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Emerging Contaminants in Trans-American Waters

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ABSTRACT

Industrial development has made new products available to people to make their lives easier. Items such as food, cleaning, personal care and health products, among others, are processed, sold and consumed daily by all age groups. These products include in their formulation inorganic and organic chemicals with the purpose of improving or increasing some of their properties, making them more attractive to the consumer. These substances are strictly controlled during production so that the final product may be safely consumed. In most cases, the constituents of commercial products end up in wastewater, where they are not controlled. These uncontrolled pollutants of differing chemical natures are known as "Emerging Contaminants" (ECs). Research worldwide has found ECs in various environmental matrices, especially water. To understand this problem, four fundamental aspects must be addressed: 1) the analytical methods for its determination; 2) the occurrence in environmental matrices; 3) the treatments for the removal of ECs in wastewater and drinking water plants; and 4) the risks to health and the environment. This document reviews these four aspects with regard to 14 ECs commonly found in the studies around the world and addresses the state of these ECs in trans-American waters.

Keywords: America, analytical chemistry, drinking water, environmental risks, health risks, sewage water.

Contaminantes Emergentes em Rios Transamericanos

RESUMO

O desenvolvimento industrial gerou novos produtos para facilitar a vida das pessoas. Itens

como alimentos, higiene, cuidados pessoais e produtos de saúde, entre outros, são processados, vendidos e consumidos diariamente por todas as faixas etárias. Esses produtos incluem em sua formulação produtos químicos orgânicos e inorgânicos com o objetivo de melhorar ou aumentar algumas de suas propriedades, tornando-os mais atraentes para o consumidor. Essas substâncias são rigorosamente controladas durante a produção para que o produto final possa ser consumido com segurança. Na maioria dos casos, os constituintes dos produtos comerciais acabam em águas residuais onde não são controlados. Esses poluentes não controlados, de diferentes naturezas químicas, são conhecidos como "Contaminantes Emergentes" (CEs). Pesquisas em todo o mundo encontraram CEs em várias matrizes ambientais, especialmente na água. Para entender esse problema quatro aspectos fundamentais devem ser abordados: 1) os métodos analíticos para sua determinação; 2) a ocorrência em matrizes ambientais; 3) os tratamentos para a remoção de CEs em estações de tratamento de águas residuais e de água potável; e 4) os riscos para a saúde e o meio ambiente. Este documento analisa esses quatro aspectos em relação aos 14 CEs comumente encontrados em estudos internacionais que abordam a situação desses CEs em águas transamericanas.

Palavras-chave: água de esgoto, água potável, América, química analítica, riscos ambientais, riscos para saúde.

1. INTRODUCTION

Human population increase has inevitably entailed the greater production of wastewater. New pollutants are frequently found in these waters due to the synthesis or use of new chemicals in legal or illegal products. These pollutants are part of the so-called “Emerging Contaminants” (ECs) that stand out for their diversity and generally complex chemical composition. “ECs” is a term that covers a wide range of chemical products, which are mainly of anthropogenic origin and are not included in monitoring studies (Tran *et al.*, 2018). Most of them are organic; but some authors have included inorganic nanoparticles as well. These substances can be grouped into drugs, personal care products, UV filters, hormones, illicit drugs, food additives, metabolites, flame retardants, pesticides, plastic additives, stimulants and nanoparticles, among others. Pharmaceutical compounds usually enter aquatic systems through wastewater after being ingested by humans and/or animals and excreted in the form of parent compounds or non-metabolized metabolites (Hilton and Thomas, 2003). In fact, it is estimated that up to 90% of oral drugs that pass through the human body end up in wastewater (WQA, 2019). Compounds that are part of commercial products, such as surfactants, are released through water used for house cleaning or in the rinse after bathing. Other sources of ECs are landfill leachate and agricultural runoff. The ECs present in treated and untreated wastewater of domestic, industrial and/or commercial origin are released into the environment. Figure 1 shows the origin and different transport routes of the ECs in the water.

It is therefore necessary to study the occurrence and risks of the ECs to include them if needed in water-quality monitoring programs and consider the redesign and/or update of technologies available for the treatment of wastewater and drinking water (Becerril Bravo, 2009). This task is not easy, because there are thousands of compounds with different physical and chemical properties that can be classified as ECs. According to the NORMAN network (2018), more than 1000 substances were identified in the European aquatic environment (NORMAN, 2018). To understand the problem of ECs, four aspects must be investigated: 1) Protocols and analytical methods to quantify and qualify the ECs; 2) Studies of the occurrence and persistence of ECs in different natural matrices; 3) Treatment of wastewater and drinking water for the removal of ECs; and, 4) Toxicity and risks to human health and the environment of the ECs individually and jointly.

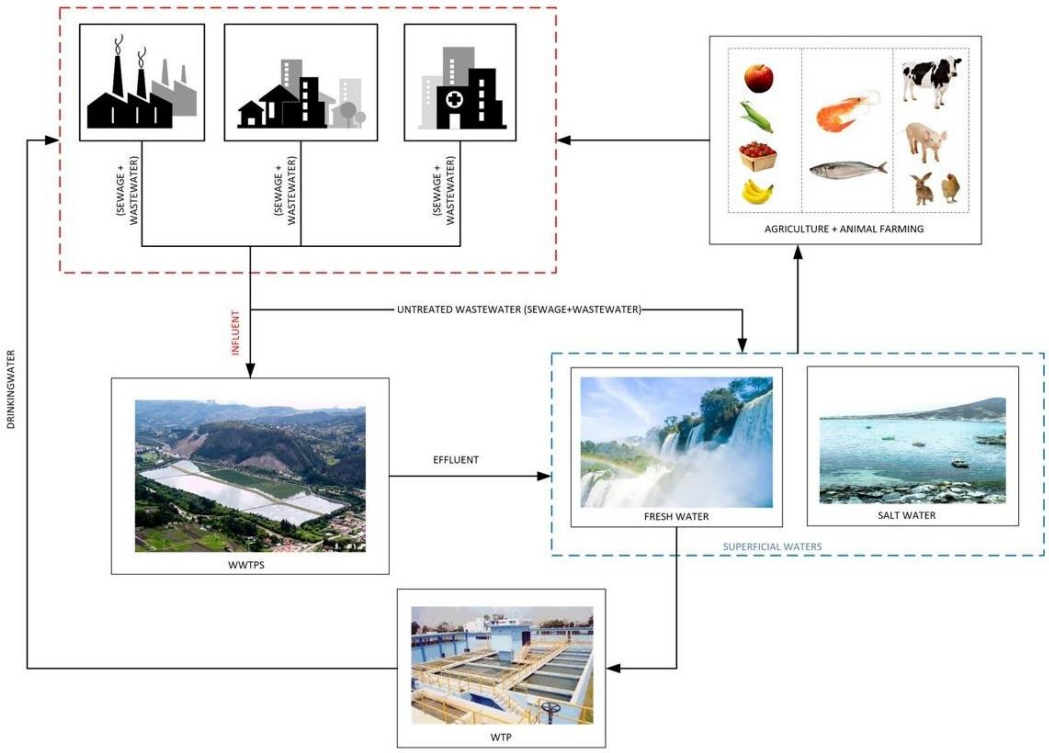


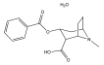
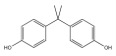
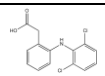
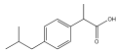
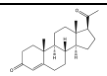
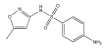
Figure 1. Description of the origin and transport of ECs in water.

This short review is oriented towards the search for information regarding ECs in aquatic environments located on the American continent, in order to identify progress made on the four aspects mentioned above. The ECs studied in the collected articles were identified and the 14 most-studied ECs were chosen (See Table 1. The American continent was chosen because it includes countries with different Human Development Indices (HDIs) (PNUD, 2016; 2018); while the United States and Canada enjoy high HDIs, and have robust systems for the control of water quality and sanitation as well as important infrastructure for research in analytical chemistry and engineering, among others, most of Latin America and the Caribbean lack policies for the care of water and/or wastewater treatment facilities, and in some cases, even for drinking water. In fact, it is considered one of the geographic areas most susceptible to higher levels of pollutants in aquatic biota (Llorca *et al.*, 2016).

2. ANALYTICAL METHODS FOR THE IDENTIFICATION AND QUANTIFICATION OF ECS

The number of publications found shows that the greatest effort made by the scientific community is in the development of analytical methods to identify and quantify the ECs in small concentrations and in different environmental matrices. Having such diverse physical-chemical properties, it is impossible to propose a technique capable of analyzing them all in a single procedure. Most of the analytical procedures that have been proposed are for organic ECs and generally involve three stages: 1) extraction, 2) separation, and 3) detection-quantification of the analyte. The most commonly-used extraction method is solid phase extraction (SPE), which in addition to extracting the analytes of interest allows large volumes of sample to be treated to concentrate the analytes under study (Fang *et al.*, 2012; Vidal-Dorsch *et al.*, 2012; Li *et al.*, 2013; Comtois-Marotte *et al.*, 2017). The phases typically used for the SPE are hydrophilic, lipophilic, water-wettable and based on a reverse phase sorbent that can operate over a wide pH range and can concentrate a wide range of compounds (Ferrer *et al.*, 2010; Ferrer and Thurman, 2012; Huerta *et al.*, 2016; Petrie *et al.*, 2016).

Table 1. Properties of the most-studied ECs in waters of the American continent.

ECs (CAS)	Description	Structure	Molar mass $gmol^{-1}$	Water solubility a 25ºC, mgL^{-1}	pKa a 25ºC	Log K_{ow}	PNEC ng/L^{-1}
Acetaminophen ACE, (103-90-2)	Analgesic		151.165	14000	9.38	0.46	1000
Atrazine* ATZ, (1912-24-9)	Herbicide		215.685	33	1.6	2.61	
Benzoylecgonine BZE, (519-09-5)	Cocaine metabolite		289.331		3.15 9.54	2.71	
Bisphenol A BPA, (80-05-7)	Additive for plastics		228.291	120-300	9.6	3.32	
Caffeine CAF, (58-08-2)	Stimulant		194.194	21600	14	-0,07	5200
Carbamazepine CBZ, (298-46-4)	Anticonvulsant		236.274	18	13.9	2.45	250
Cocaine COC, (50-36-2)	Illicit drug		303.358	1800 a 22ºC	8.61	2.3	
Diclofenac DCF, (15307-86-5)	Anti-inflammatory		296.147	2.37	4.15	4.51	1000
Estrone E1, (19973-76-3)	Estrogens		270.372	30	10.4	3.13	3
Ibuprofen IBU, (15687-27-1)	Anti-inflammatory		206.285	21	5.3	3.97	2300
Progesterone PRO, (200-350-6)	Progestogens		314.469	8.81		3.87	
Sulfamethoxazole SMX, (723-46-6)	Antibiotic		253.276	610 a 37ºC	0.25 1.97 6.16	0.89	10
Triclosan TCS, (3380-34-5)	Antibacterial Fungicide		289.536	10 a 20ºC	7.9	4.76	12
Trimethoprim TMP, (738-70-5)	Antibiotic		290.323	400	7.12 a 20ºC	0.91	16

Information taken from: PubChem (2019); Comtois-Marotte *et al.* (2017); Sodré *et al.*, (2018).
*regulated in some countries such as the United States and Canada.

The most-common SPE phase used is C18, which can be used to concentrate polar compounds (Fang *et al.*, 2012; Lonappan *et al.*, 2016). Another technique for concentrating ECs is liquid-liquid extraction (LLE), which is generally used to analyze ECs by gas chromatography (GC) (Vidal-Dorsch *et al.*, 2012, Filippe *et al.*, 2018). In general, solid phase extraction (SPE) and liquid phase extraction (LLE) have the disadvantage of consuming large amounts of toxic solvents. An alternative method to minimize the use of solvents is solid phase microextraction (SPME), which works under the principle of the SPE on a small scale through the use of fibers that are directly exposed to the sample and by which the analytes are extracted (Lopes *et al.*, 2017). For identification and quantification, chromatographic techniques coupled with mass spectroscopy are generally used (Vidal-Dorsch *et al.*, 2012; Li *et al.*, 2013; Comtois-Marotte *et al.*, 2017). Liquid chromatography (LC) is preferred to gas chromatography, since most ECs are polar and non-volatile; hence, for the use of GC in most cases, it would be necessary to perform a derivatization of the analyte. The LC detectors most commonly used to detect ECs are fluorescence (FLD), diode array (DAD), ultraviolet-visible (UV / VIS) and mass spectrometer (MS). Of these detection systems, mass spectrometry is the only technique that allows the identification of each analyte through its mass spectra. In addition, it allows the analysis of several analytes under the same instrumental conditions obtaining the lowest quantification limits in comparison with other analytical techniques (Berset *et al.*, 2010; Gosetti *et al.*, 2016; Sodré *et al.*, 2018).

A problem with most analytical methods used to analyze ECs is the so-called "matrix effect" (Alcaraz *et al.*, 2016). The matrix effect can lead to relatively significant negative or positive errors in the detected concentration of some compounds. For example, a study conducted in Canada, where the matrix effect in wastewater was determined, found differences in the concentrations of some compounds analyzed using the same method, finding higher concentrations of atrazine (herbicide) and lower concentrations of caffeine (stimulant), carbamazepine (anticonvulsant) and estrone (hormone) (Comtois-Marotte *et al.*, 2017). Therefore, the matrix effect must be determined in each analytical method for each analyte and matrix. Table 1 shows the physico-chemical properties of the 14 most-studied ECs in American waters. In Table 2, the analytical methods proposed for the continent are presented to determine the ECs in wastewater described in Table 1. Most of the methods were developed in the United States and Canada. The scarcity of these studies in Latin America could be due to the political disinterest in research and environmental care issues and the high cost of the equipment and supplies required (Peña-Guzmán *et al.*, 2019). According to Table 2, most of the methods used SPE to concentrate the organic compounds and liquid chromatography coupled to mass spectrometry (LC-MS) to separate and quantify the analytes. Most of the proposed methods are expensive, complex and consider only one group or class of ECs; few of the proposals consider the metabolites associated with each ECs. For example, most of the proposed methods for caffeine determination do not consider its metabolites, such as paraxanthine, theophylline or theobromine. A protocol for the determination of ECs should not only consider the physico-chemical properties of the target compounds and their metabolites, the interferences, the limits of detection/quantification and the effect of the matrix, but also the cost and ease of execution such that use in environmental monitoring is feasible.

High-diversity compounds, increased number of ECs, complex sample matrix and the need for very low quantification limits are just some of the analytical challenges to accomplish in the method development of ECs, although important advances have been made, such as hybrid highly sensitive mass analyzers, new material development for sample preparation or automatization of sample preparation instruments. The high number of ECs introduced to the environment and added to the variability of its chemical properties makes it difficult to establish a generic method capable of simultaneously identifying the ECs, their metabolites and transformation pathways once they enter the environment (Farré *et al.*, 2012).

3. OCCURRENCE OF EMERGING CONTAMINANTS IN SURFACE WATERS

Since most of these compounds are the result of anthropogenic activities, their presence in water depends to a large extent on their contact with treated- or untreated wastewater. On average, countries with high economic incomes treat about 70% of their municipal and industrial wastewater; this proportion drops to 38% in middle-income countries, to 28% in low-middle-income countries and to 8% in low-income countries such as Haiti (UNESCO, 2017). In the case of Latin America, only between 25 and 30% of wastewater receives some treatment; the rest is released directly into surface water (BID; CEPAL, 2018).

The study of the occurrence of ECs in surface waters helps us to know the effectiveness and need for wastewater treatment plants and the consumption habits of the population, as well as the possible risks to health and the ecosystem. For the study of the occurrence, seasonality should be considered, since it is related to the products consumed as well as to climatic events. For example, the evidence indicates that the presence of ECs is exacerbated in the dry period. In the rainy season, due to the dilution effect, the concentration of ECs decreases (Roberts *et al.*, 2016). Moreover, in summer or in sunny periods, the use of sunscreen products increases. In winter or in rainy seasons, the use of drugs and antibiotics to treat or relieve the symptoms of flu and colds increases.

An additional consideration when conducting studies on the occurrence of ECs is to propose an adequate sampling. In most of the studies reviewed, few sampling campaigns are carried out and few samples are collected. This is justified because in most studies natural matrices are used for the purpose of validating an analytical method and not for environmental monitoring (Ort *et al.*, 2010). The use of passive samplers such as Biofilms or Polar Organic Chemical Integrative Samplers (POCIS) are an option to carry out systematic monitoring studies in composite samples (Bayen *et al.*, 2014; Huerta *et al.*, 2016). These passive samplers can accumulate ECs of different characteristics for long periods; the main disadvantage of these systems is the difficulty involved in controlling the incoming flow to properly calculate the concentration of the ECs. Therefore, most of the information provided is qualitative; if quantitative results must be obtained, a mass/time relationship may be performed. In any case, for a study of the occurrence of ECs, a sampling plan should be designed considering spatial distribution, meteorology and climate of the location, type and frequency of sampling, and conservation and transport of the sample.

Table 3 shows the concentration ranges of the ECs in the rivers of American countries, described in Table 1. In most cases, the studies were conducted in Canada, the United States and Brazil. The table shows that the highest concentrations of ECs in the United States and Canada are found at the points of rivers where the effluents are released from WWTPs. The highest concentrations in the studies conducted in Latin America are at points where wastewater is released without treatment, and secondly, where it is released with treatment. The lack of wastewater treatment in Latin American countries partly explains the values shown in Table 3, which in some cases exceed by more than 1,000 times those found in Canada and the United States. Caffeine was the most-studied, prevalent and concentrated EC in the studies carried out in waters of Latin American rivers; this may be due not only to inadequate wastewater management, but also because countries such as Ecuador and Costa Rica are coffee producers.

Table 2. Summary of the analytical methods used to determine the ECs, Table 1, in wastewater: 2010-2018.

	Sampling		Methods				Affluent	Effluent	Ref
Compounds (Analyzed /found)	**Sampling site, WWTP**	**Campaigns (volume, sample type, number of WWTPs)**	**Extraction SPE (Cartridge, Solvent, STD) LLE (Solvent)**	**µg/L Max–Min, % occurrence**	**µg/L detected Max–Min, % occurrence**	**% Recovery/ LOQ ngL^{-1}/ matrix effect**	**µg/L Max–Min, % occurrence**	**µg/L Max–Min, % occurrence**	
(5/5) Diclofenac Ibuprofen Carbamazepine Caffeine	Argentina, Buenos Aires, Córdoba, La Plata, Pampas, Santa Fé, Not reported.	1 (-, simple, 6)	SPE (OASIS HBL, MeOH)	LC (Kinetex PFP o C18, $H_2O/NH_4CH_3CO_2$ /Formic acid + MeOH/AcN/$CH_3CO_2NH_4$, gradient)	ESI-MS	91.1-142.4/ 1-15/ -	- - - -	<0.03-1.2 0.4-13, 100 0.2-2.3 0.9-44.2, 100	1
(4/4) Sulfamethoxazole Trimethoprim	Bolivia, El Alto, Primary, 2 parallel bars to remove solids. Secondary: 2 series of lagoons with 6 lagoons each series.	2 (-, simple, 1)	SPE (OASIS HBL, MeOH/Acetic acid, ILS)	LC (Waters-Xterra-C18, H_2O/ Formic acid + H_2O/AcN, gradient, ILS)	ESI-MS	76-128/ 1.2-7.6/ MED	1.3 -	0.4-1.3 0.27-0.34	2
(3/3) Diclofenac	Brasil, Ceará, Primary; secondary, waste stabilization pond: 1 facultative and 2 maturation	- (0.5L, simple, 2)	SPE (DSC 18, Acetone / Hexane)	Potentiostat / Galvanostat		- / 49.5-146.3/ -	14.0-30.5, 100	-	3
(1/1) Diclofenac	Quebec/Canada, Primary and secondary Clarifier, treatment of UV disinfection.	1(-, simple, 1)	SPE (Sep-Pak-Plus-18, MeOH/AcN, ILS)	LDTD (BetaBasic-C18, H_2O/ Acetic acid + AcN/ Acetic acid, isocratic, ILS)	APCI-qQq/MS	98.2-104.6/ 1000/ -	71.6-58.2, 100	19.7-12.3,100	4
(20/31) Atrazine Bisphenol A Caffeine Carbamazepine Diclofenac Estrone Progesterone Sulfamethoxazole	Quebec/Canada, Not reported	20 (-, simple, 2)	SPE (Strata-X-C, ethyl acetate and MeOH /NH_4OH, ILS)	LC (Hypersil-GOLD-C18, H_2O/NH_4HCO_3, MeOH, gradient)	QqQ-MS/MS	43-122/ 0.5-104/ MED	- - - - - - - -	0.01-0.006 0.59-0.36 27.20-13.42 0.22-0.06 0.04-0.03 0.05-0.03 0.02-0.01 0.09-0.01	5

Continue...

Continued...

(35/56) Acetaminophen Atrazine Bisphenol A Carbamazepine Diclofenac Estrona Ibuprofen Progesterone Sulfamethoxazole Triclosan	California/EEUU, Primary: screening and sedimentation. Secondary: activated sludge and sedimentation or advanced primary.	4 (2L, simple, 4)	F1: SPE (OASIS HBL, MeOH + MeOH/MTBE, ILS) F2: SPE (OASIS HBL, CH_2Cl_2, ILS) F1': LLE (F1, NaCl, CH_2Cl_2/hexane, ILS) LLE (F1, F2, Isooctane, ILS)	LC GC (DB5-MS)	API, ESI-qQq/MS MS-MS	80-120/ 0.2-50/ MED	- - - - - - - - - -	11.00-ND, 44 0.02-ND, 63 1.60-0.21, 100 0.36-0.22, 100 0.18-0.07, 100 0.12-0.01, 100 12.00-ND, 94 0.05-ND, 63 2.04-0.48, 100 1.50-0.31, 100	6
(10/13) Caffeine Carbamazepine Ibuprofen Naproxen Sulfamethoxazole Triclosan	Illinois/EEUU, Primary: Screening bar. Waste stabilization pond Secondary: 2 aerated ponds and sand tank.	2 (2-4L, simple, 1)	SPE (OASIS HBL, MeOH + Acetone /MeOH OR ethyl acetate /MeOH + MeOH/H_2O, Acetic acid + MeOH/H_2O, NH_4OH and MeOH/NH_4OH, ILS)	LC (C18, H_2O/ NH_4OH /Acetic acid + AcN/MeOH OR H_2O/ NH_4OH + AcN/NH_4OH gradient)	ESI-qQq/MS	71-116/-/MED	57.70-51.30 0.067-0.047 26.20-18.60 38.80-19.40 3.80-0.93 5.44-4.65	0.49-ND 0.22-0.15 5.03-0.15 0.91-0.06 0.04-0.17 0.22-0.02	7
(5/5) Bisphenol A Ibuprofen Triclosan	México/México, Not reported	4 (1L, simple, 3)	SPME (Polyethylene Glycol fiber)	GC (column ZB-5, Silanization)	MS-Q	-/ 22-1232/ -	4.27-0.21, 92 2.83-0.23, 100 10.1-0.87, 100	0.41-0.02 0.34-0.02, 89 7.33-0.08, 100	8

Ref: 1. Elorriaga *et al.* (2013b); 2. Archundia *et al.* (2017); 3. Oliveira *et al.* (2015); 4. Lonappan *et al.* (2016); 5. Comtois-Marotte *et al.* (2017); 6. Vidal-Dorsch *et al.* (2012); 7. Li *et al.* (2013); 8. Peña-Álvarez and Castillo-Alanís (2015).

LOQ = limits of quantification; SPE = solid-phase extraction; LLE = liquid-liquid extraction; STD = internal and / or substitute standards; ILS = marked isotopic standards; LC = liquid chromatography; GC = gas chromatography; qQq (triple quadrupole); DAD = Diode array detector; UV - Vis UV detector; FSFD = fast scan fluorescence detector; MED = determined matrix effect; AcN = acetonitrile, MeOH = methanol.

Table 3. Minimum and maximum concentrations of the ECs of Table 1 in rivers of the American continent (ngL^{-1}).

País	Río	ACE	ATZ	BZE	BPA	CAF	CBZ	COC	DCF	E1	IBU	PRO	SMX	TCS	TMP	Ref
Argentina	Luján	-	-	-	-	2600	900	-	50	-	4600	-	-	-	-	1
	Tercero	-	-	-	-	1000	450	-	<5*	-	50	-	-	-	-	
Bolivia	El Seco	-	-	-	-	-	-	-	-	-	-	-	12 13	-	<4.5*	2
	Katari	-	-	-	-	-	-	-	-	-	-	-	<0.8* 18	-	<4.5* 135	
Brasil	Atabaia	<34* 13440	-	-	25 13016	90 127092	-	-	<14* 115	<16* 39	<51*	-	-	<700* 38	-	3
	Barigui													48 450		4
	Brillahante	-	<12.8* 171.3	-	<29.7* 48.7	<19.8* 50.3	-	-	-	-	-	-	-	<34.7*	-	5
	Capivari	-	-	127 522	-	700 42000	-	<6* 10		-	-	-	-	<700* 49	-	6
	Dourados	-	<12.8*	-	<29.7* 20.7	<19.8* 1040	-	-	-	-	-	-	-	<34.7* 8.6	-	5
	Monjolinho	-	-	-	-	<0.04* 129585	1.71 215.4	-	<0.04* 385.6	<0.1* 11.7	<2* 743.9	<0.08* 77.3	-	<0.8* 281.13	-	7
	Sousa	-	-	-	-	-	-	-	87.8 3224	<40*	-	-				8

Continue...

Continued...

Ecuador	Esmeraldas	-	-	2900 72100	-	<2* 16900	3700 19300	<1*	-	400 600	-	-	400 13000	-	-	9
	Guayllabamba	-	-	28500 427500	-	<2* 927400	26100 408000	200 277200	-	ND 2000	-	-	4600 81500	-	-	
	Machángara	-	-	81500 1109900	-	<2* 10674000	394400 1265600	302100 644900	-	900 21500	-	-	<1* 493900	-	-	
	Monjas	-	-	1065000	-	550000	670000	100000	-	-	-	-	250000	-	-	
	San-Pedro	-	-	<10* 58000	-	800 198000	<1* 100000	<1* 23900	-	ND 400	-	-	<1* 27000	-	-	
Canada	Lawrence	-	17 24	ND 10.1	39 81	ND 513	<20*	ND 4	1.0 3.0	-	-	1.2 2.6	1.33 1.47	-	-	10
Costa Rica	Corredores	<7*	-	-	-	<18* 104	<1*	-	<12* 43	-	<5*	-	<11*	<10* 20	<7*	11
	Java	<7*	-	-	-	1121446	<1*	-	<12*	-	<5*	-	<11*	12	<7*	
	Tarcóles	<7*	-	-	-	590	12	-	<12*	-	28	-	56	<10*	<7*	
	Térraba	<7* 3697	-	-	-	<18* -19	<1*	-	<12* 30	-	5 36788	-	<11*	<10*	<7*	
	Toyogres	13216	-	-	-	<498*	<3*	-	<15*	-	<984*	-	<14*	<91*	23	
USA	Hudson	<0.1* 327.7	-	-	-	22.2 2265.1	0.9 542.6	-	-	-	-	-	<0.32* 616.6	-	<0.35* 350	12
	South Platte	-	<10* 1250	-	<50* 923	<25* 3760	<10* 390		<10* 4830	<100* 165	-	-	<10* 727	<50* 872	<10* 633	13
	Zumbro	<13*	<390*	-	-	<4.1* 250	<0.11* 210	-	-	-	-	-	<* 2400	-	<2.8* 68	14

*<LOQ (Limit of quantification); References: 1. Elorriaga *et al.* (2013a); 2. Archundia *et al.* (2017); 3. Santos *et al.* (2016);4. Sodré *et al.* (2010); Montagner and Jardim (2011); Montagner *et al.* (2014); 5. Sposito *et al.* (2018); 6. Montagner and Jardim (2011); Campestrini and Jardim (2017); 7. Campanha *et al.* (2015); 8. Sousa *et al.* (2019); 9. Voloshenko-Rossin *et al.* (2014); 10. Comtois-Marotte *et al.* (2017); 11. Spongberg *et al.* (2011); 12. Cantwell *et al.* (2018); 13. Bai *et al.* (2018); 14. Fairbairn *et al.* (2016).

Table 3 shows the concentrations of the 14 ECs listed in Table 1 found in the rivers of the American continent. For example, in the Zumbro River Basin, Minnesota, United States, researchers found 16 of the 26 ECs that were evaluated; the most frequently found compounds were atrazine (97%) and caffeine (94%) (Fairbairn *et al.*, 2016). In the Hudson River, all 18 evaluated ECs were found; caffeine and carbamazepine were found in all the samples (Cantwell *et al.*, 2018). In a study of rivers of the Denver, Colorado metropolitan area, 151 of the 199 ECs studied and 39 of 72 analyzed pesticides were found; the most frequent compound in the 2014 and 2015 campaigns was sulfamethoxazole; In 2014, it was detected in 87.50% of the samples (Medium 119, Maximum: 727 ngL^{-1}), and in 2015, it was detected in 87.40% of the samples (Medium 90, Maximum: 772 ngL^{-1}) (Bai *et al.*, 2018). In the Lawrence River, Quebec, Canada, 15 of the 31 ECs studied were found; caffeine was the most prevalent compound (Mean: 208 ngL-1) (Comtois-Marotte *et al.*, 2017). Only one study was found in Central America, which was conducted in Costa Rica. In this study, 26 of the 34 target ECs were found; the most concentrated contaminant was caffeine (Maximum: 1.1 mgL^{-1}) (Spongberg *et al.*, 2011). A study conducted on five rivers of the Esmeraldas watershed, Ecuador, found 16 of the 18 ECs studied; the highest concentrations were found at points where untreated wastewater is released directly into the rivers; caffeine was the most-concentrated and frequent compound (100%) (Voloshenko-Rossin *et al.*, 2014). In a study of the Iguazú Basin in Brazil, triclosan was found in all samples of 7 rivers (Maximum: 0.415 μgL^{-1}) (Santos *et al.*, 2016). In the rivers of the Atibaia River Basin, located in the state of São Paulo, 10 of 15 target ECs were found; the highest concentrations were registered during the dry season, and caffeine was the most-prevalent compound (Mean: 10.29 μgL^{-1}, Maximum: 127 μgL^{-1}, 100%) (Montagner and Jardim, 2011). A study of six rivers in São Paulo, Brazil showed that triclosan was a ubiquitous pollutant; triclosan reached a maximum concentration of 66 ngL^{-1} and caffeine had a maximum concentration of 42 ngL^{-1} (Montagner *et al.*, 2014). In the Monjolinho River of São Carlos, 10 of the 11 studied ECs were detected; caffeine was detected in 93% of the samples and showed the highest concentration among the analyzed compounds (Mean: 14.95, Maximum: 129.58 μgL^{-1}) (Campanha *et al.*, 2015). In a study of 16 Brazilian rivers, cocaine was found above the quantification limit in 85% of the samples studied with concentrations between 6 to 62 ngL^{-1}; its metabolite, benzoylecgonine, was also found in 94% of the samples and with concentrations between 10 and 1019 ngL^{-1} (Campestrini and Jardim, 2017). A study of the surface waters of the Dourados and Brilhante Rivers in the state of Mato Grosso do Sul, Brazil, found 9 of the 21 ECs studied, with caffeine the most-concentrated (Maximum: 1040 μgL^{-1}) (Sposito *et al.*, 2018). In another study done in Brazil, 8 ECs were found in the Ave River and 13 in the Sousa River among the 17 ECs studied (Sousa *et al.*, 2019).

Studies were also carried out on lakes, where ECs have been found. In Lake Michigan in the United States, 17 ECs were found; the second most-prevalent compound was caffeine (Medium: 31 ngL^{-1}, Maximum 100 ngL^{-1}, 44%) (Ferguson *et al.*, 2013). In the Great Lakes, 32 ECs were found in the United States; anthrazine was the most-concentrated (85.2 μgL^{-1}) and 23 ECs were found on the Canadian side, with anthrazine being the second most-concentrated (3.6 μgL^{-1}), following nonylphenol (Hull *et al.*, 2015). In a study of the Titicaca River in Bolivia, sulfamethoxazole was found in a concentration between 11.5 and 26 ngL^{-1} (Archundia *et al.*, 2017).

Studies on sources of drinking water in the Americas have also detected the presence of ECs, although in most cases at very low concentrations. In a study conducted in the state of Sao Paulo, Brazil, 5 of 7 studied EC endocrine disruptors were found; Bisphenol A was the most-concentrated (maximum: 11.4 ngL^{-1}, 60%) (Jardim *et al.*, 2012). In a study in Arroio do Carvão, Morro Redondo, Brazil, 16 of the 51 target ECs were found (Caldas *et al.*, 2013). In a Brazilian study that included five reservoirs (Guarapiranga, Bellings, Cantareira and Vargem das Flores), Cuiabá Lake and the das Velhas River, sources of drinking water, 5 of the 17 ECs studied were

found; the most-concentrated were atrazine (Mean: 12.1, maximum value: 19 ngL^{-1}, 100%), and caffeine (Mean: 3.54 μgL^{-1}, Maximum: 18.83 μgL^{-1}, 100%) (Machado *et al.*, 2016). In a study conducted in Colombia, in the Río Grande and La Fe de Medellín reservoirs, 6 of the 9 ECs studied were found, among them ibuprofen (max 62 ngL^{-1}) (Aristizabal-Ciro *et al.*, 2017). Eleven of eighteen ECs studied were found in the Esmeraldas River, source of drinking water for the population of Esmeraldas in Ecuador; benzoylecgonine, a coca metabolite, was found with the highest concentration (Mean: 37.5 μgL^{-1}) (Voloshenko-Rossin *et al.*, 2014). In underground and surface water as well as tanks for obtaining drinking water from Mexico City, 11 of the 17 ECs studied were found; Bisphenol A was found in 63% of the samples (max 10 ngL^{-1}) (Félix-Cañedo *et al.*, 2013). In the United States, a study that included Puerto Rico found 63 of the 100 target ECs analyzed at 25 groundwater sources and 49 surface water sources; Bisphenol A was found among the most-concentrated (Maximum: 1.90 μgL^{-1}, 9.5%) (Focazio *et al.*, 2008). Another study carried out in the United States found 11 of the 51 ECs studied; the most-frequent compounds were atrazine (Maximum: 870 ngL^{-1}, Medium: 32 ngL^{-1}), carbamazepine (Maximum: 51 ngL^{-1}, Median: 4.1 ngL^{-1}) and sulfamethoxazole (Maximum: 110 ngL^{-1}, Median: 12 ngL^{-1}) (Benotti *et al.*, 2008). In the Karst Aquifer in Illinois, United States, 14 of 19 ECs studied were found; the most-concentrated was caffeine (Maximum: 39.2 ngL^{-1}) (Dodgen *et al.*, 2017). Another study found several ECs; the contaminants with the highest concentrations were caffeine (Maximum: 124; Minimum: 91 ngL^{-1}) and carbamazepine (Maximum: 269, Minimum: 36 ngL^{-1}) (Glassmeyer *et al.*, 2017). Another study found 11 of the 24 pharmaceutical compounds studied during the first phase of the study; carbamazepine was the most-prevalent compound (Maximum: 269 ngL^{-1}, 78%). During the second phase of this study, 47 of 118 pharmaceutical products studied were found; caffeine was the most-concentrated compound in both phases, 0.124 μgL^{-1} and 0.091 μgL^{-1}, respectively (Furlong *et al.*, 2017). In a study of lakes and rivers located in Ontario, Canada, sources of drinking water, 27 of the 48 analyzed ECs were found; carbamazepine was the most-prevalent compound (Median: 3 ngL^{-1}, Maximum: 749 ngL^{-1}, 50%) (Kleywegt *et al.*, 2011).

In studies of sea or ocean water, generally, lower concentrations of ECs are found in relation to those found in freshwater; this may be due to the dilution effect. In a study conducted in Brazil (Santos Bay), 4 of the 8 endocrine disruptors studied were found; one of the most-concentrated compounds was Bisphenol A (Maximum: 77.2 ngL^{-1}, 100%) (Lisboa *et al.*, 2013). In another study of Santos Bay, 9 of the 33 ECs studied were found; the ubiquitous compounds were caffeine (Mean: 272 ngL^{-1}, Maximum: 648.9 ngL^{-1}, 100%), ibuprofen (Maximum: 2094 ngL^{-1}, 100%) and cocaine (Maximum: 400.5 ngL^{-1}, 100%) (Pereira *et al.*, 2016). In a study carried out in Costa Rica, caffeine was one of the most-concentrated ECs (Spongberg *et al.*, 2011). In a study done in southern California, United States, 20 of the 56 ECs studied were found; triclosan (mean: 1.7 ngL^{-1}) was found in 40% and sulfamethoxazole (mean: 0.8 ngL^{-1}) in 70% of the samples (Vidal-Dorsch *et al.*, 2012). In a Washington estuary, 25 of 150 ECs studied were detected in concentrations below 5 $ngL^{-1,}$ which included Bisphenol A, carbamazepine, cocaine, sulfamethoxazole and triclosan (Meador *et al.*, 2016).

4. WASTEWATER (WWTP) AND DRINKING WATER PLANTS (DWTP) TO ELIMINATE ECS

As the population grows, there is an increase in water demand for agriculture, industrial production and human consumption, and a consequent increase in the production of wastewater. In Latin America and the Caribbean, the problem of drinking water and sanitation services has not been solved; only 65% of the population of the region has access to drinking water and 22% to sanitation (BID and CEPAL, 2018). Due to the increased demand for fresh water and its shortage, countries such as Chile are studying the possibility of using water from sewage treatment plants as a source of water for water treatment plants (Vera *et al.*, 2016). It is therefore

important to implement wastewater treatments where necessary, as well as to improve current facilities to consider the removal of ECs that represent a risk to health and the environment. Many of the ECs are not removed due to the fact that conventional water treatment plants were not designed to remove them. Although it is undoubtedly better to treat wastewater with conventional treatments than to not treat them.

Studies indicate that WWTPs are not effective systems for the elimination of most of the ECs, with the exception of the most biodegradable and/or hydrophobic compounds (Bolong *et al.*, 2009; Kermia *et al.*, 2016; Xiong *et al.*, 2018). For example, anticonvulsant, antidepressant and anxiolytic agents were found in the main discharge to rivers and sludge from 10 WWTP (González *et al.*, 2010). Conventional ternary treatments are also not adequate for eliminating many of the ECs (Cabeza *et al.*, 2012). Research indicates that only a small amount of the ECs studied were efficiently eliminated after tertiary treatments of ultrafiltration, reverse osmosis and UV disinfection (Teijon *et al.*, 2010). Advanced oxidation processes are an alternative, but have the disadvantage that they are specific for certain compounds, expensive and in many cases difficult to implement and may generate more toxic and recalcitrant compounds than the original ones (Pinos-Vélez *et al.*, 2018).

An important factor that influences the removal efficiency of the ECs is the ability of water contaminants to interact with solid particles, either natural (clay, sediment or microorganisms) or added to the environment as treatment additives (active carbon or coagulants). In general, those compounds with low adsorption coefficients tend to remain in the aqueous phase, which favors their mobility (Carballa *et al.*, 2004). Non-polar ECs show a strong tendency to sorption in sewage sludge, while polar ECs dissolve in water. Those compounds with good affinity with particulate matter can be eliminated by physical-chemical processes such as sedimentation or flotation, but also through biological-based water treatment processes (biodegradation). This mud is mixed with the soil and frequently used for agricultural purposes (Buchberger, 2011). Depending on their solubility, the ECs present in the sludge can enter the aquatic environment or remain adsorbed in solid particles (Fatta *et al.*, 2007). But most ECs are polar and remain soluble in water, where they are easily dispersed. Studies have determined that these ECs are easily transported through the permeable layers in the soil and can be found in groundwater (Fang *et al.*, 2012). For example, in Bolivia, sulfamethoxazole was detected in all groundwater samples (47.8-251.5 ngL^{-1}) and trimethoprim in 25% of the samples (108 - 200 ngL^{-1}) (Archundia *et al.*, 2017).

There is a scarcity of data available in the Americas on the occurrence of ECs in wastewater; there is not enough information to compare or evaluate the treatment processes. Regarding the efficiency of the removal of the ECs, a Canadian study on a WWTP that included UV disinfection found diclofenac in the affluent and effluent; the results show that around 19% diclofenac was eliminated in the first process with gravel and sand; from the rest, 34% was eliminated in the primary clarifier, 30% of the rest was eliminated in the second clarifier and the remaining 35% was removed in UV disinfection. In total, 75.5% of diclofenac was removed in this treatment (Lonappan *et al.*, 2016). In Table 2, the determined concentrations of ECs before and after wastewater treatment are presented. The evidence found in Table 2 suggests that traditional wastewater treatments are not effective for the removal of ECs.

Regarding potabilization, the evidence indicates that conventional water treatment systems cannot completely remove most of the ECs (Batt *et al.*, 2017). The effectiveness of drinking-water treatment plants (DWTPs) in reducing or degrading contaminants to safe concentrations for humans depends on several factors, such as the physical- and chemical properties of the compounds. Hydrophilic compounds show poor reactivity to oxidizing agents such as chlorine or ozone. One study found that chlorine treatment is useful for removing ECs such as estrone and trimethoprim, while ozone eliminates ECs such as estrone, trimethoprim, DEET and atenolol; neither chlorination nor ozone were able to eliminate compounds such as atrazine (Benotti *et al.*, 2008). In a study conducted in Campiñas, Brazil, 6 of 11 ECs were found in

drinking water; Caffeine and bisphenol A were detected in 100% of the samples, with average values of 220 ngL^{-1} and 216 ngL^{-1}, respectively (Sodré *et al.*, 2010). In a study done in Morro Redondo, Brazil, 14 of the 16 ECs studied were detected in drinking water samples; one of the most concentrated compounds was atrazine (Maximum: 92.3 ngL^{-1}) (Caldas *et al.*, 2013). Another study conducted at 6 DWTPs in the state of São Paulo found 6 UV filters (da Silva *et al., 2015*). A national survey conducted in Brazil found 4 of the 16 ECs in drinking water; the most frequent being atrazine (Medium: 6.5 ngL^{-1}, Maximum: 24 ngL^{-1}, 75%) and caffeine (Medium: 146 ngL^{-1}, Maximum: 2.77 μgL^{-1}, 93%) (Machado *et al.*, 2016). In a study carried out in São Paulo, Brazil, cocaine was found in all drinking water samples (Minimum-Maximum: 2-22 ngL^{-1}, 100%) as was its metabolite, benzoylecgonine (Maximum: 652, Minimum: 10 ngL^{-1}, 100%) (Campestrini and Jardim, 2017). In Ecuador, 10 of the 18 ECs studied were found in the drinking water of Esmeraldas, with carbamazepine as the most concentrated compound (Minimum-Maximum: 11.80 - 20.20 μgL^{-1}). The treatment consists of alum flocculation, sedimentation, and deep bed sand filtration (Voloshenko-Rossin *et al.*, 2014). In the United States, a national study on 19 DWTPs found 20 of the 51 ECs in the treated water and 15 in the distribution system; Atrazine was the most concentrated in water treated at plants (Maximum: 870, Minimum: 49 ngL^{-1}, 83%) and in the distribution network (Maximum: 930, Minimum: 50 ngL^{-1}, 80%). Some treatments used in 19 DWTPs included coagulation/flocculation, sedimentation, filtration with sand or activated carbon or biofiltration, oxidation and disinfection with chlorine (hypochlorite) or chloramine or chlorine dioxide, ozonation among others (Benotti *et al.*, 2008). In another national study on drinking water, 41 ECs were detected in 25 DWTP samples (Benson *et al.*, 2017). In another national study conducted in the United States on 29 DWTPs, ECs such as caffeine (Maximum: 88 ngL^{-1}) and carbamazepine (Maximum: 586 ngL^{-1}) were found in the first phase and carbamazepine (Maximum: 26.5 ngL^{-1}) in the second phase. Some treatments used included flocculation/coagulation, clarification, filtration with sand or powdered or granular activated carbon, sedimentation, disinfection with ozone or chloramine or chlorine or chlorine dioxide or ultraviolet radiation between others (Glassmeyer *et al.*, 2017). In a study that included 25 United States DWTPs, 6 of the 24 pharmaceutical products studied were found in the first phase of the study, where carbamazepine was the most concentrated (586 ngL^{-1}); in phase II, 37 of 118 investigated pharmaceutical products were found (Furlong *et al.*, 2017). In a study carried out in Ontario, Canada on 17 PWTPs, 27 of the 48 ECs analyzed were found in drinking water; Carbamazepine was the most frequently detected compound (Maximum: 601 ngL^{-1}, 25%). Some treatments used were filtration with sand, coal or activated carbon and disinfection with chloride sometimes with fluoridation or UV radiation (Kleywegt *et al.*, 2011).

5. RISKS TO HUMAN HEALTH AND THE ENVIRONMENT

Research has shown the occurrence of ECs in water and soil; therefore, they can be accumulated in animals and plants, and through these mediums reach human beings. The rate of transfer of ECs to water, plants and animals depends on the polarity of the pollutant and the characteristics of the environment. That is to say, the higher the lipid content in plants or animals, the higher the sorption rates of non-polar ECs. Thus, the transfer of ECs to plants depends on the lipid-water partition coefficient (Yang *et al.*, 2016). For example, sulfonamide-type antibiotics such as sulfamethoxazole are predominantly found in water, while quinolones such as ciprofloxacin are found mostly in sediments and in aquatic plants; however, quinolones and macrolides such as azithromycin are often found in aquatic animals and birds (Li *et al.*, 2012).

Given the impossibility of regulating all the ECs, studies on the risk of these compounds are necessary. The studies should not only consider each EC individually, but also in joint occurrence with other ECs. That means it is not only important to analyze the effects of individual substances, but also to study the possible synergistic effects of the mixture of substances (Sánchez-Murillo, 2016). A substance is controlled when a health risk is

demonstrated. For example, a substance such as atrazine is controlled once it has been shown to cause health problems. In this case, it causes problems in cardiovascular and reproductive systems; therefore, laws in the United States (0.003 mgL^{-1}) and Canada (0.005 mgL^{-1}) restrict their concentration in drinking water (USEPA, 2017; Canada, 2018).

One way to measure the risk of the ECs is through the concentration of a chemical product that marks the limit at which continual adverse effects of exposure in an ecosystem (PNEC) are not measured. A Brazilian study proposed PNEC values for ECs (See Table 1) (Sodré *et al.*, 2018). In studies carried out on rivers throughout the continent, some compounds were found in values higher than PNEC (see Figure 2). For example, higher values were found in ECs in rivers of Argentina: carbamazepine (4 PNEC) and caffeine (0.5 PNEC); in rivers of Bolivia: sulfamethoxazole (2 PNEC) and trimethoprim (8 PNEC); in rivers of Brazil: caffeine (25 PNEC), acetaminophen (13 PNEC), triclosan (23 PNEC), estrone (13 PNEC); in rivers of Ecuador: caffeine (2052 PNEC), carbamazepine (5063 PNEC) and sulfamethoxazole (49390 PNEC); in rivers of Costa Rica: acetaminophen (13 PNEC), caffeine (216 PNEC), sulfamethoxazole (6 PNEC) and in rivers of the United States: estrone (55 PNEC) and sulfamethoxazole (240 PNEC). It is observed that antibiotics and hormones have the lowest value of PNEC and therefore, represent higher risk.

Antibiotics and endocrine disruptors are of particular concern because the former is related to bacterial resistance and the latter can modify the biochemical pathways in the body. Antibiotics can induce bacterial resistance through continuous exposure, even in low concentrations (Hernández *et al.*, 2007). Endocrine disruptors can also interfere with the endocrine system and disrupt the physiological function of hormones by mimicking, blocking or disrupting the role of hormones that affect the health of human and animal species. Endocrine disruptors can also interfere with natural hormones even at low concentrations. Examples of endocrine disruptors are some pesticides, steroid hormones, plasticizers and pharmaceuticals (Becerril Bravo, 2009; Huerta-Fontela *et al.*, 2010; Aufartová *et al.*, 2011, Ramírez-Sánchez *et al.*, 2015; Huerta *et al.*, 2016). Different studies have found that endocrine disruptors can affect the reproductive systems, prostate, breast, lung, liver, thyroid, metabolism and cause obesity (Colborn *et al.*, 1993; Kabir *et al.*, 2015). Toxicological evidence indicates that endocrine disruptors may increase the risk of cancer, specifically breast cancer (Siddique *et al.*, 2016). Therefore, studies are needed to investigate how endocrine disrupting ECs affect human beings with an emphasis on child development during pregnancy or in childhood, in addition to its impact on wildlife (Kabir *et al.*, 2015; USEPA, 2017). Another effect of endocrine disruptors is the appearance of changes in the sexual characteristics of fish because the male reproductive tissues show morphological changes related to feminization. These changes have been found in freshwater fish around the world (Niemuth and Klaper, 2015).

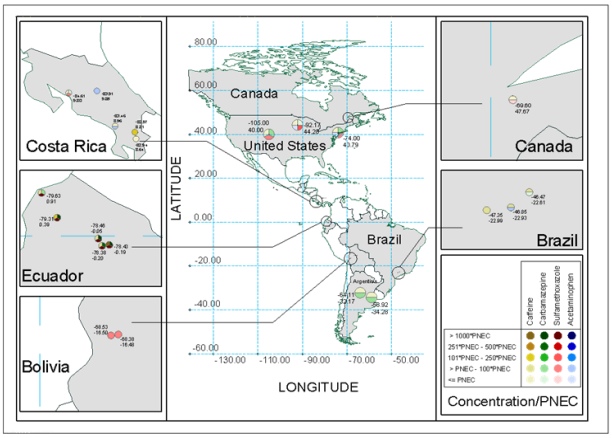


Figure 2. Concentration index / PNEC of ubiquitous ECs in the rivers of the American continent.

Although, the main route of exposure to endocrine disruptors for humans and animals is the intake through food and beverages (Bolong *et al.*, 2009), an important route of exposure is the environment. This occurs because some of these endocrine-disrupting ECs are found in water used for consumption and irrigation. Some ECs are sufficiently mobile to filter from the top of the soil into deeper layers where they can easily transfer to the plants by absorption. If these plants are used in food, they could cause food safety problems (Kinney *et al.*, 2006; Yang *et al.*, 2016).

Studies in food irrigated with water and/or cultivated in soil with ECs show that these have transferred to vegetables and fruits. For example, one study found 26 ECs including pesticides, pharmaceuticals, personal care products, estrogens, antioxidants and disinfection byproducts in irrigation waters; five of these contaminants were also found in watered fruits and vegetables, such as alfalfa and apples, in concentrations between 13.9 to 532 ng g^{-1} (Calderón-Preciado *et al.*, 2011). At the continental level, a study on the wastewater irrigation system of the Mezquital Valley in Mexico found 7 of the 11 ECs studied, such as diclofenac (120 - 160 ngL^{-1}) and ibuprofen (230 - 300 ngL^{-1}) (Siemens *et al.*, 2008). Another source of ECs for humans and animals is through the consumption of foods of animal origin. For example, research carried out in the United States found ECs in mussels collected in California where sixty-seven samples had at least one compound detected (Dodder *et al.*, 2014). Another study conducted in the United States also detected five antibiotics in shrimp, salmon, trout and tilapia purchased from a farm (Done and Halden, 2015). The presence of these antibiotics in those farms are due mostly to their direct incorporation as part of the process; nevertheless, studies in fish in naturals environments also show ECs. For example, a study found 42 ECs out of the 150 studied, including estrone and triclosan, in the tissue of wild species of whole-body juvenile Chinook Salmon (Oncorhynchus Tshawytscha) and Pacific Staghorn Sculpin (Leptocottus armatus), which lived near two effluents from WWTPs (Meador *et al.*, 2016). Very few studies regarding ECs in food were found, and none regarding the consequences to health for the intake of these foods. In one way or another, the ECs have become present in the environment; for example, a study in the United States found ECs in gull eggs and the Caspian Tern (Su *et al.*, 2017) Table 4.

Table 4. Main Risks of Emerging Contaminants.

Type of EC	Examples	Risk for humans	Risk for wildlife
Endocrine disruptors	Atrazine Bisphenol A, F y S Sulfamethoxazole Triclosan Estrone progesterone	Cancers: testicular, prostate, breast, cervix and vaginal Endometriosis Reduced sperm count and quality Decreased testosterone level Changes in thyroid hormone concentrations Obesity Embryonic and fetal death Malformations in the offspring: low birth weight, problems in development and operation of the central nervous system and reproductive system, cognitive behavioral dysfunctions, decreased intelligence, etc	sterility or loss of reproductive capacity Deaths deformations in reproductive organs decreased immune system
Antibiotics	Sulfamethoxazole Trimethoprim	Antibiotic resistant bacterial infection	Bacterial resistence

6. CONCLUSIONS

Emerging contaminants found in the waters of the American continent include a wide range of polar- and non-polar organic compounds. Given the impossibility of controlling all ECs, research is needed on their impacts on humans and the environment to determine which should be subject to control; special attention should be given to the adverse effects of antibiotics and endocrine disruptors. Some efforts have been made to develop methods to analyze ECs, but a standardized method is still needed, validated in environmental matrices with an emphasis on wastewater. Additionally, improving current water- and wastewater treatment technologies should be prioritized as a way to reduce the concentration of these pollutants and achieve to safe levels for consumption and environmental conservation. The implementation of wastewater treatment plants should be mandatory to avoid the incorporation of ECs in water sources for drinking water. This is of vital importance in Latin America, because in many cases there is no adequate management of wastewater, which often ends up being discharged into surface waters without treatment. As a consequence, developing countries are exposed to high concentrations of ECs putting the health of the population and the environment at risk. Finally, it is necessary to create awareness programs to promote the responsible consumption of products related to the ECs and reduce their concentration from the source. In this sense, updated legislation is also needed to regulate the use of raw materials as potential ECs.

7. ACKNOWLEDGMENTS

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