Brazilian Journal of Development

Micropollutants management in urban hydrographic basins: the Belém River case, Curitiba, Paraná

Gestão de micropoluentes em bacias hidrográficas urbanas: o caso do Rio Belém, Curitiba, Paraná

DOI:10.34117/bjdv6n3-256

Recebimento dos originais: 05/02/2020
Aceitação para publicação: 17/03/2020

Demian da Silveira Barcellos
Engenheiro Ambiental pela Pontifícia Universidade Católica do Paraná em 2014, mestre em Gestão Urbana (Gestão e Tecnologias Ambientais) pela Pontifícia Universidade Católica do Paraná em 2018, doutorando pelo mesmo programa.
Endereço:R. Imaculada Conceição, 1155 - Prado Velho, Curitiba - PR, 80215-901
E-mail: demian.barcellos@gmail.com

Harry Alberto Bollmann
Engenheiro Civil pela Pontifícia Universidade Católica do Paraná em 1983, Mestre em Engenharia Hidráulica e Saneamento pela Escola de Engenharia de São Carlos da USP em 1986, Doutor em Engenharia de Recursos Hídricos e Saneamento Ambiental pelo Instituto de Pesquisas Hidráulicas da Universidade Federal do Rio Grande do Sul em 2003. Professor do Programa de Pós-Graduação em Gestão Urbana da Pontifícia Universidade Católica do Paraná.
Endereço:R. Imaculada Conceição, 1155 - Prado Velho, Curitiba - PR, 80215-901
E-mail: harry.bollmann@pucpr.br

ABSTRACT

The main objective of this research was to characterize the situation of water pollution by micropollutants and its current management context in the Belém River basin in Curitiba, emphasizing the residues of pharmaceuticals. For this, a literature review was conducted to identify which classes of micropollutants have been monitored in this basin and which were the concentration ranges found. Thirty-two semi-structured interviews were also conducted with stakeholders who interface with the reduction and control of pharmaceutical residues or who are linked to the management of the Belém River waters. Quantified micropollutant concentrations in this basin reveal levels of endocrine disruptors far above the limits considered safe by European toxicologists, which indicates the need to reduce and control these pollutants. Nevertheless, stakeholders interviewed point out that micropollutants (pesticides, metals and pharmaceuticals) are the priority aquatic pollutants for urban water management, to the detriment of pathogens and nutrients. Priorities for pharmaceutical residues, according to respondents, mirrored precisely the focus of European and USA studies

Brazilian Journal of Development

and management initiatives that have prioritized antibiotics and hormones. However, despite the prioritization of micropollutants, management initiatives aimed at reducing and controlling them in the Belém River basin are scarce. The highlights were: the Water Purification Program of the Environment Department of Curitiba; collaborative projects between institutions (notably universities and the sanitation company); and unused or expired drug take-back.

keywords:Micropollutants, Water management, Pollution control, Urban rivers, pharmaceuticals.

RESUMO

O objetivo principal desta pesquisa foi caracterizar a situação da poluição hídrica por micropoluentes e seu atual contexto de gestão na bacia hidrográfica do Rio Belém em Curitiba, enfatizando os residuais de produtos farmacêuticos. Para isso, foi realizada uma revisão bibliográfica buscando identificar quais classes de micropoluentes têm sido monitorados nesta bacia e quais foram os intervalos de concentração encontrados. Também foram realizadas trinta e duas entrevistas semiestruturadas com os atores que possuem interface na redução e controle dos residuais de produtos farmacêuticos ou que estejam ligados à gestão das águas do Rio Belém. As concentrações de micropoluentes quantificadas nesta bacia revelam teores de desreguladores endócrinos muito acima dos limites considerados seguros pelos toxicologistas europeus, o que indica a necessidade de redução e controle destes poluentes. Apesar disso, os *stakeholders* entrevistados apontam que os micropoluentes (pesticidas, metais e fármacos) são os poluentes aquáticos prioritários para a gestão das águas urbanas, em detrimento dos patógenos e nutrientes. As prioridades, quanto aos residuais de produtos farmacêuticos, segundo os entrevistados espelharam justamente o foco dos estudos e das iniciativas de gestão europeias e norte-americanas que tem priorizado os antibióticos e os hormônios. Entretanto apesar da priorização dos micropoluentes, as iniciativas de gestão voltadas para a redução e controle deles na bacia do Rio Belém ainda são escassas. Os destaques foram: o Programa de Despoluição Hídrica da Secretaria de Meio Ambiente de Curitiba; projetos colaborativos entre instituições (notadamente universidades e a companhia de saneamento); e a logística reversa de medicamentos domésticos expirados ou em desuso.

Palavras-Chave: Micropoluentes, Gestão das águas, Controle da poluição, Rios urbanos, Fármacos.

1 INTRODUCTION

Micropollutants are elements found in very low concentrations in the environmental matrices and that is why they receive this name. Term has been used for a long time in the scientific literature, so much so that in the 1980s it was already used to designate compounds present in the environment in concentrations below 1 mg / L (REIS FILHO; ARAUJO; VIEIRA, 2006). Despite their low concentrations, these pollutants have shown a vast amount

of adverse effects on organisms, such as: aquatic toxicity, genotoxicity, endocrine interference and selection of resistant pathogenic bacteria (KIM; AGA, 2007; SCHWARZENBACH et al., 2006; HALLING-SØRENSEN et al., 1998). This group of pollutants includes thousands of compounds, but the main interest groups are Emerging Organic Pollutants (EOPs), Persistent Organic Pollutants (POPs) and traces metals.

Within the wide range of compounds considered micropollutants, the groups of trace metals and Persistent Organic Pollutants are already controlled in the water of most countries, by legal instruments, whether they are in development such as Brazil, Mexico and Chile, or developed as European Union countries, United States, Canada and Australia (USEPA, 2009; EU, 1998; HC, 2014; AG, 2011; SSM, 1994; NCO, 2005; BRAZIL, 2011). The group of Emerging Organic Pollutants has recently attracted greater attention from the scientific community, as they are very frequent in surface waters, are related to harmful effects on the environment and possibly human health, are persistent to conventional treatments, are widely used by society modern and mainly because their concentrations are not yet properly controlled by management instruments (BOXALL, 2012). Within this group, since the mid-1990s, research has been more intensively dedicated to the pharmaceutical class (KÜMMERER, 2009), which are currently considered the priority group of emerging pollutants for monitoring and regulation in urban waters.

This research aimed to contextualize the case of the Belém River basin, the main hydrographic basin of the city of Curitiba, regarding the pollution by micropollutants and its current context of management, giving special attention to pharmaceuticals because they do not yet have regulations specific. Hydrographic basin of the Belém River is typically urban and is entirely within the municipality of Curitiba (Figure 1). It has an area of 87.85 km², occupies 20% of the city's territory. In 2010, according to the IBGE Census data by census sector, the basin was home to 475,606 inhabitants, among the 1,751,907 inhabitants of Curitiba - which consists of 27% of the city's population. Considering that in 2019, according to IBGE estimates, the population of Curitiba reached 1,933,105 inhabitants, the number of inhabitants of the Belém River basin must have reached about 524 thousand inhabitants. According to the Paraná State Sanitation Company (SANEPAR), 97% of the Belém basin area has a sewage network, but only 45% of the population is connected to it, consequently the basin has high levels of pollution by domestic sewage. Regard to the general quality of the waters of the Belém River, there is a degradation of the springs towards the mouth due to point and diffuse

sources of pollution, with about 90% of this pollution from domestic sewage discharged through drainage networks (BOLLMANN; EDWIGES, 2008).

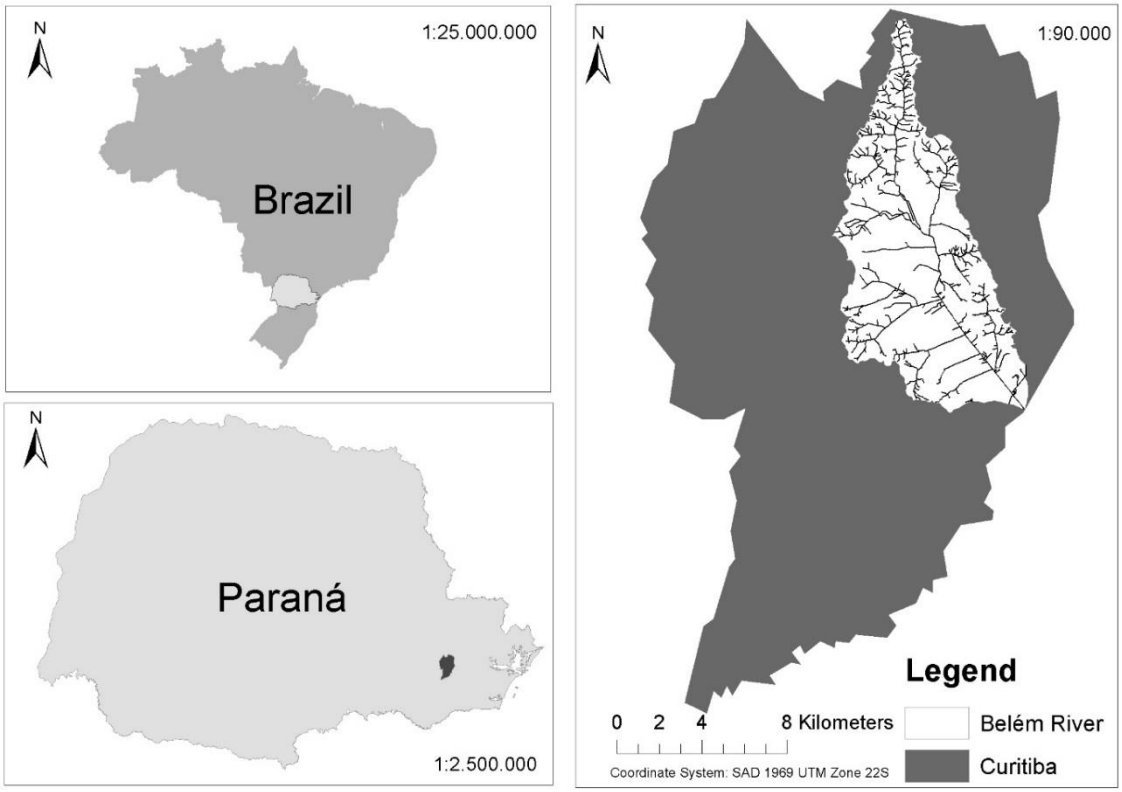

Figure 1: Location of the Belém River hydrographic basin.

2 MATERIALS AND METHODS

A bibliographic review was made identifying the concentrations of micropollutants already found in water of hydrographic basin of the Belém River. Also were carried out 32 interviews (Table 1) with stakeholders that have an interface in the reduction and control of pharmaceutical product residuals or that are linked to the management of the waters of the Belém River. Sought to observe through these interviews the pharmaceuticals water management activities applicable to this basin, as well as the priorities for the water quality of stakeholders selected.

Interviews with stakeholders were conducted in person, by telephone, or by email (this was only in one case, because the selected person was studying abroad). Five questions were asked, three open question and two objective question. The first question of the interview was open, about what were the main pollution control activities of urban rivers that the stakeholder was involved in. The second question was objective, asking that classes of pollutants

(pathogens, pharmaceuticals, pesticides, metals, organic solvents) were numbered in order of importance, as made for Doerr-MacEwen and Haight (2006) in Europe and North America. The third question was open and similar to the first but focused on the main activities of the stakeholders for the control of drug pollution in urban rivers. The fourth question was also opened, to know which was the most important medicine for urban water management. And last question was objective, asking that classes of drugs (contraceptives, antibiotics, anti-inflammatories, analgesics, lipid and anti-hypertensive) were numbered in order of importance.

Respondents were selected by intentional sampling, considering their contributions to the literature on micropollutants, their involvement with water pollution control management initiatives and recommendations from their institution colleagues. The interviewees were not chosen at random, as the objective was not to generate information that could be generalizable, but to learn about management initiatives and explore the views of a variety of stakeholders.

Table 1: Actors interviewed by institution.

Sector	Institutions	Interviewed
Government	SEMA (Environment Department of Paraná)	2
	SESA (Health Department of Paraná)	1
	SMMA (Environment Department of Curitiba)	1
	SMS (Health Department of Curitiba)	1
	SEED (Education Department of Paraná)	1
	IAP (Environmental Institute of Paraná)	1
	SANEPAR (Paraná Sanitation Company)	2
	AGUASPARANA (Waters Institute of Paraná)	1
Universities	PUCPR (Catholic Pontifical University of Paraná)	2
	UTFPR (Federal Technological University of Paraná)	1
	UFPR (Federal University of Paraná)	6
	UP (Positivo University)	2
Pharmaceutical	CRF-PR (Regional Pharmacy Council of Paraná)	1
	SINDIFAR (Syndicate of Pharmaceuticals of Paraná)	1
	SINDIFARMA (Syndicate of Retail Trade Pharmaceutical Products of Paraná)	1
Pharmaceutical production and distribution	Herbarium	1
	Prati-Donaduzzi	1
	Ervas Curam	1
	Nunes Farma	1
Community	Local Health Council	1
	Residents' Association	1
	Residents' Association	1
	State School	1
Total		32

Brazilian Journal of Development

3 RESULTS AND DISCUSSION

Regard to pollution by micropollutants, several studies have recently been carried out on the Belém River, as shown in Table 2. However, the monitoring campaigns had an exploratory character with a network and a sampling frequency, in general, not significant, measuring only a few compounds according to the interests of each researcher and with monitoring efforts carried out in different periods. In addition, the focus of monitoring has still been the concentration and not the pollution load, which is a more significant measure, since it relates the concentration to the flow. All these factors do not allow a safe and detailed characterization of pollution by these compounds in the basin, but they are part of a necessary exploratory step. Among the group of micropollutants the classes so far most studied in this basin are, metals, with a much more significant number of researches, followed by natural and synthetic hormones.

Table 2: Micropollutants in the waters and sediment of the Belém River.

Class	**Compound**	**Concentration**		**Reference**
		Water	**Sediment**	
		P0% - P100%	**P0% - P100%**	
Hormone	17β-estradiol	<25 - 5880 ng/L	12710 - 16690 ng/kg	Padilha e Leitzke, 2013; Ide, 2014
	17α-ethinylestradiol	<48 - 5830 ng/L	31650 - 33890 ng/kg	Padilha e Leitzke, 2013; Ide, 2014
	Estrona	<26 - 2420 ng/L	58080 - 128080 ng/kg	Padilha e Leitzke, 2013
Antihypertensive	Metoprolol	<4.5 – 2125.9 ng/L		Osawa *et al.*, 2015; Osawa, 2013
	Propranolol	<5.8 – 299.7 ng/L		Osawa *et al.*, 2015; Osawa, 2013
	Nadolol	<14.1 - 30 ng/L		Osawa *et al.*, 2015; Osawa, 2013
Anti-inflammatory	Ibuprofen	<14 - 729 ng/L	<11800 ng/kg	Kramer,2012
	Paracetamol	120* - 261 ng/L	<380 -1290* ng/kg	Kramer,2012
	Diclofenac	<9 - 61 ng/L	<19000 ng/kg	Kramer,2012
	Acetylsalicylic acid	<36.1 - 8570 ng/L		Ide,2014
	Naproxen	<9.5 - 640 ng/L		Ide,2014
	Ketoprofen	<5.0 - 2540 ng/L		Ide,2014
Psychotropic	Carbamezepine	<67 - 856 ng/L		Boger et al., 2018
	Diazepam	<130 - 763 ng/L		Boger et al., 2018
Metabolite	Salicylic acid	<33.7 - 1550 ng/L		Ide,2014
Lipid regulator	Genfibrozila	<0.92 - 217 ng/L		Ide,2014
	Fenofibrate	<0.77 - 69 ng/L		Ide,2014
UV filter	Octyl methoxycinnamate	<2.09 - 373 ng/L		Ide,2014
	Octacrylene	<1.4 - 202 ng/L		Ide,2014
	Camphor methylbenzelidene	<0.33 - 1 ng/L		Ide,2014
Stimulant	Caffeine	100 - 59810 ng/L		Ide,2014
Preservative	Methylparaben	<1.7 - 1600 ng/L		Santos *et al.*, 2016
	Ethylparaben	<1.4 – 380* ng/L		Santos *et al.*, 2016
	Propylparaben	<1.7 - 480* ng/L		Santos *et al.*, 2016
	Butylparaben	<2 - 280* ng/L		Santos *et al.*, 2016
	Benzylparaben	<1.9 ng/L		Santos *et al.*, 2016
	Triclosan	<0.4 - 325* ng/L		Santos *et al.*, 2016
Metals	Copper	<0.009 – 0.0471mg/L	<LoD – 52.22 mg/kg	Adam *et al.*, 2010; Heinrich *et al.*, 2015; Paraná, 2009

	Nickel	0.0068 – 0.0291 mg/L	<LoD – 183.63 mg/kg	Adam *et al.*, 2010; Heinrich *et al.*, 2015; Garcias e Sottoriva, 2010
	Zinc	0.0124 – 0.4999 mg/L	58.78 - 289 mg/kg	Adam *et al.*, 2010; Heinrich *et al.*, 2015; Paraná, 2009
	Silver		<LoD	Heinrich *et al.*, 2015
	Cadmium	<0.001 mg/L	<LoD	Heinrich *et al.*, 2015; Garcias e Cidreira, 2012; Paraná, 2009
	Chrome	<0.05 mg/L	10.54 – 378.84 mg/kg	Heinrich *et al.*, 2015; Garcias e Sottoriva, 2010; Paraná, 2009
	Lead	<0.01 mg/L	<LoD – 1495.1 mg/kg	Heinrich *et al.*, 2015; Garcias e Sottoriva, 2010; Garcias e Cidreira, 2012; Paraná, 2009
	Iron	0.56 – 1.38 mg/L		Garcias e Sottoriva, 2010
	Lithium	<0.05 mg/L		Garcias e Cidreira, 2012
	Mercury	<0.0002 mg/L		Garcias e Cidreira, 2012; Paraná, 2009
Polycyclic aromatic hydrocarbons (PAHs)	Anthracene		<LoD – 0.26 mg/kg	Heinrich *et al.*, 2015
	Benzo (a) pyrene		<LoD – 9.07 mg/kg	Heinrich *et al.*, 2015
	Benzo (g, h, i) perylene		<LoD – 0.53 mg/kg	Heinrich *et al.*, 2015
	Fluorene		<LoD – 0.46 mg/kg	Heinrich *et al.*, 2015
	Benzo (b) fluoranthene		<LoD – 0.06 mg/kg	Heinrich *et al.*, 2015

Note: LoD=Limit of Detection; * = approximate value.

Metals, in addition to being monitored by researchers from several universities (Pontifical Catholic University of Paraná, Federal University of Paraná, Federal Technological University of Paraná and Positivo University), have been subject to periodic monitoring by the Environmental Institute of Paraná (IAP), aiming at the verification of the adequacy of the quality of the river waters, classes 2 and 3 of CONAMA (National Environment Council) Resolution No. 357 (BRASIL, 2005). Periodic monitoring of metals carried out by IAP, in the period 2005-2009, does not show violations in the waters of the lotic environments of the basin, considering the limits established by CONAMA Resolution No. 357 (BRASIL, 2005). Violations occurred only in the water of the lentic environments of the basin (such as the lake of São Lourenço Park) and relevant concentrations were also found in the river sediment.

In case of hormones, the researches were carried out by researchers from the Federal Technological University of Paraná (UTFPR). Likely that these emerging contaminants have received greater focus because they are important endocrine disrupters that have already caught the attention of environmental and health authorities in both North America and Europe.

Hydrographic basin of the Belém River, significant concentrations of several micropollutants with environmental impact can be observed. As is the case with analgesic, diclofenac, and female sex hormones, 17α-ethinylestradiol, 17β-estradiol and estrone. Highlight is the concentrations of the synthetic hormone 17α-ethinylestradiol. Concentrations found of this compound in the waters of the Belém River ranged from <48 - 5,830 ng / L.

According to European toxicologists, 6 ng / L is the concentration necessary to cause important population damage in aquatic ecosystems, due to endocrine interference (Gilbert, 2012). Which reveals a relevant environmental and health problem. Despite the problems related general water quality in the Belém River, both of macro and micro pollutants, the stakeholders indicated that their priorities for water management are micropollutants.

3.1 STAKEHOLDER PRIORITIES

From interviews with stakeholders it was possible to identify which are the priority water pollutants of these actors and their perceptions of importance regarding pharmaceuticals waste. Among the 32 interviewees, 29 were able to answer which are the priority water pollutants (only the 3 direct representatives of the community - residents' associations and the state school - did not have the knowledge to answer). Among the priority pharmaceuticals for water quality, 28 responses were obtained, since in addition to the three direct representatives of the community not being able to respond, a member of the Environment Department of Paraná (SEMA) also did not consider himself fit for answer. This show that even sectors of the government involved with environmental management are not yet well acquainted with the problem of pharmaceutical residues.

Figure 2, built from the average of the stakeholder's responses, show that the general perception of stakeholders is that micropollutants are the most important pollutants. Surprising result, since management priorities in Brazil, for the sanitation sector, are still focused on overcoming the hygienist phase of sanitation management and reducing and controlling the concentrations of pathogens and nutrients in hydrographic basins. Although there are already management measures to reduce and control pesticides and metals by setting out limits on their concentration in the environment and monitoring campaigns, pesticides appeared first in the priorities, followed by metals (Figure 2). This probably occurred, because these two types of pollutants pose serious environmental and health risks related mainly to intoxication. And as mentioned by the interviewees, the management measures for these pollutants, although they exist, are not yet enough to ensure the desired environmental quality of Brazilian urban rivers. On third in the priorities of stakeholders are pharmaceuticals, followed by nutrients and pathogens, the organic solvents were last.

Research carried out by Doerr-MacEwen and Haight (2006) with stakeholders related to pharmaceuticals management in Europe and North America (USA and Canada) showed an order of priorities different from the priorities pointed out by Brazilian stakeholders. Can be

seen in Table 3, the priorities indicated by Brazilian stakeholders are more like those of Europeans. The only distinction between the priorities pointed out by Europeans and Brazilians is related to nutrients. For Europeans they are the most important pollutants, while for Brazilians list them as the least important among the six types of aquatic pollutants. However, except for nutrients, the order of priorities pointed out by Brazilians and Europeans is the same. While the Americans have a ranking of priorities quite different from both Europeans and Brazilians. Regard especially to pharmaceuticals, for Brazilians these pollutants are in third place in the ranking of priorities, for Europeans in fourth place and for North Americans in fifth.

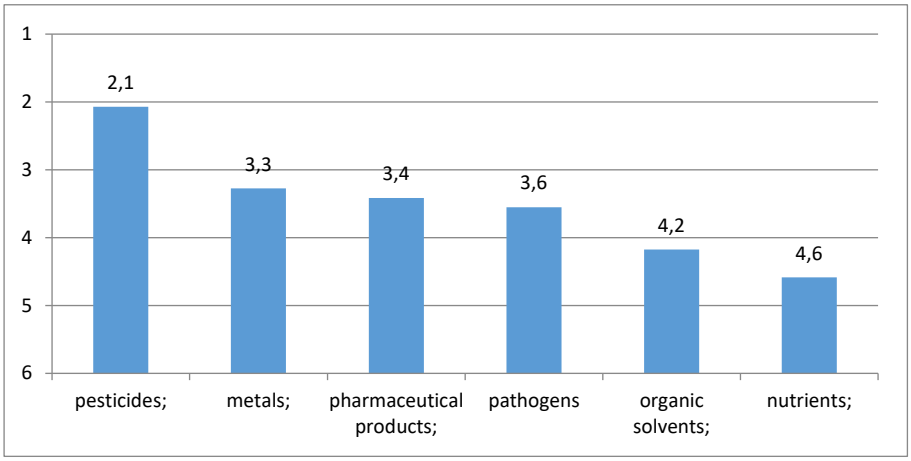

Figure 2: Priority water pollutants according to stakeholders

Table 3: Priorities in water management for stakeholders, European, North American and Brazilian

	European	**North American**	**Brazilian**
1	Nutrients	Pathogens	Pesticides
2	Pesticides	Pesticides	Metals
3	Metals	Nutrients	Pharmaceuticals
4	Pharmaceuticals	Metals	Pathogens
5	Pathogens	Pharmaceuticals	Organic solvents
6	Organic solvents	Organic solvents	Nutrients
Source:	Doerr-MacEwen e Haight, 2006		Authors, 2020

Brazilian Journal of Development

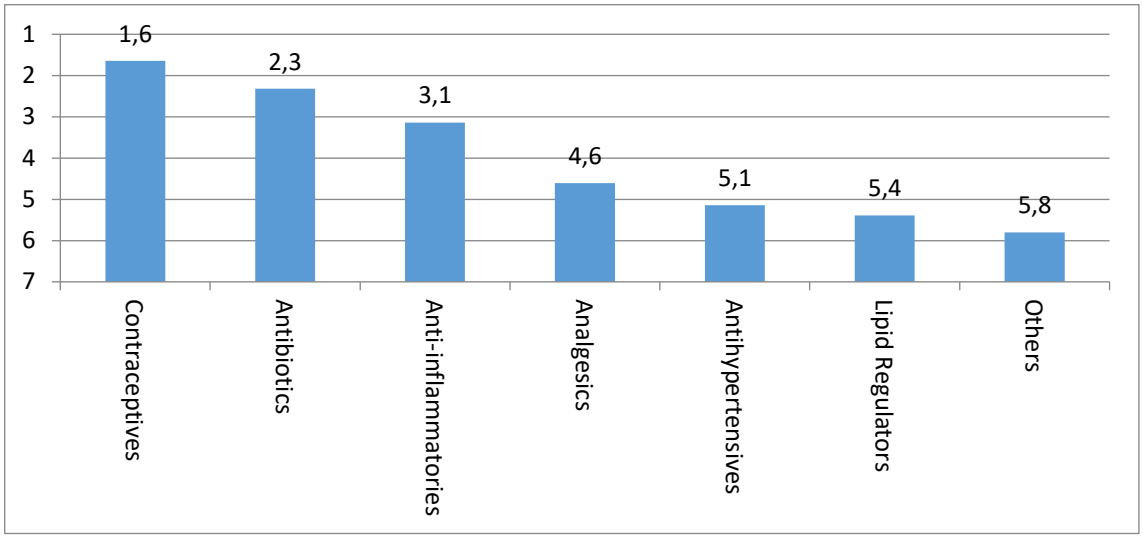

Figure 3: Priority pharmaceuticals according to stakeholders.

From the point of view of the residuals of pharmaceuticals, by the average of the stakeholder's responses (Figure 3), the priority pollutants for the stakeholders are contraceptives, followed by antibiotics and other pharmaceutical products. This reflects precisely the international concerns that also place these two classes as priorities, since natural hormones and notably synthetic hormones from birth control pills have been proven to be endocrine disrupters, while antibiotics have often been linked to the development of resistant bacterial.

However, despite these actors pointing out that their priorities are the micropollutants, the management initiatives applicable to them in the hydrographic basin of the Belém River are still in an incipient phase. Control of pollution by nutrients and pathogens, resulting from the release of raw domestic sewage, is still a major challenge that requires structural management measures.

3.2 WATER AND PHARMACEUTICALS MANAGEMENT IN THE BELÉM RIVER

The management initiatives identified by the 32 respondents were divided by sector of society that the institution of each respondent represents. Responses were tabulated by institution and divided into two groups of management initiatives for the control of water pollution, those aimed at aquatic pollutants in general, and those aimed specifically at pharmaceuticals.

Regarding government initiatives to control pollution by aquatic pollutants in general (Table 4), IAP, SEMA and AGUASPARANA indicated that they periodically monitor a network of 68 stretches of 40 rivers in the metropolitan region of Curitiba. In the Belém River Hydrographic Basin there are 7 sample points, 3 points in the main channel and 4 points in its affluent. While SANEPAR indicates that it keeps investing in the expansion of the sewage network and promotes programs that have contributed to clean up urban rivers, as is the case of the 'Connect to the Network' (know as 'Se Ligue na Rede') and the 'Urban River Revitalization Program' (know as 'Programa de Revitalização de Rios Urbanos'). In this same direction, SEED highlighted the agreement it has with SANEPAR 'Sustainability from School to the River' (know as 'Sustentabilidade da Escola para o Rio') which is also focused on urban rivers and promotes environmental education for high school students and the integration of the community with local environmental problems. Highlight of the water pollution control management initiatives applicable to the Belém River is the 'Water Depollution Program' (know as 'Programa de Despoluição Hídrica' - PDH) headed by SMMA. PDH unites structural measures, such as the inspection and correction of SANEPAR's collection networks and inadequate domestic networks, such as non-structural, as periodic monitoring of 120 sub-basins and environmental education. It is a comprehensive program that has shown positive results. Water quality data show that the PHD has improved the water quality of the Belém River, also contributing to the participatory management of the community (JORGE et al., 2015).

Regard to the management of pharmaceuticals pollution control in urban rivers, several spheres of government have not yet worked in this direction (Table 4). SANEPAR claims to support, next to Brazilian Association of State Sanitation Companies (AESB), the population awareness program, for the conscious consumed of medicines, and Drug Take-Back Program. On the practical what has really been done at the government level in the Curitiba region is the active participation of SEMA, SESA, SMMA and SMS in the 'Paraná Medicines Working Group' (know as 'Grupo de Trabalho de Medicamentos do Paraná' - GTM-PR). These departments have been played an important role in the growth of drug take-back in the region. However, it is noteworthy that at the moment the scope of the Drug Take-Back Program is small, but the effort that has been made by the municipal government of Curitiba and by the state of Paraná, in addition to other sectors of society, for its growth have been significant. Effort of the government of the state of Paraná and the municipality of Curitiba to promote a sectoral agreement that guarantees the shared responsibility of medicines in unused or expired

resulted in State Law nº 17.211 / 2012 (PARANÁ, 2012) and Municipal Law nº 13.978 / 2012 (CURITIBA, 2012).

Table 4: Initiatives to control water pollution of government sector.

Sector	Institution	Type of water pollution control management initiative	
		Pollutants in general	**Pharmaceuticals**
Government	IAP (Environmental Institute of Paraná)	Periodic monitoring of rivers.	Control of effluents from pharmaceutical industries.
	SEMA (Environment Department of Paraná)	Periodic monitoring of rivers.	Participation in GTM-PR and Drug Take-Back Program induction.
	AGUASPARANA (Waters Institute of Paraná)	Periodic monitoring of rivers.	It still does not have working directly with this issue.
	SANEPAR (Parana State Sanitation Company)	Investment in expansion of the sewage network and treatment capacity, 'Connect to the Network' program, participation in the basin committee and in the Upper Iguaçu basin revitalization group.	Awareness program for the population regarding the conscious use and return of pharmaceutical products headed by the Brazilian Association of State Sanitation Companies (AESB).
	SEED (Education Department of Paraná)	Agreement with SANEPAR in project 'Sustainability from School to River' and lectures on this topic for students.	It still does not have working directly with this issue.
	SESA (Health Department of Paraná)	Participation in the Upper Iguaçu basin revitalization group.	Inspection of the disposal of waste from health units and hospitals, participation in GTM-PR and Drug Take-Back Program induction.
	SMMA (Environment Department of Curitiba)	Inspection and correction of SANEPAR collecting networks and inadequate domestic sewage connections (PDH), periodic monitoring of 120 sub-basins, environmental education, participation in GTM-PR and Drug Take-Back Program induction.	Participation in GTM-PR and Drug Take-Back Program induction.
	SMS (Health Department of Curitiba)	Participation in GTM-PR and Drug Take-Back Program induction.	Participation in GTM-PR and Drug Take-Back Program induction.

Initiatives for the management of aquatic pollutants and pharmaceuticals applicable to the case of the Belém River, both in the pharmaceutical sector and in the pharmaceuticals production and distribution sector, are also summarized in the participation in the GTM-PR and in the promotion of Drug Take-Back Program (Tables 5 and 6). The four companies in the productive sector interviewed have guaranteed the transport and destination of the medicine residues collected at 19 points in the state of Paraná, 9 of which in the metropolitan Curitiba region. These companies (three industries and one distributor) were pioneers in the state of Paraná regard to the sectoral agreement for the medicines sector. But due to the laws created at the municipal and state level, the large pharmacy chains in Curitiba have also already received medicines expired or unused. These networks have pay the cost of transporting and treating these residues, since the adhesion of the productive sector is still small. What in these cases does not characterize the sectoral agreement for the medicine sector proposed by the state and municipal laws on take-back program (PARANÁ, 2012; CURITIBA, 2012), but, anyway it is already a breakthrough even if in a disorganized way. Institutions in the pharmaceutical sector have also been essential for the growth and solidification of Drug Take-Back Program in the Curitiba region. Highlight is the CRF-PR, which has spearheaded the GTM-PR and united the various sectors of society that are involved in the pharmaceutical products chain. This institution was also in charge of the Pilot Project, which added government, the productive sector, pharmaceuticals sector and universities.

Table 5: Initiatives to control water pollution of productive sector.

Sector	**Institution**	**Type of water pollution control management initiative**	
		Pollutants in general	**Pollutants in general**
Pharmaceutical production and distribution	Nunes Farma	Promotes the Drug Take-Back Program and participates in the GTM-PR.	Promotes the Drug Take-Back Program and participates in the GTM-PR.
	Herbarium	Promotes the Drug Take-Back Program, participates in the GTM-PR and collects expired drugs from distributors.	Promotes the Drug Take-Back Program, participates in the GTM-PR and collects expired drugs from distributors.
	Prati-Donaduzzi	Promotes the Drug Take-Back Program, participates in the GTM-PR, collects expired drugs from distributors and produces multi-fractionable tablets.	Promotes the Drug Take-Back Program, participates in the GTM-PR, collects expired drugs from distributors and produces multi-fractionable tablets.
	Ervas Curam	Promotes the Drug Take-Back Program and participates in the GTM-PR.	Promotes the Drug Take-Back Program and participates in the GTM-PR.

Brazilian Journal of Development

Table 6: Initiatives to control water pollution of pharmaceutical sector.

Sector	Institution	Type of water pollution control management initiative	
		Pollutants in general	**Pollutants in general**
Pharmaceutical	SINDIFAR (Syndicate of Pharmaceuticals of Paraná)	Participation in the pilot project Drug Take-Back Program and the GTM-PR.	Participation in the pilot project Drug Take-Back Program and the GTM-PR.
	SINDIFARMA (Syndicate of Retail Trade Pharmaceutical Products of Paraná)	Participation in the pilot project Drug Take-Back Program and the GTM-PR.	Participation in the pilot project Drug Take-Back Program and the GTM-PR.
	CRF-PR (Regional Pharmacy Council of Paraná)	Creation of GTM-PR and drug take-back induction in Curitiba, Paraná and throughout the country.	Creation of GTM-PR and drug take-back induction in Curitiba, Paraná and throughout the country.

Role of academia for water management in the Belém River region was analyzed in the four institutions that have the largest number of studies on this river and on aquatic micropollutants (Table 7). Beyond from the characterization, treatment and management studies that the researchers interviewed reported, it was possible to identify several collaborative projects between professors with other departments and other institutions (other universities and SANEPAR). Collaborative projects of this nature are promising for water management, especially when they involve sanitation institutions. Various European experiences of collaborative projects show this (START, 2008; PILLS, 2012; NOPILLS, 2015), but, in capacity of intervention, Brazilian collaborative projects need to progress. As for the pharmaceuticals in the waters of urban rivers, the scope of the academy's contributions has been basically the same as that of pollutants in general. Exception for UFPR, which in the phase of Pilot Project (Drug Take-Back Program) gave strong support to GTM-PR by producing various materials to present and publicize the campaign to the community. UFPR developed an environmental education activity with children from municipal schools, presenting the problem of inappropriate disposal of expired or unused medicines and in a playful way, raising awareness and guiding them.

Brazilian Journal of Development

Table 7: Initiatives to control water pollution of academic.

Sector	Institution	Type of water pollution control management initiative	
		Pollutants in general	**Pollutants in general**
Universities	PUCPR (Catholic Pontifical University of Paraná)	Characterization and management research.	Management research.
	UFPR (Federal University of Paraná)	Characterization, treatment and reduction research; advisory to companies in treatment systems; and collaborative projects between other researchers and institutions (such as other universities and SANEPAR).	Characterization, treatment and reduction research; support for the activities of GTM-PR; advisory to companies in treatment systems; and collaborative projects between other researchers and institutions (such as other universities and SANEPAR).
	UTFPR (Federal Technological University of Paraná)	Characterization research and collaborative projects between other researchers and institutions (such as other universities and SANEPAR).	Characterization research and collaborative projects between other researchers and institutions (such as other universities and SANEPAR).
	UP (Positivo University)	Research on the assessment of ecotoxicological effects, removal mechanisms and management proposals; collaborative projects with SANEPAR; and involvement in environmental education work.	Research on the assessment of ecotoxicological effects, removal mechanisms and management proposals; collaborative projects with SANEPAR; and involvement in environmental education work.

Table 8: Initiatives to control water pollution of community.

Sector	Institution	Type of water pollution control management initiative	
		Pollutants in general	**Pollutants in general**
Community	Local Health Council	It still does not have working directly with this issue.	It still does not have working directly with this issue.
	Residents' Association	Partnership with health units where the Belém River was focused, with distribution of pamphlets to raise awareness among the population, organizing lectures and promote joint efforts to collect garbage in the river.	It still does not have working directly with this issue.
	Residents' Association	Environmental education activity with SANEPAR for the connection of houses in the region with the sewage network. Participation in the municipal program 'Green Exchange' (know as 'Câmbio Verde'), which exchanges recyclable waste for fruits and vegetables (which also contributes to less waste being thrown into the river).	It still does not have working directly with this issue.
	State School	Teachers' projects that lecture about pollution processes and the biggest polluters of the Belém River.	It still does not have working directly with this issue.

Community is considered in Brazil as an essential element for the management of water resources, as postulated by the National Water Resources Policy (National Law No. 9,433/1997). Integrate the community on the process is a goal of Brazilian model water management, based on the formation of basin committees. Practical level, this model has not working and in the case of the Belém River this is clear. Hodja et al. (2014) shows that regard to the Belém River basin, the Upper Iguaçu and Afluentes do Upper Ribeira Committee (COALIAR) had a history of few decisions and discussions on projects and improvements for the basin. In turn, few community insertions in the Belém River management initiatives could be expected. Table 8 shows that three direct representatives of the community, community leaders from two associations of residents and the representative of a state school, participated in environmental education activities involving the Belém River. However, these activities conducted by SANEPAR or by local health units were isolated and localized efforts that did not continue. The manager of the local health council did not report any activity of this institution aimed at controlling pollution in the Belém River. Regard to the presence of pharmaceuticals in the river, the community is completely unaware of the environmental problems related to this. And then, none of the four respondents reported activities focused on pharmaceuticals pollution in the Belém River.

4 CONCLUSIONS

Concentrations of micropollutants found in the hydrographic basin of the Belém River represent conditions of environmental unhealthiness that need to be further investigated and controlled by the public administration. Became evident the need for periodic monitoring efforts that evaluation the pollution load (relationship between concentration and flow), and not just the concentration of these compounds. Measure pollution load will allow to know the real average variability of these pollutants in the basin. However, even with the limitations of monitoring, due not measure the flow, the concentrations of pharmaceuticals found in the Belém River are much higher than the limits considered safe by European studies. Indicating that the effects of endocrine disruption on the aquatic ecosystems are likely. This context shows the need for initiatives aimed at controlling pollution by micropollutants. The discourse of the stakeholders interviewed has the same direction, placing micropollutants as priorities for the management of urban waters in the region.

Although the stakeholders interviewed have an interface with the management of micropollutants, it was expected that the priorities of these stakeholders were the

macropollutants. Because in urban rivers in large Brazilian cities, management initiatives are focused the macropollutants. But the results obtained showed that stakeholders already understand that the priority pollutants for urban waters are micropollutants. Priorities of these stakeholders regarding water pollutants showed great similarity with the ranking of priorities of European stakeholders and an order of priorities pretty different from that of the Americans. Inferring about what leads to similarities and dissimilarities of visions in Brazil, Europe and North America is quite difficult, since the social, economic and environmental conditions of these regions are plenty different, as are the management models of water pollution control. Considering only the priorities regarding pharmaceuticals, the order of importance pointed out by stakeholders showed congruence with North American and European studies and management initiatives, placing hormones and antibiotics as priority pharmaceuticals for urban rivers. Despite the prioritization of micropollutants, their management is in an incipient phase needing more attention, since even in low concentrations they offer environmental and health risks.

Management initiatives aimed at controlling water pollution by micropollutants in the Belém River are in an initial state. Major challenge in this basin is controlling the concentrations of nutrients and pathogens in waters and even in this context, the management of pollution control has been inefficient. Regard to water quality management initiatives applicable to micropollutants, the government's Water Depollution Program stands out, which despite being a program that works to reduce water pollution by sewers, consequently, also contributes a lot to the reduction of micropollutants to the Belém River. Since many micropollutants, such as pharmaceuticals, are discharged into the Belém River by domestic sewage. Another highlight is the contribution of the academy, which in addition to characterize and proposing forms of management through research, has also been working on collaborative projects. Despite having a small contribution related to practical intervention, compared to Europeans, they already show a promising configuration that in the long-term can contribute significantly to the reduction of pollution by micropollutants. However, the biggest highlight of the micropollutant management initiatives applicable to the Belém River is Drug Take-Back Program. Initiative already has some representation in the basin, due to the merits of the government and mainly of the pharmaceutical sector, which organized a working group / technical chamber for the theme. Technical chamber, in addition to inducing the government to regulate the drug take-back, ensured that it had a viable and coherent design, based on shared responsibility and seeking a sectoral agreement. The GTM-PR is like European experiences

of managing micropollutants that through a network of environmental governance between government, organized civil society and the productive sector, finds feasible paths that can effectively provide advances in management. Initiatives of this type are uncommon in Brazil and represent an opportunity to move forward regarding the water resources management model.

ACKNOWLEDGMENTS

The authors are grateful to the collaborators of the WENSI Project (Water Environment Micropollutant Science Initiative: A Collaboration to explore emergent pollutants in Brazilian watercourses) and their funders, the Brazilian Federal Agency for the Improvement of Higher Education through Edict PGCI n. 02/2015 of International Cooperation, Project no. 004/2016, and the British Council through the Newton Fund: Institutional Links, application ID 122728076.

REFERENCES

ADAM, M. L. TORRES, R. A. SPONCHIODO, G. MOTTA, T. S. OLIVEIRA, C. M. R. CARVALHO – FILHO, M. A. CORREIA, M. I. S. Environmental Degradation at a Public Park in Southern Brazil as Revealed Through a Genotoxicity Test (MN) on Peripheral Blood Cells from Poecilia vivipara (Teleostei). **Water Air Soil Pollut** (2010) 211:61–68.

AG - Australian Government. **Australian drinking water guideline/2011**. Available at: <https://www.nhmrc.gov.au/_files_nhmrc/file/publications/nhmrc_adwg_6_february_2016.pdf> Access July 8, 2016.

BRASIL. **Ordinance No. 2,914 of the Ministry of Health, of December 12, 2011.** Provides for the control and surveillance procedures of the quality of water for human consumption and its standard of drinking. Official Gazette of the Union, Brasília, DF, 12 dec 2011.

BRASIL. **CONAMA Resolution 357 of March 18, 2005.** Provides for the classification of bodies of water and environmental guidelines for their classification. Official Gazette of the Union, Brasília, DF, 18 mar 2005.

BÖGER, B.; AMARAL, B. ; SILVEIRA, P. L. ; WAGNER, R. ; PERALTA-ZAMOR, P. G. ; GOMES, E. C. . Determination of carbamazepine and diazepam by SPE-HPLC-DAD in Belém river water, Curitiba-PR/Brazil. **Revista Ambiente e Agua**, v. 13, p. 1-12

BOLLMANN, H.; EDWIGES, T. Avaliação da qualidade das águas do rio Belém, Curitiba-PR, com o emprego de indicadores quantitativos e perceptivos. **Engenharia Sanitária e Ambiental**. v. 13, n.4, p. 443-452, out/dec 2008.

BOXALL, A. B. A. **New and Emerging Water Pollutants arising from Agriculture** (2012). Available at: <https://www.oecd.org/tad/sustainable-agriculture/49848768.pdf> Access July 8, 2016.

CURITIBA. **Law No. 13.973, of April 30, 2012.** Provides for the collection of expired or unused medicines by points of sale of medicines installed in the city of Curitiba and provides other measures. Official Gazette of the Municipality, Curitiba, PR, 30 abr 2012.

DOERR-MACEWEN, N.A.; HAIGHT, M.E. Expert stakeholders' views on the management of human pharmaceuticals in the environment. **Environ. Manage**. v. 38 p. 853–866, 2006.

GARCIAS, C. M. CIDREIRA, L. E. Poluição difusa em ambientes urbanos: cádmio, chumbo e mercúrio. 33º Congresso interamericano de engenharia sanitária e ambiental. **Anais eletrônico**. 2012.

GARCIAS, C. M. SOTTORIVA, E. M. Poluição difusa urbana decorrente do desgaste dos freios automotivos: estudo de caso na sub-bacia do rio Belém em Curitiba – PR. **REDES**, Santa Cruz do Sul, v. 15, n. 3, p. 5 - 25, set/dec 2010.

GILBERT, N. Drug-pollution law all washed up. **Nature**, v. 491, n. 7425, p. 503–504, 2012.

HALLING-SØRENSEN, B.; NIELSEN, S.N.; LANZKY, P.F.; INGERSLEV, F.; LUTZHEFT, H.C.H.; JØRGENSEN S.E. Occurrence, Fate and Effects of Pharmaceutical Substances in the Environment – A review. **Chemosphere**, v. 36, n. 2, p. 357-393, 1998.

HC - Health Canada. **Guidelines for Canadian Drinking Water Quality/2014**. Available at: <http://www.hc-sc.gc.ca/ewh-semt/alt_formats/pdf/pubs/water-eau/sum_guide-res_recom/sum_guide-res_recom_2014-10_eng.pdf> Access July 8, 2016.

HEINRICH, A. B, METZGER, J. W, FISHER, K. M, MATHIAS, A. L. Gerenciamento de sedimentos do desassoreamento do rio Belém na área urbana de Curitiba: um estudo de caso. **Revista Brasileira Ciências do Solo**, 39:626-636, 2015.

HOJDA, A.; VODONIS, B.; DUTRA, M.; FREDER, S. M.; VAZ, T. C. Comitê do Alto Iguaçu e Afluentes do Alto Ribeira: uma proposta do "Subcomitê da Bacia do Rio Belém". **Revista Meio Ambiente e Sustentabilidade**, v. 6, p. 330-343, 2015.

IDE, A. H. **Produtos farmacêuticos e de higiene pessoal no Rio Iguaçú e seus afluentes**. Dissertation (Master in Environmental Science and Technology) - Academic Department of Chemistry and Biology - Federal Technological University of Paraná, Curitiba, 2014.

JORGE, M. T. E; HARTMANN, R.; GUTMANN, M. M. Renascentes - Programa de Despoluição Hídrica PDH. XIX Exposição de Experiências Municipais em Saneamento. **Anais eletrônico**. 2015.

KIM, S.; AGA, D.S. Potential ecological and human health impacts of antibiotics and antibiotic-resistant bacteria from wastewater treatment plants. **Journal of Toxicology and Environmental Health**, Part B, v. 10, n. 8, p. 559-573, 2007.

KRAMER, R. D. **Bacia hidrográfica do Alto Iguaçu: caracterização física e química e determinação de diclofenaco, ibuprofeno e paracetamol**. Dissertation (Master in Environmental Science and Technology) - Academic Department of Chemistry and Biology - Federal Technological University of Paraná, Curitiba, 2012.

KÜMMERER, K. The presence of pharmaceuticals in the environment due to human use – present knowledge and future challenges. **Journal of Environmental Management**, 90 (2009) 2354–2366.

NCO – Norma Chilena Oficial. **NCh 409/1.Of2005**. Available at: <http://ciperchile.cl/pdfs/11-2013/norovirus/NCh409.pdf> Access July 8, 2016.

NOPILLS. **noPILLS Report** (2015). Available at: <http://www.no-pills.eu/> Access July, 2016.

OSAWA, R. A. **Determinação de Fármacos Anti-hipertensivos em Águas Superficiais na Região Metropolitana de Curitiba**. Dissertation (Master in Water and Environmental Resources Engineering) Federal University of Paraná, Curitiba, 2013.

OSAWA, R. A. ; IDE, A. H. ; SAMPAIO, N. M. F. M. ; AZEVEDO, J. C. R. . Determinação de Fármacos Anti-hipertensivos em Águas Superficiais na Região Metropolitana de Curitiba. **Brazilian Journal of Water Resources**, v. 20, p. 1039-1050, 2015.

PADILHA, C. F.; LEITZKE, F. L. S.. **Determinação de Hormônios sexuais femininos na bacia do Alto Rio Iguaçu na região de Curitiba – PR**. Monograph (Bachelor in Technological Chemistry with Environmental emphasis) - Academic Department of Chemistry and Biology - Federal Technological University of Paraná, Curitiba, 2013.

PARANÁ. **Law no. 17,211, of July 3, 2012.** Provides for the responsibility for the disposal of disused drugs in the State of Paraná and its procedures. Official Gazette of the state, Curitiba, PR, 3 jul 2012.

PARANÁ. **Qualidade das águas: rios da bacia do Alto Iguaçu na Região Metropolitana de Curitiba 2005 a 2009**. Paraná Environmental Institute (IAP), Curitiba, 2009, p. 114.

PILLS. **PILLS Report** (2012). Available at: <new.production.nwe.beenetwork.eu/admin/doc?id=246&download=1> Access July 18, 2016.

REIS FILHO, R. W.; ARAÚJO, J. C.; VIEIRA, E. M. Hormônios Sexuais Estrógenos: Contaminantes bioativos. **Química Nova**, v. 29, p. 817-822, 2006.

SANTOS, M. M. ; BREHM, F. A. ; FILIPPE, T. C. ; KNAPIK, H. G. ; AZEVEDO, J. C. R. . Occurrence and risk assessment of parabens and triclosan in surface waters of southern Brazil: a problem of emerging compounds in an emerging country. **Brazilian Journal of Water Resources**, v. 21, p. 603-617, 2016.

SCHWARZENBACH, R.P, et al. The challenge of micropollutants in aquatic systems. **Science**, 313(5790):1072–1077, 2006.

SSM - Secretaría de Salud de México. **Norma oficial mexicana NOM-127-SSA1-1994.** Available at: <http://www.salud.gob.mx/unidades/cdi/nom/127ssa14.html> Access July 18, 2016.

START. **START: A Practical Guide** (2008). Available at: <http://www.start-project.de/downloads/start_Practical_Guide.pdf > Access: June 24, 2016.

UE - União Europeia. **Diretiva 1998/83/CE**. Available at: < http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:330:0032:0054:pt:PDF > Access June 20, 2016.

USEPA - United Stated Environmental Protection Agency. **National Primary Drinking Water Regulations/2009.** Available at: <https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf> Access June 22, 2016.