3 Characterization of microplastic-like particles in water samples

First, it's important to define the term MP-like as particles with polymeric properties that may have been extracted using the protocol employed. Plastic waste has been reduced to microscopic and nanometric sizes, leading to a more difficult process to differentiate between plastic particles and natural debris using microscopes in the samples (Ríos and Balcer,

2019). After all, in an analysis where only visual classification of MP is performed, without a more thorough analysis to accurately identify the composition of these particles, errors in overestimating the amount of MP can occur. This is because some particles may resemble plastic but be of a different origin. The extract of MP-like particles can include particles of plastic polymers and other particles with similar physical properties. While spectroscopic verification (FTIR/Raman) remains the standard for polymer chemical characterization, such equipments are not available in Bolivia and a lot of Global South countries. The use of 'MP-like' concept in this study serves as a rigorous proxy for environmental risk assessment in resource-constrained project environments in Global South countries. This approach allows for the identification of potential chemical vectors providing essential baseline data for the risk management plans of local water management projects.

The extraction of the MPs involved two stages. First, digestion was performed to remove organic matter particles from the samples. This was done by adding 23 mL of 30% H_2O_2 to 20 mL of the water sample (final concentration of 16% H_2O_2 in each sample). The mixture was heated to 40°C until bubbling ceased or was minimal (Coral et al., 2024). Each sample was then vacuum-filtered using a 0.45 μm pore diameter microcellulose filter, and the filters were washed with 10 mL of distilled water. Finally, the MPs were separated by density by adding and dissolving 4.13 g of ZnCl_2 in each of the filtered samples. The final density of ZnCl_2 was 1.37 g/mL in each sample (36.20% w/v) (Maes et al. 2017). Three drops of Nile red dye at a concentration of 1 $\mu\text{g/mL}$ were added to each sample for identification by fluorescence microscopy. The upper portions of the samples were collected and filtered through a 0.45 μm pore diameter microcellulose filter.

The identification of MP-like particles was performed using a fluorescence microscope (Optika, B1000LD4) at 10X magnification. For characterization, the MP-like particles were classified according to Crawford and Quinn (2017) as follows: spheres, fragments, films, fibers, and sponges. Likewise, the size was classified according to Duis & Coors (2016) into the following groups: 1 - 100 μm ; 100 - 350 μm and 350 μm - 1 mm.

The same physical characterization procedure for MP-like particles was performed on the water samples using an ultrapure water blank (control). This was done to evaluate the contribution of particles from sample processing.

3.4 Statistical analysis

This stage consisted of performing simple descriptive statistics (mean, variance, RSD), inferential statistics (ANOVA, Tukey's test, Z-score), and multivariate descriptive statistics (PCA). The data were then standardized to ensure that all variables were on the same scale and had equal weight in the analysis. This data processing aims to identify the principal components that explain most of the data variability.

3.5 Release of Bisphenol A by microplastics in water

This experiment aims to confirm the release of BPA by MP in a controlled environment to better understand the relationship between MP and BPA in water.

For the preparation of MP, polyvinyl chloride (PVC) was used, as it is one of the most widely used plastics in Bolivia (Sectoriales, 2021). Subsequently, it was shredded using an electric shredder. Finally, the plastic fragments were sieved (with a pore size of 300 μm), recovering the fraction smaller than 300 μm .

2 g of MP were placed in 250 mL blue screw-cap ISO glass bottles containing 150 mL of ultrapure water. The bottles were thoroughly washed with ultrapure water and sterilized in a pressurized steam autoclave at 120°C to eliminate ubiquitous contaminants (Mohammed F. Zaater, 2013). Subsequently, the pH of the 18 samples was adjusted using 0.1 M sodium hydroxide (NaOH) solutions, phosphate buffer, and acetate. BPA release was evaluated after

1 week under the defined pH (4.68, 7.61, and 9.85) and temperature (5°C, 23°C, and 40°C) conditions (Santhi, 2012; Comte Loera, 2018).

The experimental design matrix was based on a 3² factorial design, consisting of nine treatments (3²=9) with two replicates, for a total of eighteen experimental units. The response variable was the BPA concentration in ppm.

An analysis of variance was performed to evaluate the relationship between environmental factors (Fernández Bao, 2020). The pH and temperature variables were considered the independent variables, and the amount of BPA was the response variable. Likewise, the analysis of variance ANOVA was performed with a confidence level of 95%, this was applied in all cases with a significance level of 0.05.

4. Results

This section presents the results of the different parts of the experimentation.

4.1 Characterization of water samples

Table 2 presents the average results and standard deviations of the field measurements of the physicochemical parameters of the 7 water samples. pH controls the chemical form of BPA and its affinity for MPs (Corrales et al., 2015). Temperature can favor both its release and its degradation (Le et al., 2008; Petrucci et al., 2023). Finally, the EC has opposing effects by influencing the adsorption and solubility of BPA (Martins et al., 2024; Rizo, 2014).

Table 2: Physicochemical parameters of the water samples

Sample	pH	Temperature [°C]	EC [µS/cm]
M1	7.56 ± 0.02	18.22 ± 0.05	124.33 ± 0.58
M2	8.92 ± 0.01	26.62 ± 0.08	3570.67 ± 44.05
M3	7.44 ± 0.02	22.98 ± 0.06	1054.00 ± 11.27
M4	7.30 ± 0.02	25.69 ± 0.07	3390.33 ± 4.04
M5	7.15 ± 0.02	21.56 ± 0.03	320.33 ± 0.58
M6	7.15 ± 0.02	21.96 ± 0.01	1924.33 ± 16.07
M7	7.53 ± 0.03	20.10 ± 0.03	70.33 ± 0.58

The results show that surface waters have pH, temperature, and conductivity within generally acceptable ranges, although with indications of possible contamination at some points (Karyab et al., 2013; Benz et al., 2017). The groundwater presents close to the upper limits of conductivity (Massa et al., 2016). Tap water parameters are within the standards of potability (Sanitino, 2023).

BPA was spotted in all the water samples (Table3). All surface water samples in this study are similar to those from other countries, such as the Netherlands, South Korea, and China. Regarding drinking water, although bottled water from India should be purer than tap water from Cochabamba, since it is intended exclusively for human hydration, both have very similar BPA concentrations. On the other hand, groundwater from Cochabamba shows higher concentrations than those reported in countries like England or Switzerland, but the

difference is not drastic, especially when considering the lower end of the standard deviation range. (Ruiz 2013; Huang, et al., 2012; Gupta et al.,2023; Corrales et al., 2015; Pal et al., 2025)

Table 3: Average concentration of BPA in water samples

Sample	Average concentration [ppb]	%RSD
M1	35.57 ± 6.72	18.89%
M2	42.16 ± 32.2	76.38%
M3	68.81 ± 51.7	75.13%
M4	26.03 ± 11.29	43.38%
M5	54.88 ± 14.06	25.61%
M6	30.39 ± 17.75	58.40%
M7	30.55 ± 8.66	28.33%

4.2 Characterization of MP-like in water samples

MP-like particles were identified in all the water samples (Table 4).

ANOVA analysis at a 95% significance level revealed differences in the amount of MP-like particles among the different sampling points.

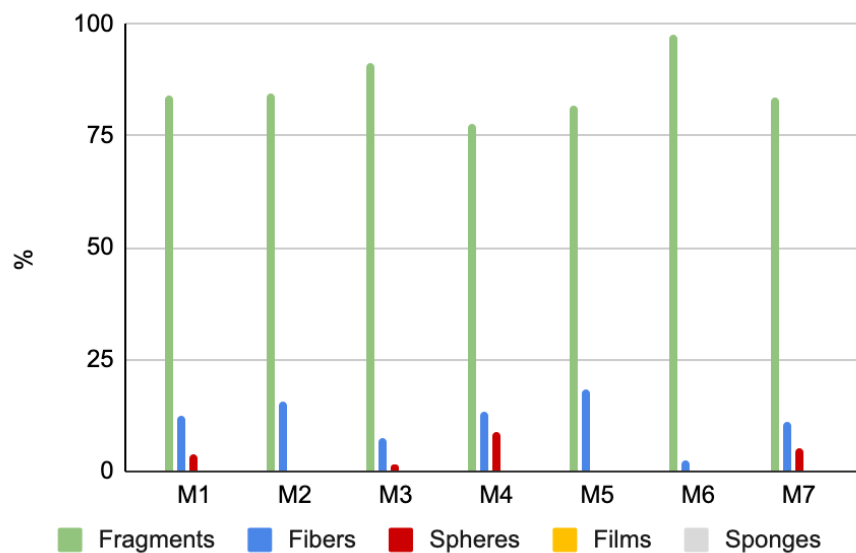
According to Tukey's post-hoc test, Coña Coña lake (M1) presented the highest concentration of MP-like particles and was placed in a statistically distinct group (A), indicating that its level of contamination by these particles is significantly higher than at other points. In contrast, Alalay lake (M2) and the groundwater (M6) grouped together in a second group (B), suggesting that these water bodies have a significantly lower amount of MP-like particles compared to Coña Coña. The other sampling points, such as tap water (M7), the Rocha river (M3), Angostura lake (M5) and the Tamborada river (M4), were placed in an intermediate group (A, B), indicating that they do not present significant differences among themselves, but they do differ from the extremes. These results suggest that MP-like contamination is not homogeneous across the different sampled water bodies, with certain areas showing a greater accumulation of these particles.

Table 4: Average concentration of MP-like in water samples

Sample	Average concentration [particles/L]	%RSD	Group - Tukey's test
M1	10,500 ± 1,590	15.14%	A
M2	3,367 ± 2,501	74.28%	B
M3	6,317 ± 3,700	58.57%	AB
M4	4,433 ± 1,365	30.79%	AB
M5	5,317 ± 2,693	50.65%	AB
M6	2,917 ± 804	27.56%	B
M7	7,683 ± 1,511	19.67%	AB

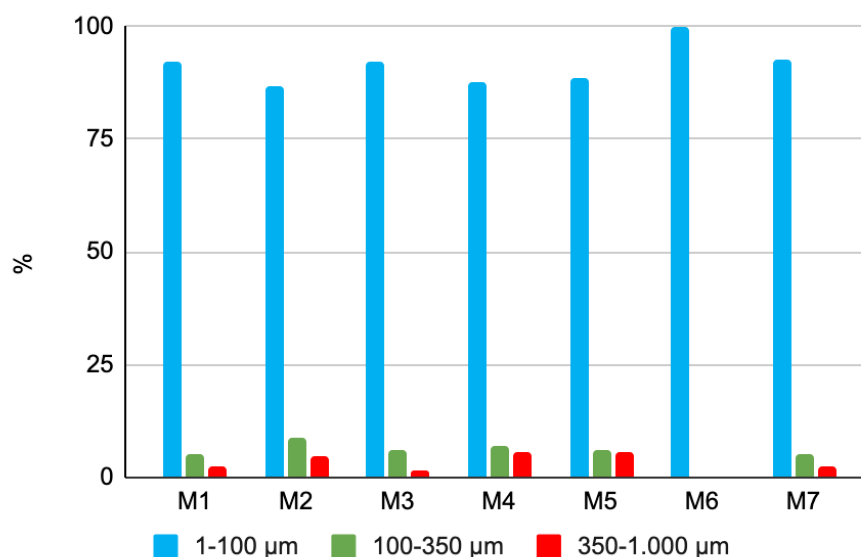
The predominant shapes of MP-like particles in all samples were fragments and filaments (Figure 1). This result was expected, as these correspond to the most common secondary MP and are usually more abundant compared to primary MP (Jing et al., 2024; Rodríguez-Seijo and Pereira, 2017).

Figure 1: MP-like distribution according to shape



Analyzing the size of the MP-like particles, it was observed that the smallest MP-like particles were the most predominant (Figure 2) as expected according to the literature, which states that microplastic concentration increases as particle size decreases (Scherer et al., 2020).

Figure 2: MP-like distribution according to size



4.3 Principal component analysis

Using the Z-score statistical test with a threshold of $1.92 \approx 2$, sensitive for a small number of data points ($n < 10$), an outlier was identified in the Rocha river sample with respect to the BPA concentration (68.81 ppb). Furthermore, given that the Alalay Lagoon sample presented the highest RSD values for BPA and MP concentrations (Tables 3 and 4), which could affect the interpretation of the results and the quality of the analysis, the Z-score test was applied to the RSD values of the samples. In this instance, the most sensitive threshold of 1.5 was used, and the Alalay Lagoon sample was identified as an outlier with respect to the RSD for MP concentration (74.28%).

The PCA shows that the biplots between CP1–CP2 and CP1–CP3 explain approximately 80% and 70% of the total variance, respectively, making them suitable for interpreting the relationships between variables (Jolliffe, 2002). The results show that BPA concentration is positively correlated with MP-like and pH, and negatively correlated with temperature and EC. This confirms that pH influences the chemical form of BPA. At low pH, it favors its adsorption onto MP due to its hydrophobic nature, while at high pH, its solubility in water increases (Corrales et al., 2015). Furthermore, although temperature can promote the release of BPA from MP, it also accelerates their degradation, which explains the observed negative correlation (Le et al., 2008; Fu et al., 2021; Petrucci et al., 2023). Regarding EC, the "salting out" effect predominates, favoring BPA adsorption onto MP-like particles and reducing its concentration in water (Martins et al., 2024; Rizo, 2014).

On the other hand, the shape and size of MP-like particles significantly influence BPA dynamics. Microspheres are associated with lower BPA concentrations due to their low roughness, smaller surface area, and the fact that they are not derived from polymers like polycarbonate (Zhao et al., 2022). In contrast, microfragments and microfilaments show a greater association with BPA, both because they originate from the degradation of plastics that can release this compound (Andrady, 2011; Xu et al., 2018), and because their larger surface area favors adsorption (Zhao et al., 2022; ERIA, 2023). Larger particles (350–1000 µm) show a stronger association with BPA than smaller ones, likely because the latter have undergone greater degradation and have already released a significant portion of the contaminant (Andrady, 2017; Liu et al., 2020).

4.4 Release of BPA from PVC microplastics

These results aim to confirm the above scope in controlled conditions. PVC MP were exposed for 1 week in different conditions of pH and temperature and BPA was quantified (Table 5).

Table 5: BPA concentrations after one week of exposure

pH	Temperature	Average concentration of BPA (ppm)
4.61	5°C	5.48
4.61	23°C	7.15
4.61	40°C	6.41
7.68	5°C	1.99
7.68	23°C	2.97
7.68	40°C	6.09
9.85	5°C	2.15
9.85	23°C	2.91
9.85	40°C	2.30

The results show that BPA release increases with temperature, being higher at 23°C and 40°C compared to 5 °C. This is because the increase in kinetic energy favors desorption by increasing the frequency of molecular collisions and the reaction rate. Furthermore, at higher temperatures, the CH/π hydrogen bonds between BPA and microplastics weaken and break, facilitating its release (Pengfei, 2019; Zhou and Wei, 2014; Liu, 2017). Regarding pH, greater BPA release is observed under acidic conditions (pH 4.61), which is related to its pKa and its behavior as an ionizable compound, as well as to electrostatic interactions that favor desorption (Godoy and Lara, 2020). Likewise, the acidic medium can induce the degradation and reduction of the size of microplastics, increasing the diffusion and release of BPA due to a greater surface area and porosity (Lopez and Bayo, 2019; Chen et al., 2019; Ambrogio, 2017).

4.5 Chemical Risk Assessment and Regulatory Compliance

The critical nature of Bisphenol A (BPA) as a public health concern was recently redefined by the European Food Safety Authority (EFSA). While the 2015 standards established a Tolerable Daily Intake (TDI) of 4 µg BPA/kg body weight/day, exhaustive clinical and toxicological re-evaluations concluded in April 2023 led to a drastic reduction of this threshold. The updated TDI is currently set at 0.2 ng/kg body weight/day, which represents a 20,000-fold decrease from the previous limit (EFSA, 2023). For an average adult weighing 75 kg, this translates to a maximum daily intake of only 15 ng of BPA.

When contrasting these international safety standards with the empirical data gathered in Cochabamba, the results reveal a significant failure in chemical risk mitigation. The concentration detected in the local potable water supply reached 30.55 ppb. Assuming an average daily consumption of 2.5 L of water, an adult would be ingesting approximately 76.38 µg of BPA per day. This dose is 5,092 times higher than the updated EFSA safety limit.

From an engineering and project management perspective, this gap necessitates an immediate reassessment of the current water purification processes. To align with the

updated TDI, the maximum allowable concentration of BPA in drinking water should be approximately 6 ppt. Consequently, the implementation of advanced treatment technologies is required to reduce current levels from 30.55 ppb to the recommended 6 ppt. Constant monitoring and the integration of emerging contaminant removal stages into local hydraulic projects are essential to transition from a reactive management model to a proactive, health-centered engineering strategy, thereby protecting the population from the long-term deleterious effects of endocrine disruption.

5. Conclusions

This study confirms the coexistence of BPA and MP-like particles in the various water matrices of Cochabamba. The presence of BPA in all analyzed samples, with concentrations reaching 68.81 ppb in surface water sources and persistence in drinking water (30.55 ppb), places the region in a chemical risk scenario under the new EFSA standards (2023).

From a physicochemical perspective, pH is identified as the determining factor in the dynamics of the BPA contaminant. The predominantly alkaline conditions in the basin facilitate the ionization and subsequent release of BPA from the polymer matrix. Furthermore, the positive statistical correlation between the abundance of microfragments and microfilaments with dissolved BPA levels demonstrates that the morphology of MP-like particles, and specifically their surface area, plays an important role in the dynamics of BPA in water.

Ultimately, these findings underscore that systemic deficiencies in metropolitan waste management have effectively transformed local watersheds into uncontrolled chemical reactors, where plastic debris not only persists but actively leaches endocrine-disrupting compounds. Consequently, it is imperative that future water treatment policies in Bolivia mandate the integration of specialized microplastic removal technologies, as current conventional infrastructures fail to mitigate the toxic nexus between particulate matter and emerging organic pollutants. From a Project Management perspective, this research provides the empirical evidence necessary to de-risk the decision-making process in environmental engineering. Characterizing the interaction between BPA and MP-like particles is no longer an isolated chemical concern; it has become a foundational requirement for the sustainable design, technical viability, and lifecycle management of water supply projects across South America.

6. Bibliography

- Ambrogi, V. (2017). *Aditivos poliméricos*. Elsevier, 87–108.
- American Chemistry Council. (s.f.). Bisfenol A: usos y beneficios del BPA. Facts About BPA. https://es.factsaboutbpa.org/benefits-applications/?utm_source=chatgpt.com
- Andrady, A. L. (2011). Microplastics in the marine environment. Elsevier, 1596–1605.
- Aristiawan, Y., Aryana, N., Putri, D., & Styarini, D. (2015). Analytical method development for bisphenol A in tuna by using high performance liquid chromatography-UV. *Procedia Chemistry*, 16, 202–208. <https://www.sciencedirect.com/science/article/pii/S1876619615001904>
- Benz, S., Bayer, P., & Blum, P. (2017). Global patterns of shallow groundwater temperatures. *Environmental Research Letters*, 12(3). <https://iopscience.iop.org/article/10.1088/1748-9326/aa5fb0/meta>

- Bollaín, P., & Vicente, A. (2019). Presence of microplastics in water and the potential impact on public health. *Revista Española de Salud Pública*, 93. <https://pmc.ncbi.nlm.nih.gov/articles/PMC10560522/>
- Careghini, A. (2014). Bisphenol A, nonylphenols, benzophenones, and benzotriazoles in soils, groundwater, surface water, sediments, and food: A review. *Environmental Science and Pollution Research*, 22(8). <https://www.researchgate.net/publication/270287930>
- Chen, Q., et al. (2019). Lixiviación de sustancias químicas disruptoras endocrinas de microplásticos y mesoplásticos marinos en condiciones de estrés vital comunes. Elsevier.
- Comte Loera, H. (2018). Efecto del PET en la vida útil de agua embotellada. Querétaro, México.
- Contraloría General del Estado (CGE). (2023). Informe de seguimiento de la auditoría ambiental en la cuenca del Río Rocha (K2/002/L5). Estado Plurinacional de Bolivia.
- Coral, L., Ruíz, J., Criales, M. I., & Cabanzo, R. (2024). Evaluación de las técnicas para la digestión y extracción de microplásticos ingeridos por el zooplancton marino. *Boletín de Investigaciones Marinas y Costeras*, 53(1), 175–186. <https://www.researchgate.net/publication/377194853>
- Corrales, J., Kristofco, L., Steele, B., Yates, B., Breed, C., Williams, S., & Brooks, B. (2015). Global assessment of bisphenol A in the environment: Review and analysis of its occurrence and bioaccumulation. *Dose-Response*, 13(3). <https://journals.sagepub.com/doi/10.1177/1559325815598308>
- Crawford, C., & Quinn, B. (2017). Microplastic pollutants. Elsevier. <https://drive.google.com/drive/folders/1i1BgjUWiLuBBpACMvHdM-3caiSU-EBh>
- Dueñas-Moreno, J., Mora, A., Cervantes-Avilés, P., & Mahlknecht, J. (2022). Groundwater contamination pathways of phthalates and bisphenol A: Origin, characteristics, transport, and fate – A review. *Environment International*, 170. <https://www.sciencedirect.com/science/article/pii/S0160412022004779>
- Duis, K., & Coors, A. (2016). Microplastics in the aquatic and terrestrial environment: Sources, fate and effects. *Environmental Sciences Europe*, 28(1), 1–25. <https://pubmed.ncbi.nlm.nih.gov/27752437/>
- EFSA. (2023). Re-evaluation of the risks to public health related to the presence of bisphenol A (BPA) in foodstuffs. <https://www.efsa.europa.eu/en/efsajournal/pub/6857>
- Fernández Bao, S. (2020). Diseño de experimentos: diseño factorial. Barcelona, España.
- Fuentes, S. (2024). Mecanismos de adsorción de plomo y zinc sobre microplásticos de polietileno y tereftalato de polietileno [Tesis de grado]. Universidad Católica Boliviana.
- García, A. (2021). ¿Son los microplásticos vehículos de contaminación microbiana? [Tesis de maestría]. Universidad de La Laguna. <https://riull.ull.es/xmlui/bitstream/handle/915/27948/>
- Godoy, V., & Lara, M. (2020). La relevancia de la interacción de productos químicos/contaminantes y microplásticos como ruta de transporte. Elsevier, 312–323.

- Gupta, A., Singh, A., & Mishra, V. (2024). Impact of bisphenol-A in the environment and its removal through biological agents: A review. *Environmental Quality Management*, 34(4). <https://www.researchgate.net/publication/380494032>
- Hale, R., Seeley, M., La Guardia, M., Mai, L., & Zeng, E. (2020). A global perspective on microplastics. *Journal of Geophysical Research: Oceans*, 125. <https://doi.org/10.1029/2018JC014719>
- HEAL. (2020). Invertir la tendencia de los plásticos: Sustancias químicas del plástico que perjudican la salud. https://www.env-health.org/wp-content/uploads/2022/03/HEAL_Plastics_ES.pdf
- Huang, Y. Q., Wong, C. K. C., Zheng, J. S., Bouwman, H., Barra, R., Wahlström, B., Neretin, L., & Wong, M. H. (2012). Bisphenol A in China: A review of sources and impacts. *Environment International*, 42, 91–99.
- Instituto Nacional de Tecnología Agropecuaria (INTA). (2011). Protocolo de muestreo, transporte y conservación de muestras de agua. https://www.produccion-animal.com.ar/agua_bebida/107-Protocolo_Aguas_INTA.pdf
- Jing, S., Chunhui, W., & Gang, L. (2024). Defining primary and secondary microplastics. *ACS ES&T Water*, 4(6), 2330–2332. <https://pubs.acs.org/doi/10.1021/acsestwater.4c00316>
- Jolliffe, I. (2002). *Principal component analysis* (2nd ed.). Springer.
- Juan-García, A., Gallego, C., & Font, G. (2015). Toxicidad del bisfenol A: Revisión. *Revista de Toxicología*, 32, 144–160.
- Karyab, H., et al. (2013). Polycyclic aromatic hydrocarbons in drinking water. *Journal of Environmental Health Science & Engineering*, 11(1). <https://doi.org/10.1186/2052-336X-11-25>
- Khalili, E., et al. (2023). Bisphenol A release from food and beverage containers – A review. *Food Science & Nutrition*, 11, 3718–3728. <https://doi.org/10.1002/fsn3.3398>
- Le, H., Carlson, E., Chua, J., & Belcher, S. (2008). Bisphenol A release and neurotoxic effects. *Toxicology Letters*, 176(2), 149–156.
- Liu, H. (2017). *Materia orgánica y microplásticos*. PubMed, 907–917.
- Liu, P., et al. (2020). Effect of weathering on microplastics. *Chemosphere*, 242.
- López, C., & Bayo, B. (2019). Presencia y evolución de microplásticos en aguas residuales. *Dialnet*, 46–52.
- Maes, T., et al. (2017). Detection of microplastics using Nile Red. *Scientific Reports*, 7.
- Martins, G., Rodrigues, E., & Tavares, M. I. (2024). *Avanços em química e bioquímica*. Atena.
- Massa, E., et al. (2016). Línea base de calidad de aguas subterráneas. *Congreso Uruguayo de Geología*.
- Mohammed F. Zaater. (2013). Determination of phthalates in bottled water. *Journal of Chromatographic Science*, 447–452.

- Morillo-Velarde, L. (2021). Efectos potenciales de los microplásticos en la salud humana [Tesis]. Universidad de Sevilla.
- Napierska, D. (2019). Hacia un cuidado de la salud sin sustancias tóxicas. *Health Care Without Harm Europe*.
- Pal, N., et al. (2025). Detection and risk assessment of bisphenol-A. *International Journal of Environmental Health Research*.
- Pengfei, W. (2019). Mecanismos de adsorción de bisfenoles en microplásticos. Elsevier, 671–678.
- Petrucci, R., et al. (2023). General chemistry (20th ed.). Pearson.
- Pjanic, M. (2017). Role of bisphenol-A in insulin resistance. *PeerJ*. <https://pmc.ncbi.nlm.nih.gov/articles/PMC5600722/>
- Oporto, C., et al. (2021). Microplásticos atmosféricos en la ciudad de Cochabamba: Primeros hallazgos. *Revista de Actas del CICEI*, 5(1), 12-18.
- Rios, L., & Balcer, M. (2019). Microplastics in freshwater environments. *TrAC Trends in Analytical Chemistry*, 113, 402–408.
- Rizo, C. (2014). Optimización de extracción de proteína [Tesis]. UNAM.
- Rodríguez-Seijo, A., & Pereira, R. (2017). Characterization of microplastics. *Comprehensive Analytical Chemistry*, 75, 49–66.
- Ruiz, M. (2016). Cochabamba: Tres ríos y torrenteras. Eju.tv.
- Santhi, V. (2012). Occurrence of bisphenol A in water. Elsevier, 332–338.
- Sanitino. (2023). La temperatura ideal del agua. <https://www.sanitino.es/>
- Sánchez, G., et al. (2019). Biorremediación del BPA. *Alianzas y Tendencias BUAP*, 4(13), 18–31.
- Sectoriales, C. (2021). El PVC: uno de los plásticos más rentables. <https://www.interempresas.net/>
- UNEP. (2021). Plastic planet. <https://www.unep.org/>
- Wang, L., et al. (2023). Desorption of bisphenol A. *Frontiers in Marine Science*, 10.
- Whelshons, W., Nagel, S., & vom Saal, S. (2006). Endocrine mechanisms of BPA. *Endocrinology*, 147, 56–69.
- WWF Bolivia. (2021a). Diagnóstico sobre plásticos de un solo uso en Bolivia.
- WWF Bolivia. (2021b). Llamado urgente para reducir la contaminación plástica.
- Xu, P., et al. (2018). Microplastic risk assessment. *Marine Pollution Bulletin*, 133, 647–654.
- Xuemin, L., et al. (2019). Microplastics as sink/source of BPA. *Environmental Science & Technology*, 53.

Zhao, M., et al. (2022). Adsorption of pollutants by microplastics. *Nanomaterials*, 12(13).
<https://doi.org/10.3390/nano12132256>

Zhou, X., & Wei, J. (2014). Adsorción de bisfenol A. *Langmuir*, 30, 13861–13868.

Zoeller, J. (2023). Mobile phase in HPLC. Quora.

Use of Generative Artificial Intelligence

AI tools were used for language improvement

Communication aligned with the Sustainable Development Goals

