

Monitoring of Pharmaceuticals and Personal Care Products (PPCPs) in springs in the southwestern region of Paraná

Monitoramento de Fármacos e Produtos de Cuidado Pessoal (PPCPs) em Mananciais da Região Sudoeste do Paraná

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Abstract

Contamination of water by drugs and personal care products (PPCPs) has been drawing the attention of the scientific community in recent years due to the constant and reticent contamination and possible chronic effects on living things. Concern increases when these compounds are found in waters used for public supply. Consequently, the present study monitored PPCPs in springs of three small cities in the southwestern region of Paraná, with an average of 15,000 inhabitants. After treatment, the waters from these springs are used for public supply. The analyses were carried out following the method proposed by Caldas et al. (2013). The results obtained evidenced the presence of 7 different compounds classified as PPCPs in the four samplings carried out between the years of 2015 and 2017. Atenolol (0.041-0.088 $\mu\text{g L}^{-1}$), Eusolex® 6300 (0.043-0.067 $\mu\text{g L}^{-1}$), furosemide (0.612 $\mu\text{g L}^{-1}$), methylparaben (0.009-0.011 $\mu\text{g L}^{-1}$), nimesulide (0.006 $\mu\text{g L}^{-1}$), miconazole nitrate (0.072 $\mu\text{g L}^{-1}$) and triclocarban (0.001-0.018 $\mu\text{g L}^{-1}$) were quantified, highlighting the growing need for more efficient water and sewage treatment along with legislation that regulates the maximum level of these compounds in the environment to avoid serious public health problems.

Keywords: PPCPs, Contamination, Surface water.

Resumo

A contaminação das águas por fármacos e produtos de cuidado pessoal está chamando a atenção da comunidade científica nos últimos anos, por ser um tipo de contaminação silenciosa, constante e de possíveis efeitos crônicos aos seres vivos. A preocupação aumenta quando esses compostos são encontrados em águas utilizadas para abastecimento público, assim o presente estudo monitorou PPCPs (do inglês *Pharmaceuticals and Personal Care Products*) em mananciais de três pequenos municípios da região sudoeste do Paraná, com média de 15 mil habitantes. As águas desses mananciais são utilizadas após tratamento, para abastecimento público. As análises foram realizadas seguindo o método proposto por Caldas, *et. al.* (2013). Os resultados obtidos evidenciaram a presença de 7 compostos diferentes classificados como PPCPs nas quatro amostragens realizadas entre os anos de 2015 e 2017. Foram quantificados atenolol (0,041-0,088 $\mu\text{g L}^{-1}$), Eusolex® 6300 (0,043-0,067 $\mu\text{g L}^{-1}$), furosemida (0,612 $\mu\text{g L}^{-1}$), metilparabeno (0,009-0,011 $\mu\text{g L}^{-1}$), nimesulida (0,006 $\mu\text{g L}^{-1}$), nitrato de miconazol (0,072 $\mu\text{g L}^{-1}$) e triclocarban (0,001-0,018 $\mu\text{g L}^{-1}$), o que evidencia a crescente necessidade de tratamentos de água e esgoto mais eficientes juntamente com uma legislação que regulamente o nível máximo destes compostos no meio, a fim de evitar sérios problemas de saúde pública.

Palavras-chave: PPCPs, Contaminantes, Água Superficial.

Introduction

Brazil is a privileged country with about 12% of the global freshwater resources in its territory, being extremely rich in food production due to the abundance of water in its territory [1]. However, this resource is under constant threat due to its uncontrolled use and the increasing contamination by various substances that are inserted daily in the aquatic matrices, by either personal use, agriculture or industries.

Pharmaceuticals and personal care products (PPCPs) are one of the classes of substances that are present in aquatic matrices in extremely low concentrations. They are classified as contaminants of emerging concern because they are not usually monitored and there are few toxicological studies that proves their action in organisms or the environment [2, 3].

In Brazil, the Consolidation Ordinance N° 5, Annex XX (former PRT MS/GM 2914/2011) published in 2017 by the Ministry of Health [4], addresses water quality control and monitoring procedures and its potability for human consumption, regulating microbiological standards, turbidity, pH and maximum limits for some metals, some inorganic and organic substances. However, this ordinance does not refer to any contaminants of the PPCPs class. But the US Environmental Protection Agency has been publishing and updating over the last few years a list of non-regulated chemicals and microbial contaminants that are contaminant candidates, and currently the Contaminant Candidate List 4 (CCL4, published in 2016) includes 97 chemicals (among them some PPCPs, such as estrogenic hormones) and 12 microbial contaminants [5]. Similarly, in 2011 the European Union published a list of 48 priority substances in the field of water policy, such as diclofenac and estrogenic hormones, which contains some maximum permissible concentrations in $\mu\text{g L}^{-1}$ for surface water and other environmental samples [5-7].

PPCPs are continuously inserted in the medium through domestic and industrial sewage, both in their original form and in the form of metabolites [8]. They are not completely removed from surface water in Wastewater Treatment Plants (WWTPs) and in Drinking Water Treatment Plants (DWTPs), being able to remain in the water that is subsequently used for urban supply, can affect the health of the consumer population, since they are biologically active compounds and can alter the physiology and behavior of a non-target organism at low doses [9, 10].

Toxicological studies of these compounds in the environment report the feminization of fish, delay in the breeding period and size of future generations of certain species of fish, increase or decrease in the diversity of species in the environment, among others [11-13]. A study has reported the possible influence of endocrine disruptors on the high obesity rate of the world population, present in surface and ground waters [15].

In recent years the number of published works investigating the presence of PPCPs in aquatic matrices, sediments and wastewater has grown [16]. In China, for example, in a study conducted by some researchers, salicylic acid, caffeine, ibuprofen and paracetamol were detected in more than 95% of wastewater samples from 17 cities in the country [17]. Subedi and collaborators [18] investigated the presence of PPCPs in samples of septic effluents and water from Lake Skaneateles, in the state of New York - USA. Sulfamethoxazole, triclocarban, ibuprofen, carbamazepine and caffeine were found in more than 68% of the septic effluent samples. Despite the high index of the presence of these compounds in the effluent samples, many of them were not detected in tap water and lake samples, because they originated from spring water that must be free of the effluents.

In Brazil, research that investigates this type of contamination is still scarce. Most of the studies are from aquatic matrices in the southwestern region of the country, mainly in the states of São Paulo and Rio de Janeiro, and a few in the other regions [19, 20]. However, Machado et al. [7] carried out a national research in 22 Brazilian capitals, where a total of 100 samples of drinking and source waters were collected in two sample campaigns, revealing the presence of caffeine, atrazine, triclosan and phenolphthalein, with caffeine and atrazine being quantified in 93% and 75% of the samples, respectively.

In São Paulo, for example, Souza and collaborators [21] detected the presence of caffeine, triclosan, atenolol, carbamazepine, diclofenac, propranolol and triclosan in surface water samples from the Jundiá River Basin and, Locatelli and collaborators [22] quantified some antibiotics such as amoxicillin and cephalexin, as well as illicit drugs such as cocaine and its metabolite benzoylecgonine in the Atibaia River Basin.

In the Federal District, Sodré et al. [23] quantified caffeine and the antihypertensive drug atenolol in surface water samples from Lake Paraná and from two sources in the central region of Brazil. In Mato Grosso do Sul, Américo et al. [24] detected the presence of the anti-inflammatory piroxicam and the antihypertensive atenolol in the Arroio da Onça stream, in the city of Três Lagoas. In southern Brazil, a research group carried out studies in the water sources of the municipalities of Rio Grande and Morro Redondo, quantifying haloperidol, methylparaben and nimesulide [13, 14, 25]. Similar research carried out in Brazil, with samples of marine sediments, sewage treatment plant effluent and water treatment sludge, can also be found [26-29].

More specifically in the state of Paraná, studies are even more scarce. However, some studies have demonstrated the presence of female sex hormones, caffeine, acetylsalicylic acid, diclofenac, paracetamol, ibuprofen, methylparaben, and triclosan in the metropolitan region of Curitiba [11, 12, 30-32]. In the reservoir of Lake Itaipu, in the western region of the state, nimesulide was quantified in a study by Miranda and collaborators [33]. Meanwhile in the southwest region of the state, where the present research was conducted, only one study has investigated PPCPs in the environment, to date. Koerich determined the presence of 10 different PPCPs in surface water samples from the Lontra River in the municipality of Salto do Lontra [34]. In the study of Koerich [34], it can be observed that these compounds are inserted in the environment even in less populated regions (municipalities with about fifteen thousand inhabitants), showing that the contamination with PPCPs is not only related to population density, but also to precarious conditions of basic sanitation.

Therefore, the objective of this study was to monitor 18 PPCPs in springs of the southwestern region of Paraná by monitoring the rivers of the cities of Ampére, Santa Izabel do Oeste and Planalto.

Methods

Sampling

For the accomplishment of the samplings, a partnership was made between the Departments of Agriculture and Environment of the municipalities of Ampére, Santa Izabel do Oeste and Planalto, responsible for collecting the samples of the springs located in these municipalities, after training by researchers.

Two samples were collected from each spring in two distinct points, by sampling, before the point of capture by the Water Treatment Station of these municipalities. In Ampere, the points were identified as point A1 (25°54'11.58"S; 53°25'19.51"W) and A2 (25°50'6.55"S; 53°29'19.43"W). In Santa Izabel do Oeste the points were S1 (25°52'35.48"S; 53°25'11.06"W) and S2 (25°52'37.99"S; 53°30'4.79"W) and finally in Planalto, where the points were P1 (25°41'3.99"S; 53°44'54.73"W) and P2 (25°46'11.20"S; 53°42'28.93"W).

About 1L of surface water was collected at each collection point, stored in amber glass bottles and cooled during transportation to the where the samples were prepared by Solid Phase Extraction (SPE).

Four sampling campaigns were carried out in November 2015 (sampling 1, AM 1), April (sampling 2, AM 2) and November 2016 (sampling 3, AM 3) and February 2017 (sampling 4, AM 4) totaling 20 samples. The Ampére municipality participated only in the first two campaigns.

Sample Preparation

The sample preparation procedure was performed using the method proposed by Caldas et al. (2013) [13]. Initially, the samples were filtered in 0.45 μm cellulose acetate filters to remove any solid residues present, with the aid of a filtration system and a vacuum pump.

The SPE process followed the filtration, with two 250 mL aliquots of each sample being separated, one was acidified to pH 3 with PA phosphoric acid. The acidification process of one of the aliquots is necessary for better retention of the analyte because some of these are more stable in acid medium than others and thus, these compounds can be quantified in the medium of greater stability. C18 cartridges (Strata®) were used for extraction. These were then conditioned with 3 mL of methanol, 3 mL of ultrapure water and 3 mL of ultrapure water at pH 3.0 for the acidified samples. For non-acidified samples, the cartridge was conditioned with 6 mL of methanol and 6 mL of ultrapure water.

After conditioning the cartridge, the samples were percolated through the SPE cartridge with the aid of a vacuum pump. Each cartridge was identified, packed with aluminum paper and frozen for further elution. The samples were then eluted with 1 mL of methanol (0.5 + 0.5 mL) for chromatographic determination.

Chromatographic Determination

Following the method proposed by Caldas et al. 2013 [13]. The equipment used was an Waters Alliance 2695 Separations liquid chromatograph module, equipped with a degassing system, quaternary pump, automatic sampler, mass separator, Waters Micromass® Quatro Micro API™, API source, Eletrospray ionization mode and data acquisition system via Waters Masslynx 4.0 software.

A Phenomenex analytical column was used in the chromatographic separation with C18 adsorbent material (50 mm d.i. 3.0 mm). The components of the mobile phase were (A) ultra-pure water with 0.1% acetic acid and (B) methanol, eluting in the gradient mode. The initial composition was 20% B, which increased linearly to 90% in 20 min, held up to 23 min and then returned to the initial composition (20% B) in 0.5 min and held for 6.5 min, totaling a 30 min analysis. The injection volume was 10 μL .

Method validation

The method proposed by Caldas et al. (2013) comprises 18 compounds of the PPCP class, listed below with their respective quantification limits (LOQ), in $\mu\text{g L}^{-1}$: atenolol (0.04), avobenzone (0.04), benzophenone (0.04), caffeine (0.04), carbamazepine (0.004), chlorpropamide (0.04), diclofenac sodium (0.008), Eusolex® 6300 (0.04), gemfibrozil (0.008), furosemide (0.04), glibenclamide (0.04), mebendazole (0.008), methylparaben (0.008), nimesulide (0.004), miconazole nitrate (0.008), propylparaben (0.008), triclocarban (0.0008) and triclosan (0.04). Among them are compounds used in the formulation of drugs, stimulants, antiseptics, sunscreens and preservatives. The recoveries obtained for the above-mentioned compounds were 49 to 128% in a concentration range of 4 ng L^{-1} to 400 ng L^{-1} , with relative standard deviation (RSD) values of less than 20% for all compounds, which demonstrates that the method is suitable for determining the PPCPs, with the accuracy and precision required for this purpose.

Results

The compounds detected and quantified above the limit of quantification (LOQ) of the method are shown in Table I, II and III. Of the 18 compounds analyzed, 7 were found above the LOQ in the three springs under study. It was observed that the concentrations varied during the samplings, this can be explained due to the different seasons of the year in which the collection was carried out, the degradability of the compound in nature or the persistence of the same in the environment.

From the spring in Ampère, three compounds were quantified in the two samplings: atenolol, methylparaben and triclocarban. Six compounds were quantified from Santa Izabel do Oeste: atenolol, Eusolex® 6300, furosemide, methylparaben, nimesulide and triclocarban and small concentrations of Eusolex® 6300, nimesulide and miconazole nitrate were found in the four samplings carried out in Planalto.

Table I: PPCPs quantified from a spring in Ampère in $\mu\text{g L}^{-1}$.

Compound	Ampère			
	AM 1 (nov/15)		AM 2 (apr/16)	
	A1	A2	A1	A2
Atenolol	<LOQ	0.045	<LOQ	<LOQ
Avobenzone	<LOQ	<LOQ	<LOQ	<LOQ
Benzophenone	<LOQ	—	—	—
Caffeine	—	—	<LOQ	<LOQ
Carbamazepine	—	—	—	—
Chlorpropamide	<LOQ	<LOQ	—	—
Diclofenac sodium	—	—	<LOQ	—
Eusolex® 6300 *	<LOQ	<LOQ	—	—
Gemfibrozil	<LOQ	—	—	—
Furosemide	<LOQ	<LOQ	<LOQ	—
Glibenclamide	—	—	—	—
Mebendazole	—	<LOQ	<LOQ	—
Methylparaben	0.011	<LOQ	<LOQ	<LOQ
Nimesulide	—	—	—	—
Miconazole nitrate	<LOQ	<LOQ	<LOQ	—
Propylparaben	—	<LOQ	—	—
Triclocarban	0.001	—	—	—
Triclosan	—	<LOQ	—	—

<LOQ: less than the limit of quantification of the method. * methylbenzylidene camphor

Table II: PPCPs quantified from a spring in Santa Izabel do Oeste in $\mu\text{g L}^{-1}$.

Compound	Santa Izabel do Oeste							
	AM 1 (nov/15)		AM 2 (apr/16)		AM 3 (nov/16)		AM 4 (fev/17)	
	S1	S2	S1	S2	S1	S2	S1	S2
Atenolol	<LOQ	<LOQ	0.041	0.088	—	—	—	—
Avobenzone	<LOQ	—	<LOQ	—	—	<LOQ	—	—
Benzophenone	<LOQ	<LOQ	—	—	—	—	—	—
Caffeine	—	—	—	—	—	—	—	—
Carbamazepine	—	—	—	<LOQ	—	—	—	—
Chlorpropamide	<LOQ	—	<LOQ	—	—	<LOQ	<LOQ	—
Diclofenac sodium	—	—	<LOQ	—	—	—	—	—
Eusolex® 6300*(*)	0.067	0.059	—	—	—	<LOQ	—	—
Gemfibrozil	—	—	—	<LOQ	—	—	—	—
Furosemide	—	<LOQ	—	—	—	<LOQ	0.612	<LOQ
Glibenclamide	—	—	—	<LOQ	—	—	—	—
Mebendazole	—	<LOQ	—	—	—	—	—	—
Methylparaben	—	0.009	—	<LOQ	—	—	<LOQ	—
Nimesulide	—	—	—	—	<LOQ	0.006	<LOQ	<LOQ
Miconazole nitrate	—	—	—	—	—	—	—	—
Propylparaben	<LOQ	<LOQ	—	—	—	—	<LOQ	—
Triclocarban	—	—	<LOQ	<LOQ	0.018	—	—	—
Triclosan	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	—	<LOQ

<LOQ: less than the limit of quantification of the method. *methylbenzylidene camphor

According to the data presented, it can be observed that the municipality that has the highest frequency of contamination by PPCPs is Santa Izabel do Oeste because it presents six distinct compounds quantified in four samplings, compared to Planalto with only three compounds quantified in the same number of samplings. It was also observed that most of the quantified compounds are freely available to the population, mainly for the treatment of hypertension, as is the case of atenolol and furosemide.

Table III: PPCPs quantified from the spring in Planalto in $\mu\text{g L}^{-1}$.

Compound	Planalto							
	AM 1 (nov/15)		AM 2 (apr/16)		AM 3 (nov/16)		AM 4 (feb/17)	
	P1	P2	P1	P2	P1	P2	P1	P2
Atenolol	<LOQ	<LOQ	<LOQ	<LOQ	—	—	—	—
Avobenzone	—	—	<LOQ	<LOQ	<LOQ	—	<LOQ	—
Benzophenone	—	—	<LOQ	—	—	—	—	—
Caffeine	—	—	—	—	—	—	—	—
Carbamazepine	—	—	—	—	—	—	—	—
Chlorpropamide	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	—	—	—
Diclofenac sodium	—	—	<LOQ	<LOQ	—	—	<LOQ	—
Eusolex® 6300*	<LOQ	0.043	—	0.049	—	<LOQ	—	<LOQ
Gemfibrozil	—	—	—	—	—	—	—	—
Furosemide	—	<LOQ	—	—	—	<LOQ	<LOQ	—
Glibenclamide	—	—	—	<LOQ	<LOQ	—	—	—
Mebendazole	—	—	<LOQ	<LOQ	—	—	—	—
Methylparaben	—	—	<LOQ	—	<LOQ	—	<LOQ	—
Nimesulide	—	—	—	—	0.006	<LOQ	—	—
Miconazole nitrate	—	<LOQ	<LOQ	0.072	—	—	—	—
Propylparaben	—	<LOQ	—	<LOQ	—	—	—	—
Triclocarban	—	—	—	<LOQ	—	—	—	—
Triclosan	<LOQ	<LOQ	<LOQ	—	—	<LOQ	—	—

<LOQ: less than the limit of quantification of the method. *methylbenzylidene camphor

Discussion

Freely available in Brazil through the Popular Pharmacy Program for the treatment of cardiovascular diseases and control of arterial hypertension [23], atenolol belongs to the betablockers class of medication. It was quantified at concentrations of $0.045 \mu\text{g L}^{-1}$ at point A2 (AM 2) and at points S1 and S2 (AM 2), at concentrations of 0.041 and $0.088 \mu\text{g L}^{-1}$.

In the Rio de la Plata located in Argentina [35], average levels of atenolol of $0.800 \mu\text{g L}^{-1}$ were found. In China, atenolol was found in approximately 20% of 31 samples collected in 17 cities including large population centers, such as Beijing and Shanghai[17].

In Brazil, in a study carried out in Lago Paranoá (DF) [23], atenolol was detected in concentrations varying between 0.005 and $0.090 \mu\text{g L}^{-1}$, while in Ribeirão Pirai in São Paulo, a study indicated levels between 0.016 and $0.032 \mu\text{g L}^{-1}$ [21]. All the studies cited have values similar to those found in the present study, but the difference in population of the sites investigated should be noted, as they range from large centers to mainly agricultural municipalities.

Eusolex® 6300 (4-methylbenzylidene camphor) is widely used in the formulation of ultraviolet sunscreens and is among the sunscreens with the highest estrogenic activity in aquatic and terrestrial organisms [36]. Endocrine disruptors responsible for estrogenic activity may block the sites of cell receptors or increase the production/secretion of hormones and therefore interfere with the reproductive system of living beings [37].

Of the 20 samples analyzed, Eusolex® 6300 was detected in 4 samples at levels of 0.043 to 0.067 $\mu\text{g L}^{-1}$, thus being the most quantified compound among the 18 PPCPs included in the method used. In a similar study, Díaz-Cruz and collaborators report the first evidence of Eusolex® 6300 in tap water in Europe [36], carried out on water samples in the city of Barcelona and its environs, with 0.035 $\mu\text{g L}^{-1}$ being the highest concentration of the compound detected in the analysis. Compared with the values found in this study, the detected concentrations are above those found by the Spanish researchers.

Studies with a toxicological focus such as Klann et al. [38], were carried out to study the effects caused by 4-methylbenzylidene camphor (4MBC) on amphibians and found that it may be a potentially harmful substance for aquatic animals when present in micromolar concentrations, which is the case of the present study. Moreover, in a study developed by Paredes and collaborators [39], with marine organisms of several tropical levels with continuous exposure and with different concentrations of four UV filters, among them 4MBC, demonstrated that it has a potential risk to the environment and consequently (EC_{50} above 171.45 $\mu\text{g L}^{-1}$ for the organisms under study), since the authors also quantified these compounds in seawater samples on beaches in the Iberian Peninsula region used by tourists.

However, for chronic adverse effects to be observed, higher concentrations and periodicity of the compound in the environment are necessary, besides the influence of the numerous variables of the environment in which it is inserted, such as seasons of the year, rainfall, among others. Therefore, part of this contamination can be explained by the use of springs in hot seasons for recreation, where bathers end up introducing the Eusolex® 6300 from the sunscreens they use to protect the skin against ultraviolet rays, quite intense in the months in which the samplings were made. Although this compound has proven harmful effects for aquatic animals, in Brazil there is no restriction of its use in sunscreens. However, in Denmark its use is not indicated in children, because it is identified as one of the sunscreens with the highest estrogenic activity [36].

Furosemide corresponds to the pharmaceutical 5-(aminosulfonyl)-4-chloro-2-([2-furanylmethyl]amino)benzoic acid, widely prescribed for the treatment of hypertension and distributed free in the state of Paraná [40]. In a bibliographic search, no studies were found on the detection of furosemide in surface water samples. However, Osawa and collaborators [31], investigated the presence of antihypertensive drugs in the Alto Iguaçu basin in the metropolitan region of Curitiba (PR) and quantified compounds such as metoprolol, propranolol and nadolol in the samples analyzed. Of these three compounds mentioned, metoprolol and propranolol are also drugs distributed free in the state health posts.

In the present study, furosemide was quantified in only one sample in the municipality of Santa Izabel do Oeste. However, furosemide has physicochemical properties such as light instability and acid hydrolysis, which may explain the fact that the drug has been quantified in only one sample, that is, it must have been inserted in the medium shortly before the collection of the sample [41].

Methylparaben is the common name given to the methyl 4-hydroxybenzoate compound, a constituent substance of the paraben class used as preservatives in pharmaceuticals, personal care products, food and beverages. Methylparaben acts as an antimicrobial and antifungal agent, which increases the shelf life of products, preventing the appearance of mold, bacteria growth, yeast and deterioration of such goods [42].

In Brazil and the European Union, parabens used in cosmetics are limited to a maximum concentration of 0.4% when used alone or 0.8% when used as a blend. Studies have reported the discovery of parabens in tissues withdrawn from patients with breast cancer, and the possibility of parabens having estrogenic action has been discussed [43, 44]. In relation to the degradation of parabens in domestic sewage, it can be associated to the chain length, which in the case of methylparaben reaches up to 99% of degradation with 2.1 days [32], that is, the methylparaben quantified in the present work may relate to a recent contribution.

Carmona et al. [45] detected methylparaben in samples from surface waters of the River Turia Basin, in Valencia, Spain, at a mean concentration of 0.119 $\mu\text{g L}^{-1}$. In a survey conducted in a rural region in southern China by Zhang et al. [46], methylparaben was detected in mean concentrations of 0.009 $\mu\text{g L}^{-1}$ in surface water samples that did not have domestic wastewater treatment facilities.

In Brazil, methylparaben was found in surface water samples in a study carried out by Caldas et al. [13] at the water treatment plant of the municipality of Morro Redondo in Rio Grande do Sul, where the compound was detected in all samples, but in concentrations lower than the LOQ ($0.008 \mu\text{g L}^{-1}$) of the method used in the present work. In the state of Paraná, methylparaben was quantified in the Lontra River in the municipality of Salto do Lontra, in concentrations ranging from 0.026 to $0.368 \mu\text{g L}^{-1}$, in a study carried out by Koerich [34].

Comparing the studies cited and the results found in this work, methylparaben is present in lower average concentrations, suggesting that the easy degradation of the compound in the aquatic environment could be responsible for the low concentrations, since it is continuously inserted in water matrices, for being present in a variety of products, such as cosmetics and personal care products.

Nimesulide is the common name given to the N-(4-nitro-2-phenoxyphenyl) methanesulfonamide compound used as a nonsteroidal drug, as it has analgesic, anti-inflammatory and antipyretic properties. This compound has been widely used in the treatment of inflammatory and painful conditions [47].

In a study carried out by Silveira et al. [14], nimesulide was one of the compounds found in surface water samples from the city of Rio Grande (RS), presenting a concentration of $0.050 \mu\text{g L}^{-1}$. In the state of Paraná, Miranda et al. [33] quantified the pharmaceutical in the reservoir of Lake Itaipu at concentration levels between 101.7 and $385.0 \mu\text{g L}^{-1}$.

In the present study, the compound was quantified in two samples, both with higher concentrations than those found in the literature, and may indicate the high consumption of this drug by the population of Santa Izabel do Oeste and Planalto, cities where nimesulide was quantified, since it is a common prescription for the treatment of inflammation and moderate infections.

Miconazole is the common name given to the compound 1-[2-(2,4-dichlorobenzyloxy)-2-(2,4-dichlorophenyl)ethyl]-1H-imidazole and used in the form of nitrate as a pharmaceutical for the treatment of vulvovaginal infections and infections caused by *Candida* and superficial fungal infections of skin and appendages caused by dermatophytes and yeasts. It is also one of the medications present in the list of those distributed free of charge by the state government of Paraná [40].

Miconazole nitrate is slightly soluble in water and its bioavailability after topical application is less than 1%, its systemic absorption is quite limited, that is, it is released in domestic sewage and consequently in aquatic matrices in its unchanged form in a very large percentage. In this study, miconazole nitrate was quantified in only one sample in the city of Planalto, with a concentration of $0.072 \mu\text{g L}^{-1}$.

In Canada, a study conducted by the Canadian Council of Environment Ministers for the management of biosolids (treated sludge derived from effluent treatment plants, suitable for land application) reported the presence of miconazole in all 31 samples analyzed, that is, an occurrence of 100%, with a mean concentration of 441 ng g^{-1} . This result can be associated to the fact that the compound is slightly soluble in water, but with intense interaction with the organic matter, thus being retained in this medium [48].

Triclocarban, chemically known as 1-(4-chlorophenyl)-3-(3, 4-dichlorophenyl) urea, is widely used as an antimicrobial agent in personal care products such as bar and liquid soaps, deodorants, shampoos, among others. In recent years, it has been known to interfere with mammalian reproduction and may cause methemoglobinemia in humans and is also bioaccumulative in aquatic species [49].

It has been extensively investigated, as triclosan, which has already been banned in some countries, such as the United States, since its inefficacy with respect to its antimicrobial activity has been proven and because it has been shown to be responsible for resistance to antibiotics used in human medicine [49, 50]. In the study conducted by Koerich [29], triclocarban was quantified in water samples from the Lontra River in Salto do Lontra (PR) at concentrations ranging from 0.040 to $0.191 \mu\text{g L}^{-1}$, and this is the only study published to date, investigating the compound in surface waters in the state of Paraná.

Caldas and collaborators [51] proposed an analytical method for quantification of PPCPs in water samples, with triclocarban being one of the compounds studied in the city of Rio Grande (RS). Values below the LOQ of the proposed method were found.

From the present study, in which the compound was quantified in two samples at concentrations of 0.001 and $0.018 \mu\text{g L}^{-1}$, it can be noted that these concentrations are below what was described by

Koerich [29], which can be explained by sampling sites. Contrary to the present study, which took place in less populated and more agricultural areas, Koerich's study [29] was carried out in areas with higher population indexes, where the consumption of personal hygiene products is higher.

Conclusions

A pioneering study in the southwestern region of Paraná is presented here, and although most of the compounds analyzed are below the limit of quantification, it serves as an overview of the presence of PPCPs in the surface waters of this region and as an incentive for studies like these can continue and reach fields of study still unexplored.

The authors hope that the study of water and sewage treatments that can efficiently remove these compounds from water should also be encouraged. In addition, a reformulation in the Brazilian legislation to include the maximum levels of PPCPs in the aquatic matrixes is necessary.

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