REVISTA Mundi
Meio Ambiente e Agrárias
INSTITUTO FEDERAL
Paraná

ENVIRONMENTAL ANALYSIS OF URBANIZED RIVER BASINS IN SUBTROPICAL AREAS BASED ON THE WATER QUALITY INDICATOR (WQI), ENVIRONMENTAL LEGISLATION AND MANAGEMENT PLAN

ANÁLISE AMBIENTAL DE BACIAS HIDROGRÁFICAS URBANIZADAS EM ÁREAS SUBTROPICAIS COM BASE NO ÍNDICE DE QUALIDADE DA ÁGUA (IQA), NA LEGISLAÇÃO AMBIENTAL E NO PLANO DE MANEJO

Creir da Silva[1]

Stella Alonso Rocha[2]

Filipe Andrich[3]

Leilane Talita Fatoreto Schwind[4]

Máriam Trierveiler Pereira[5]

Abstract: Water is essential for the development of human life. Since the waters have very diverse quality characteristics, we must differentiate their natural characteristics from those resulting from human action. For such purpose, a series of parameters are used to determine water quality, incorporating them into indexes, such as the Water Quality Index (WQI). Our study aims at analyzing the quality of the waters of rivers destined for capture for urban supply and rivers destined for the release of treated sewage in regions with and without monitoring stations or management plans in subtropical regions. The rivers analyzed by WQI in Brazil, in the municipality of Umuarama, were the Piava and the Pinhalzinho Segundo; and in Portugal, in the city of Porto, the rivers Ave, Leça and Douro. For the Piava, water quality was from bad to good. In the Pinhalzinho Segundo, the WQI varied from regular to bad. In Porto, both Ave and Leça presented regular water quality. For the Douro, the indexes obtained were regular to good. The values obtained by analyzed parameters were corroborated by the maximum values allowed by the legislation, for Brazil, and by the Water Institute, for Portugal; however, none of the analyzed rivers are fully within the allowed thresholds. The Piava has the Area of Environmental Protection (AEP) Management Plan, but the river still suffers from problems related to land use and occupation, which directly affect water quality and availability. The Pinhalzinho Segundo, in some parts, is grounded and the lack of AEP, together with the soil characteristics of the region, may have contributed to the water quality. The Portuguese rivers have a Hydrographic Basin Plan; however, their application should be more efficient, especially in the Rivers Ave and Leça. The management plan in the Douro is more efficient than in the other two rivers.

Keywords: Sustainable Development. WQI. Water quality. Rivers.

[1]Mestra em Sustentabilidade, Instituto Federal do Paraná, creirdasilva@gmail.com
[2]Doutora em Engenharia Química, Instituto Federal do Paraná, stella.rocha@ifpr.edu.br
[3]Doutor em Ciências Biológicas, Instituto Federal do Paraná, filipe.andrich@ifpr.edu.br
[4]Doutora em Ciências Ambientais, Universidade Estadual de Maringá, leschwind@gmail.com
[5]Doutora em Engenharia Química, Instituto Federal do Paraná, mariam.pereira@ifpr.edu.br

Resumo: A água, essencial para o desenvolvimento, é usada praticamente em todas as atividades humanas, sejam elas urbanas, industriais ou agropecuárias, e dependente substancialmente de sua distribuição. Devido à diversidade de sua qualidade, torna-se indispensável diferenciar as suas características naturais daquelas conferidas pela ação do homem. Assim, parâmetros são utilizados para determinar a qualidade da água, incorporando-os em índices, como o Índice de Qualidade da Água (IQA), composto por nove indicadores. O objetivo deste trabalho foi analisar a qualidade das águas dos rios destinados à captação para abastecimento urbano e dos rios destinados ao lançamento de esgoto tratado em regiões com e sem estações de monitoramento ou plano de gestão em regiões subtropicais. Os rios analisados no Brasil, em Umuarama-PR, foram o ribeirão Piava e o córrego Pinhalzinho Segundo; e em Portugal, no Porto, os rios Ave, Leça e Douro. Os dados obtidos foram submetidos ao cálculo do IQA. Para o ribeirão Piava, a qualidade da água ficou nas faixas de ruim a bom. No córrego Pinhalzinho Segundo, o IQA variou de regular a ruim. No Porto, o rio Ave apresentou qualidade de água regular, assim como o rio Leça, e o rio Douro, de regular a bom. Os valores obtidos pelos parâmetros analisados foram corroborados com os valores máximos permitidos pela legislação nacional, para o Brasil, e pelo Instituto da Água, para Portugal, entretanto, nenhum dos rios analisados estão totalmente dentro dos limiares permitidos. O ribeirão Piava, apesar do Plano de Manejo da APA, ainda apresenta problemas relacionados ao uso e ocupação do solo. O córrego Pinhalzinho Segundo, apresenta algumas áreas assoreadas e a inexistência da APP. Os rios portugueses apresentam Plano de Bacia Hidrográfica (PBH), entretanto o seu cumprimento precisa ser mais eficiente, sobretudo nos rios Ave e Leça, sendo o plano de gestão no Douro mais satisfatório.

Palavras-chave: Desenvolvimento Sustentável. IQA. Qualidade de água. Rios.

1 INTRODUCTION

Water is essential for the development of human life, since virtually all human activities, whether urban, industrial or agricultural, depend substantially on the water distribution. In this sense, people have used water not only to meet their metabolic needs, but also to maintain their stay in the city (urban water supply, sanitary and industrial sewage, electricity generation, navigation and leisure) (BRAGA et al., 2005). However, the demographic explosion and the consolidation of the urban lifestyle occurred without planning, control of land use/occupation and implementation of adequate infrastructure, reflecting on the degradation of surface waters – rivers (CERQUEIRA, 2008).

Data provided by the World Water Assessment Program (UNESCO), global demand for water has increased at a rate of approximately 1% per year due to population growth, economic development and changes in consumption patterns, among other factors, and will continue to increase at a similar rate until 2050 (WWAP, 2019). As a way of monitoring national policies, monitoring water quality is essential for assessing the situation of aquatic ecosystems and the need for their recovery and protection; the availability of water for human and animal consumption; in addition to water security, since downstream rivers can be sources of water for other urban or rural settlements (UN, 2018). However, according to Braga, Porto and Tucci (2015), this monitoring is still insufficient.

Therefore, our study is justified by the relevance of the theme, aiming at the evaluation of the importance of an integrated management of water resources in urban regions, composed of a river monitoring network and a management plan. Moreover, our study is consistent with the United Nations Sustainable Development Goals (SDGs), which were established as an incentive for countries to seek sustainability. In this perspective, our study is directly related to SDG 6 (clean water and sanitation), SDG 11 (sustainable cities and communities) and SDG 14 (life in water), besides associating indirectly with the others.

Thus, our study sought to analyze the quality of the waters of the rivers destined for capture for urban supply and rivers destined for the release of treated sewage in two distinct subtropical regions, which, although they are medium in size and serve a local population between 100 and 500,000 inhabitants, present divergences regarding monitoring the water quality of their urban rivers and the management of water sheds by management plan. Moreover, we sought to compare, based on the Water Quality Index, the influence of monitoring and the existence of a management plan on the environmental conditions of rivers in these different regions.

2 METHODOLOGY

2.1 Characterization of study areas

2.1.1 Umuarama

Umuarama is located in southern Brazil and has a humid subtropical climate (Cfa, Köppen-Geiger classification) (NITSCHE et al., 2019). The municipality of Umuarama is located in the northwest mesoregion of the State of Paraná, at geographic coordinates 23° 45’ 59” S and 53° 19’ 30” W, with an average altitude of 442 m above sea level and territorial area of 1,234,254 km2 (IPARDES, 2020). Umuarama has an estimated population of approximately 111,000 inhabitants (IBGE, 2019) and a population density of 90.38 inhabitants/km2 (IPARDES, 2020). Regarding the water supply, 47,992 units with 42,292 sewage connections are served in the municipality (IPARDES, 2020).

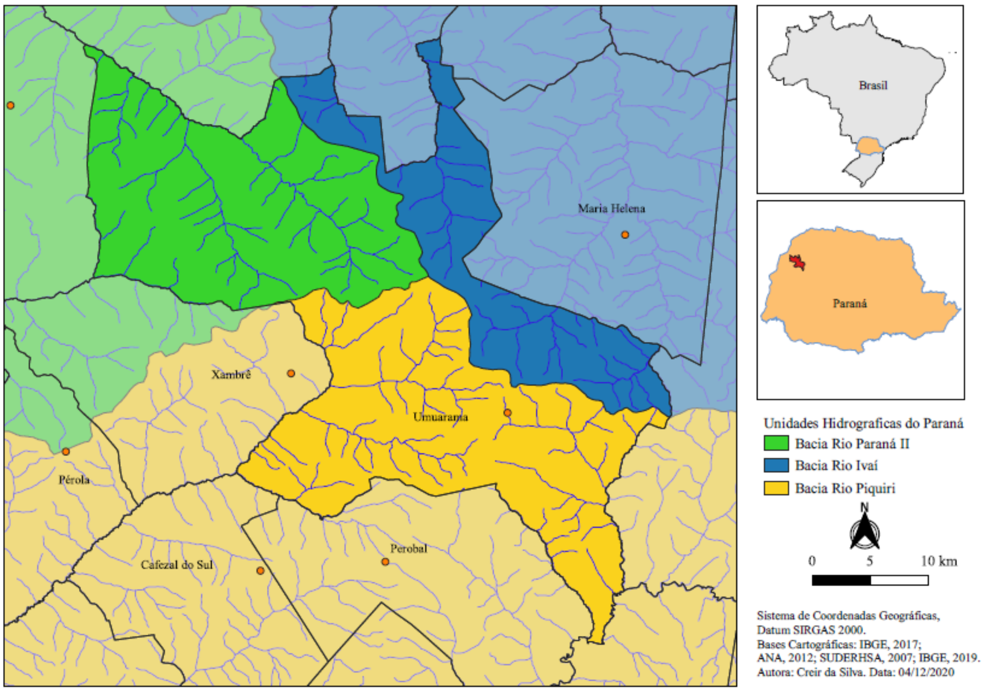
The municipal limits of Umuarama are located in three hydrographic basins of the state of Paraná: the Ivaí river basin (lower Ivaí), the Piquiri river basin and the Paraná river basin (Paraná 2) (PEREIRA & SCROCCARO, 2010; IPARDES, 2017) (Figure 1).

According to the Low Ivaí and Paraná I Hydrographic Basin Plan (AGUA PARANÁ, 2016), the municipality of Umuarama presents a fluviometric, sedimentometric and water quality station with available data installed in the

Piava River Basin. However, the data series available for this station dates from 2007; therefore, there is no information on the quality of the water on site.

The Piava river basin is a basin covers the municipalities of Umuarama and Maria Helena, and its main spring is close to the urban area of Umuarama and its mouth in the rural area of Maria Helena (SNIRH, 2020). The Piava river has an extension of 68.35 km (UMUARAMA, 2013), altitude between 365 and 503 meters (UMUARAMA, 2013).

Figure 1 – Hydrographic basins of the municipality of Umuarama



Source: Umuarama (2013)

The river has no fully urban affluent; however, the springs of Jaborandi, Jaboticaba, São Paulo and São João rivers are bordered by the urban settlements of Umuarama and Maria Helena. The Antas, the Ivaí and the Paraná rivers correspond to the water route of the Piava (SNIRH, 2020).

The municipality of Umuarama has a water deficit of 0.102 m^3/s, which is related to the capture of water in the Piava river for urban supply. The water demand for public supply is 979.1 m^3/h (ÁGUAS PARANÁ, 2016).

The Pinhalzinho Segundo river basin covers part of the municipalities of Umuarama and Cruzeiro do Oeste (Junior, 2010). With an approximate area of 182 km^2 (Souza & Gasparetto, 2012; Junior & Dalla Villa, 2013), it comprises much of the urban area of Umuarama, about 15 km^2, with an average altitude of 430 meters (Junior, 2010) and flow of 0.326 m^3/s (ANA, 2017). Pinhalzinho Second has nine affluents. The Prata, Mimosa, Figueira and Longe rivers are exclusively urban (SNIRH, 2020).

The Pinhalzinho Second rises in the city of Umuarama and has as water route the Goioerê, which flows into the Piquiri, which, in turn, overflows into the Paraná (Junior, 2010; SNIRH, 2020). The extension of the canal of the Pinhalzinho Second is 27.8 km (DALLA VILLA & GASPARETTO, 2010).

2.1.2. Porto

The city of Porto, in the northern coast of Portugal, has a Mediterranean climate of fresh summer (Csb) (Peel et al., 2007). Its geographic coordinates are -8.61024 41° 9' 0" N, 8° 36' 37" W, with an average altitude of 83 m.

The city covers a territorial area of 41.42 km^2 and is approximately 313 km from the capital, Lisbon (PORDATA, 2018). Umuarama has a population of approximately 214,353 inhabitants (IBGE, 5,736.1) and a population density of 5,736.1 hab/km^2 (PORDATA, 201)). According to PORDATA (2017), wastewater treatment plants serve 100% of the population of Porto.

The city of Porto is bordered to the south by the River Douro. The city of Matosinhos, in the Metropolitan Area of Porto (MAP), is cut by the Leça. For the management of water resources, the Leça belongs to the Hydrographic Region 2, of which the Ave is also part, further north. Thus, to characterize the water resources, the rivers studied were: i) the Douro river, belonging to the Douro river basin, which has on its right bank, near the mouth, the city of Porto and serves both for the capture of water and for the release of treated sewage from the city (APA, 2016b); ii) the Leça river, belonging to the Leça river basin, with the city of Porto on its left bank, partially covered by the basin, which receives treated sewage from the cities that border the riverbed; and iii) the Ave river, with sewage release in the surrounding municipalities (APA, 2016a; SNIRH, 2018a) (Figure 2). All aforementioned aquatic environments of Porto have water quality monitoring stations installed and in operation (SNIRH, 2013).

According to APA (2016b), the Douro river basin is located in the northern region of Portugal, has a total area of 97,477.66 km^2, of which 18,587.85 km^2 is in Portugal (19.07%) and 78,889.00 km^2 in Spain (80.93%). The Douro river rises in the Urbion Mountain (Iberian mountain range), in Spainand flows into the Atlantic Ocean in the city of Porto, Portugal. All Douro affluents rise in the mountainous systems that surround the basin.

Figure 2 - Location of the studied watersheds

Source: ICETA (2004)

In the Douro Hydrographic Region the resident population, 1,146,669 inhabitants, is concentrated in the metropolitan area of Porto and adjacent cities (APA, 2018b).

In the Douro hydrographic basin, the highest concentration of wastewater treatment plants is located in the final stretch of the basin, covering the cities of Porto, Gondomar, Vila Nova de Gaia and Valongo (APA, 2018b).

For quantitative pressures, the estimated volume of captured water per year was approximately 8,445,205.5 m^3/h, and about 99% of the volume return to the water body (APA, 2016b).

The Leça rises in Monte de Santa Luzia Hill at about 420 meters of altitude, traveling 48 km to its mouth in the Atlantic Ocean. The main affluents of the Leça are the Arquinho and the Leandro rivers. Covering eight units, the basin has an area of about 185 km^2. In the Leça river basin reside about 588,482 inhabitants (based on the population residing in HR2) (APA, 2018a). In the estuary of the Leça, all banks are occupied with port facilities, and the natural areas are non-existent (APA, 2016a). The polluting activities for the Leça river basin are industrial units linked, fundamentally, to the textile sector, and the main specific polluting activities come from urban, domestic, industrial and intensive livestock effluents (APA, 2016a).

Both the Leça and the Ave river basins, for the management of water resources, belongs to The Hydrographic Region 2 (HR2), from which a volume of water of approximately 58,980,000 m^3/h is captured for urban supply. Of all water captured, 96% of the volume returns to water resources (APA, 2016a).

In this HR, secondary-grade treatment systems predominate, with about 79% of infrastructures serving medium-sized population clusters. In the Leça basin, the main Wastewater Treatment Plants (WTP) are located in the marginal areas of the river (APA, 2016a).

The Ave rises in Spain and travel about 85 km until it flows into the Atlantic Ocean in Portugal. Its most significant affluents are the Vizela and the East rivers. The hydrographic basin (HB) of the Ave occupies an area of 1,391km^2 (APA, 2016a), incorporating, either partially or totally, sixteen Portuguese municipalities computing a population of about 712,984 inhabitants (APA, 2018a).

The course of the Ave presents the same polluting activities of the Leça river basin, because the data arranged refer to the same Hydrographic Region (HR2). It was not possible to obtain the polluting activities only for the hydrographic basin of each river, since the document guide the evaluation presents the integrated data.

2.2 Sampling

2.2.1 Umuarama

The samples were collected according to NBR 9898 – Preservation and sampling techniques of liquid effluents and receiving bodies (ABNT, 1987b), after sampling planning as determined by NBR 9897 (ABNT, 1987a).

Eleven collection points were determined, seven points in the Pinhalzinho Segundo and four points in the Piava. Urban interventions on the banks and in the river were analyzed for the disposal of the collection points. Samples were collected in different periods: rainy (second half of 2018) and drought (first half of 2019).

2.2.2 Porto

The samples were collected according to the guide of the Associação de Laboratórios Acreditados de Portugal (RELACRE, 2017), being determined fourteen collection points, five points on the Douro, four on the Leça and five on the Ave. The collection points in the Ave and Leça rivers are located in the Metropolitan Area of Porto. The Douro, the largest river in extension and flow analyzed in this study, presents all the collection points in the city of Porto.

To determine the collection points, possible human interventions in watercourses were considered (such as constructions in the banks, industrial zones, effluent release, water catchment, among others). The rivers analyzed in the MAP cover the cities of Porto, Santo Tirso, Trofa, Vila do Conde, Maia and Matosinhos.

2.3 Physicochemical, chemical and microbiological analyses

2.3.1 Umuarama

The water samples were analyzed according to the parameters established in the WQI by the methodologies of the Standard Methods for the Examination of Water and Wastewater (APHA) and the Brazilian Association of Technical Standards (ABNT).

The pH, water temperature, dissolved oxygen (DO) and electrical conductivity were determined at the collection sites, with an Aquaread Model AP-700 & AP800 multiparameter probe.

Water aliquots were also collected in 500 mL amber bottles previously sterilized, for subsequent determination of turbidity (Polycontrol Turbidimeter Model AP2000), nitrogen and total phosphorus concentration (spectrophotometric method, with acid digestion, according to NBR 13796 and NBR 12772 respectively and determination in UV spectrophotometer/Vis Edutec Model EEQ-9005), biochemical oxygen demand, total residue and fecal coliforms. They were transported to the Biology Laboratory of the Federal Institute of Paraná (IFPR), packed in a refrigerator Eletrolux Model DF36A at 4°C to perform the analyses.

To quantify the biochemical oxygen demand, the BOD5.20 method was used, according to NBR 12614 (ABNT, 1992) with incubation in BOD Lucadema Model B.O.D. LUCA-161/02 and reading of oxygen concentration in a multiparameter probe Aquaread Model AP-700 & AP800. The total residue was obtained by the gravimetric method, according to NBR 10664 (ABNT, 1989) with volatilization in a drying oven Quimis Model Q317M-63 and determination of weight in analytical scale JKI Model JK-EAB 2204N.

The quantification of thermotolerant coliforms (TC) was determined by the multiple tube technique and Most Probable Number – MPN, according to CETESB l5.202 methodology (CETESB, 2018) with sterilization of materials and media in phoenix Luferco vertical autoclave model AV30, inoculation in vertical unidirectional flow Veco Model FUV06 and incubation in bacteriological greenhouse New Instruments Model NI1522, for collection 1; and by filter membrane technique: determination of Escherichia coli, CETESB L5.230 (CETESB, 2012), using the aforementioned equipment for sterilization, inoculation and incubation, for collection 2. The data obtained by the filter membrane technique, in CFU/100 mL, were converted into NMP/100 mL, applying a correction factor of 1.25 (CETESB, 2019).

2.3.2 Porto

The samples were analyzed according to the parameters established in the WQI by the methodologies of the Standard Methods for the Examination of Water and Wastewater (APHA, 1999) and methodologies of the equipment used by the Associate Laboratory for Green Chemistry, of the Chemical Reaction and Analysis Group (GRAQ, of the Polytechnic of Porto – School of Engineering (ISEP), in Porto.

During the collections, dissolved oxygen and water temperature were determined in the environments, with consort oximeter Model C562 and Thermocouple Testo 922.

The analyses of pH, turbidity, total residue, total nitrogen, total phosphorus, BOD and thermotolerant coliforms were determined in the laboratory. To determine the pH, a potentiometric method was used with measurement in pHmeter Consort Model C5020, methodology of the equipment. For turbidity, the nephelometric method 2130 B APHA (APHA, 1999) was used with spectrophotometer analysis Hach Model DR 2000. The total residue analysis was developed using gravimetric method 2540 B APHA (APHA, 1999) in JP Selecta heating oven and analytical scale Mettler Toledo New Classic Model MS 205 DU. For total nitrogen, a Shimadzu Model TNM-1 Total Nitrogen Measurement Unit was used, coupled to a Shimadzu Total Organic Carbon Analyzer Model TOC-V CSN, by the methodology of the equipment, with sample filtration. The total phosphorus content was determined according to the method 4500 P. B APHA (APHA, 1999) with detection in spectrophotometer Hach Model DR 2000. The reading was performed in the range of 880 nm.

BOD was determined using the 5210 D respirometric method (APHA, 1999) with Oxitop WTW Model 156 sensor and WTW Model TS 601/2 incubator. Thermotolerant coliforms were quantified by the filter membrane method.

2.4 Water Quality Standards

To determine water quality, the Water Quality Index (WQI) was estimated, according to CETESB (2019).

For the analysis of water quality standards, in each country the adopted legislation was followed. In Umuarama, the Piava river belongs to the Ivaí river basin and according to SURHEMA Ordinance No. 019/92, of May 12, 1992, is classified as class 1 (PARANÁ, 1992). The Pinhalzinho Second has its framework based on Surhema Ordinance No. 017/91, of November 1, 1991, for the watercourses of the Piquiri river basin, being class 2 (PARANÁ, 1991). The maximum allowed values of the parameters analyzed were verified in CONAMA Resolution No. 357/05 according to the river classes.

The rivers of Portugal are classified according to System B of the Water Framework Directive (establishing a Framework for Community Action in the Field of Water Policy for the European Union) (EUROPEAN UNION, 2000). This system considers mandatory and optional factors for the classification of water bodies. Ave and Leça are classified as rivers of the North of medium-large size, and the Douro as river of North of large size (INAG, I.P., 2008). The rivers of northern Mainland Portugal have maximum thresholds for physical-chemical parameters that classify the river water in good class (Table 1).

Table 1 has only the limits for the parameters analyzed in the Ave, Leça and Douro. We only could compare these four parameters, because the others have no specified the values due to the lack of historical data at the national level (INAG, I. P., 2009).

Table 1 - Maximum limits for general physical-chemical parameters for the establishment of good ecological status in rivers

Parameter	Limit to good condition
pH[(1)]	between 6 and 9*
Dissolved oxygen[(1)]	≥5 mg $O_2.L^{-1}$
Biochemical Oxygen Demand (BOD_5)[(1)]	≤ 6 mg $O_2.L^{-1}$
Total phosphorus[(2)]	≤ 0.10 mg P. L^{-1}

[(1)] 80% of the samples if the frequency is monthly or higher; [(2)] annual average; * the indicated limits may be exceeded if they occur naturally. **Source:** INAG, I. P. (2009)

3 RESULTADOS E DISCUSSÃO

3.1 Study of rivers

3.1.1 Umuarama

Table 2 shows the results obtained by sampling point and WQI parameter.

For TC, the values of the first and second collection were discrepant. This can be explained by the use of different analytical methods. The technique of multiple tubes for the determination of thermotolerant coliforms, used in the first collection, estimates the amount of coliforms by the NMP/100 mL index limited to the value of > 1600. The filter membrane technique is precise in determining the amount of coliforms, as it quantifies the Colony Forming Units (CFU). This was necessary because in collection 2, dry season, the amount found of fecal coliforms (FC) was much higher due to the lack of dilution in the body of water.

The DO values obtained at the end of the $BOD_{5.20}$ analysis of points 1PR1 and 2PR1 and point 1PSR2 were higher than that initially measured. This may have occurred due to the presence of microorganisms capable of oxidizing nitrogen matter, within five days, water contaminants and/or the presence of light that stimulates the production of oxygen by the algae present in the samples (ABNT, 1992). Thus, the BOD values 5.20 of the downstream points were used to enable the estimate of the WQI of these points.

Table 2 - Results of the WQI parameters for the Piava and Pinhalzinho Second Rivers

Site	T (°C)	pH	TU (NTU)	TR (mg/L)	DO (mg/L)	BOD (mg/L)	P_{total} (mg/L)	TC (NMP/100mL)
Piava River (PR)								
Colletion 1								
1PR1	20.8	7.6	0.29	304	6.8	2.7	0.134	1600
2PR1	22.7	6.5	8.77	304	0.2	2.7	0.134	220
3PR1	22.6	7.8	45.45	235	10.4	2.7	0.062	49
4PR1	22.7	8.2	27.2	206	8.5	7	0.054	14
Colletion 2								
1PR2	18.3	7.66	35.8	32	9.9	4.45	0.036	19375
2PR2	-	-	-	-	-	-	-	-
3PR2	19.4	7.5	97.65	193	10	4.4	0.149	7750
4PR2	19.4	7.96	6.88	30	10.2	5.4	0.053	8125
Pinhalzinho Second River (PSR)								
Colletion 1								
1PSR1	22.6	5.7	2.26	176	2.1	5.8	0.024	18
2PSR1	23.2	7	32.1	315	3.1	5.8	0.05	170
3PSR1	23.3	7.2	5.77	288	3.4	5.8	0.177	1600
4PSR1	23.3	7.7	9.39	262	5.5	3.8	0.456	920
5PSR1	23	7.5	17.45	268	5.1	3.7	1.227	350
6PSR1	22.6	7.3	20.2	281	2.5	2.6	0.491	14
7PSR1	22.1	7.3	17.7	233	3.8	2.3	0.182	280
Colletion 2								
1PSR2	22.4	6.26	20.4	110	3.3	2.3	0.263	400000
2PSR2	22.9	7.92	13.8	186	8.7	2.3	0.241	300000
3PSR2	22	7.97	44.85	287	11.5	7.6	0.356	1500000
4PSR2	22.4	7.74	112	204	8.4	7.3	0.563	2200000
5PSR2	21.8	7.58	110	24666	9	8.6	1.916	10200000
6PSR2	21.3	7.4	171.5	278	6.8	6.6	0.861	1800000
7PSR2	21.3	7.7	149	180	2.9	2.8	0.554	600000

Meets CONAMA 357/05 standards	Does not meet CONAMA 357/05 standards

T: Temperature; pH: Hydrogenionic Potential; TU: Turbidity; TR: Total residue; DO: Dissolved Oxygen; BOD: Biochemical Oxygen Demand; $P_{total:}$ Total phosphorus; TC: Thermotolerant coliforms. *Total residue value adopted from the downstream point; **BOD value$_{5.20}$ adopted from the downstream point; *** Total Phosphorus value adopted from the downstream point; ****Corrected value (correction factor 1.25). **Source:** Authors' organization

For the parameters total residue and total phosphorus, the values allowed for Point 1PR1 refer to the downstream point due to failures in the realization of the methodology. The total nitrogen parameter in the samples could not be determined due to problems in the execution of the ABNT - NBR13796 methodology.

Point 2PR refers to the Jaborandi spring. In collection 2, we found that the spring is intermittent, and it was not possible to collect water for the analyses, making it impossible to determine the WQI. In intermittent springs, currents occur only at certain periods, that is, they flow during rainy seasons, but dry during part of the year (dry season) (WMO, 2012).

Based on the maximum values allowed by CONAMA Resolution No. 357/05 for class 1 and 2 rivers (Brasil, 2005), the parameters were classified as to the attendance or not of the required standards. The values that meet the resolution are represented in green and those that do not meet in red. For temperature, there are no specifications in the resolution regarding the ideal value for each class, only the requirement that the temperature of mixing effluents with the water body does not exceed 3ºC of the temperature of the water body. Likewise, for TR, the analysis is qualitative, that is, it cannot be perceptible to vision, smell and taste. The results indicate that all pH values are in accordance with the standards. For turbidity, some results were above the maximum values (Points 3PR1, 3PR2, 4PSR2, 5PSR2, 6PSR2 and 7PSR2).

Considering the dissolved oxygen parameter index required for class 1 rivers, Point 2PR1 presented a value of 0.2 $mg.L^{-1}$ O_2, this being the worst DO value found during campaigns. The other Piava points, in collections 1 and 2, met the resolution requirements. In the Pinhalzinho Second, the OD of points 4PSR1, 5PSR1, 2PSR2, 3PSR2, 4PSR2, 5PSR2 and 6PSR2 presented values above 5 $mg.L^{-1}$ (minimum value, class 2). DO in rivers is used by river fauna and aerobic microorganisms for its maintenance. The decrease in the concentration of this parameter occurs mainly due to the high concentrations of organic matter (Guedes; Teran; Guedes, 2019). The withdrawal of this oxygen to stabilize organic matter (which occurs by the respiration of putrefactive bacteria) is determined by BOD analysis (Von Sperling, 2005).

The BOD admitted by resolution is 3 and 5 mg. L^{-1} O_2, for classes 1 and 2, respectively. The points that met CONAMA specifications n°357/05 (Brasil, 2005) for BOD were: 1PR1. 2PR1, 3PR1, 4PSR1, 5PSR1, 6PSR1, 7PSR1, 1PSR2, 2PSR2 and 7PSR2. The other points exceed the maximum value. Very high BOD values give the riverbed a DO deficit.

The total phosphorus present in most of the points did not meet the standards of the ordinance, presenting higher values, which may indicate an illegal sewage dumping, and fertilizer and pesticide leaching in the river basin. Phosphorus in rivers comes mainly from the high concentration of organic matter and, together with nitrogen, it is responsible for the water body eutrophication when both present high concentration (TUNDISI & MATSUMURA-TUNDISI, 2008).

There were an expressive amount of thermotolerant coliforms in the bed of the rivers. Points 3PR1, 4PR1, 1PSR1, 2PSR1, 4PSR1, 5PSR1, 6PSR1, 7PSR1 presented values within the limits established by CONAMA n°357/05 (BRASIL, 2005). The other points presented values significantly above the maximum allowed for both class 1 and class 2. Coliform group bacteria present in river water indicate sewage contamination, mainly due to the presence of the main bacterium of the Escherichia coli group, which is found mainly in the intestinal tract of warm-blooded animals (BRANCO et al., 2015).

Based on the analysis of compliance with the parameters established by CONAMA n°357/05 (BRASIL, 2005), the Piava and Pinhalzinho Second rivers do not belong in their respective classes, class 1 and class 2.

To determine the WQI at the points whose total nitrogen was not possible to determine, we used the value for this parameter (q) obtained from the phosphorus parameter (q) if its values presented with a maximum difference of 35 units. The maximum difference of 35 units only causes an expressive result after the second digit of precision, thus being classified by a satisfactory mathematical approximation. This feature has no possibility to change the water quality rating of the river.

After performing the analyses, the data were inserted in a table and the index estimated. Table 3 shows the WQI of the analyzed points.

The WQI of the points analyzed in the Piava are classified in the range from good to bad. In collection 1, Points 1 (Piava spring), 3 (downstream of the water catchment of the city of Umuarama) and 4 (mouth of the Piava) presented the best WQI, classified in the range of 51 < WQI ≤ 79, which indicates the water quality of the points as good. The second point (Jaborandi spring) obtained an unsatisfactory classification with a bad score. In collection 2, Points 1 and 3 were classified in the range determined as regular, 36 < WQI ≤ 51, and Ponto 4, good. Therefore, the WQI for Piava was between 35.25 and 62.86.

Table 3 – WQI of Piava

Site	Colletion 1	Classification	Colletion 2	Classification
Piava River (PR)				
1PR	52.33	Good	47.62	Regular
2PR	35.25	Bad	-	-
3PR	62.54	Good	43.42	Regular
4PR	62.86	Good	51.47	Good
Pinhalzinho Second River (PSR)				
1PSR	48.89	Regular	31.83	Bad
2PSR	45.65	Regular	35.93	Bad
3PSR	45.05	Regular	32.81	Bad
4PSR	45.94	Regular	33.89	Bad
5PSR	44.24	Regular	27.61	Bad
6PSR	42.83	Regular	29.26	Bad
7PSR	46.15	Regular	26.66	Bad

Source: Authors' organization

Piava, although it does not present direct urban anthropic interference in the main riverbed, is bordered by forestry activities and some springs of its affluents are located in the urban perimeter. These factors probably contributed to the WQI obtained. Between Points 2 and 3 is located the water catchment point of the city of Umuarama, and precisely between these points there is a significant disparity between the WQI estimated in the 2018 campaign. Since Point 2 corresponds to a source and further downstream this water body drains into Piava, there may have been a dilution of the parameters that consider the concentration, and the self-purification capacity of the river may have increased, thus resulting in the value of WQI obtained.

The 2019 campaign (dry season) was marked by the permanence of the collection points, especially in the classification as regular. This is probably due to the rainfall regime in the region. With lower rainfall in the winter months and higher in the summer. According to Alencar et al. (2019), during the months of higher rainfall, the parameters of pH, temperature, conductivity, dissolved oxygen and turbidity tend to decrease their concentrations and in the period of lower precipitation, the opposite occurs, these concentration values increase considerably. This disparity in parameter concentrations directly influences the WQI obtained.

The Piava, because it is a supply source of Umuarama, has had an Area of Environmental Protection Management Plan (AEP)) since 1998, with a final version published in 2013 (UMUARAMA, 2013). However, after 20 years, the river still suffers from problems related to land use and occupation, which directly affect water quality and availability. The river presents a water deficit and a long silting process, consequence of the lack of conservation of the banks, compromised riparian vegetation, lack of policies that protect the flooded bed and lack of environmental education for the population. In addition to the problems related to the amount of water, the results of this research showed that Piava presents regular to bad water quality. Thus, the water treatment process needs to be very efficient and, consequently, more expensive, so that the integrity of the population’s health is maintained, especially regarding water-delivery diseases.

For the Pinhalzinho Second, in collection 1, all points obtained the WQI with regular water quality classification. Point 1 spring of the Prata (Pinhalzinho contributor), presented the best WQI. For collection 2, all points of Pinhalzinho Second were classified as bad. Point 7 had the lowest index, with 26.66 being the worst result.

A better WQI index was observed in collection 2 probably due to the same reason already discussed for Piava, that is, in the dry season the quality of the river is impaired because there is no possibility of dilution of pollution. Unlike the Piava, the Pinhalzinho Second has no river basin management plan.

3.1.2 Porto

After the analysis, the data were inserted in a table and the results for the Douro, Leça and Ave by WQI parameter are in Table 4.

The results obtained in the analyses of the rivers of Portugal were classified according to the compliance with the maximum thresholds allowed per class. Table 4 shows the values within the specified for the class and in red, the values determined to obtain a good water quality are obtained in green, according to the specifications of the Water Institute of Portugal (INAG, I. P. 2009).

Table 4 - Results of WQI parameters for the Ave, Leça and Douro

Site	T (°C)	pH	TU (NTU)	TR (mg/L)	DO (mg/L)	BOD (mg/L)	N_{total} (mg/L)	P_{total} (mg/L)	TC (NMP/100mL)
Douro River (DR)									
1DR	13.7	6.7	10	2684	9.5	1.5	1.73	0.38	750
2DR	13.5	6.82	7	2835	9.15	6.5	2.9	0.45	3875
3DR	13.3	6.99	6.5	3564	9.3	3.5	1.69	0.355	875
4DR	13.3	7.11	6	3803	9.15	1	1.841	0.39	1000
5DR	14	7.35	5.5	8690	10.25	1	1.743	0.57	750
Leça River (LR)									
1LR	12.9	6.72	7.5	158.8	7.25	9.5	10.446	1.5	10000
2LR	12.7	7.04	8	193.7	6.7	12	11.116	1.035	10000
3LR	13.8	7.12	10.5	190.7	8.15	10	12.116	1.155	10000
4LR	14.2	7.25	13.5	256.4	7.9	1	13.376	1.29	10000
Ave River (AR)									
1AR	16.2	6.86	6.5	2897.3	8.2	8	3.831	0.85	4625
2AR	19.6	7.36	5.5	3358.3	9.75	4.5	4.38	0.925	3500
3AR	14.6	7.28	6.5	3640.2	9.35	6	3.888	1.04	2750
4AR	15.3	7.32	7	3531.4	8.9	9.8	4.87	1.08	13000
5AR	16.3	7.19	5	4949.2	8.95	6.6	5.568	0.955	8625

Meets the standards of the Water Institute of Portugal	Does not meet the standards of the Water Institute of Portugal

T: Temperature; pH: Hydrogenionic Potential; TU: Turbidity; TR: Total residue; DO: Dissolved Oxygen; BOD: Biochemical Oxygen Demand; $N_{total:}$ Total Nitrogen; P_{total}: Total phosphorus; TC: Thermotolerant coliforms. *Corrected value (correction factor 1.25). **Source:** Authors' organization.

The values obtained for the pH, DO, BOD and total phosphorus analyses were compared with the values determined for the rivers of northern Mainland Portugal and within the established range were the pH and DO values for all the analyzed points of the three rivers.

For BOD, whose recommended value for northern rivers is below 6 mg.L^{-1}, 50% of the analyzed points were below the limit, namely 1DR, 3DR, 4DR and 5DR, 4LR, 2AR, 3AR. All points of all rivers analyzed in Portugal presented total phosphorus values higher than the allowed (≤ 0.10 mg P.L^{-1}).

Except for some observations, to define these analyses of compliance with the values based on Table 1, some predeterminations should be considered, especially the frequency of collections. For our study, only one campaign was carried out, so the analysis described above elucidates only the situation of this river in this campaign.

In general, the water of the Ave, Leça and Douro rivers do not have a good environmental condition. Table 5 shows the WQI estimated for all points.

Table 5- WQA of the Ave, Leça and Douro River

Site	Douro River	Classification	Leça River	Classification	Ave River	Classification
1	51.68	Good	39.85	Regular	41.99	Regular
2	45.99	Regular	40.24	Regular	44.02	Regular
3	52.28	Good	40.86	Regular	45.01	Regular
4	51.88	Good	39.93	Regular	38.86	Regular
5	52.12	Good			40.62	Regular

Source: Authors' organizations.

In the Ave, all collection points presented regular water quality. Textile industries surround the banks of this river, which release their treated effluents and a large number of Wastewater Treatment Plants (WTP) into the riverbed. At the end of the 20th century, water from the Ave was considered inappropriate for consumption (MAP, 2009) and this condition did not show a considerable improvement.

The Leça points analyzed presented regular WQI, according to Table 4. The Leça riverbed is bordered by small towns and rural properties. In the initial stretch of the river, agricultural activities predominate and the stretch, where the collection points are located, is predominantly urban. The WQI values obtained may come from the anthropic activities that occurred in the Leça hydrographic basin. Of the points analyzed in the Leça, Point 1 presented the lowest WQI, 39.85.

As a way to mitigate and evaluate the pressures caused in the water bodies, the Ave and Leça rivers have the Hydrographic Region Management Plan – Cávado, Ave and Leça region, which guides the management of water resources of this region. This plan was proposed in three cycles, the first of which was in force from 2009 to 2015; the second, from 2016 to 2021; and the preparation of the third cycle for 2022 to 2027 (APA, 2019). Also for the Leça, a cooperation agreement was signed at the end of 2018 between the municipalities of Santo Tirso, Valongo, Maia and Matosinhos, aiming at conducting a study to qualify and value the Leça river corridor (MAP, 2018). These actions possibly contributed positively to the maintenance of the water quality of the rivers.

The WQI results for the points on the Douro (Table 5) show that only Point 2 presented regular water quality. The other points (Points 1, 3, 4 and 5) were classified as good and the WQI values were between of 51.88 to 52.28. Throughout the analyzed stretch there are installed several WTP, among them Crestuma-Lever, Gramido, Areinho, Febros, Tinto and Sobreiras, adding with the urban mesh installed on the banks of the river the main conditions for possible interferences in water quality.

4 FINAL CONSIDERATIONS

In our study, we analyzed urban rivers responsible for public supply and sanitary sewage in Brazil and Portugal. We found that some water analysis methodologies are different in Portugal, such as for total nitrogen (TN). This allowed the parameter to be analyzed in the samples collected in the Metropolitan Area of Portugal and streamlined the process.

Efforts of the countries, Brazil and Portugal, reflected in municipal efforts to achieve the SDGs. Municipal and regional managers must understand that water quality interferes with the quality of life of the population and the preservation of species. Actions to achieve the SDGs include all local initiatives for global sustainable development. Therefore, we expect that the results of our study contribute to this purpose.

The Piava and the Pinhalzinho Second rivers are water bodies of extreme importance for the city of Umuarama and their protection and preservation is essential for the quality of life of the population, ecosystems and the watercourse and downstream uses. Regarding the parameters of water quality for Piava and Pinhalzinho Second rivers, compared to CONAMA Resolution No. 357/2005, we observed the non-compliance with the maximum values allowed by the resolution. Therefore, rivers do not belong to classes to which they are classified.

We suggest some measures according to the analysis results. First, verifying the fulfillment of the actions established in the Piava Management Plan and providing updates based on the needs of water preservation.

Secondly, creating a Management Plan for the Hydrographic Basin of the Pinhalzinho Second, with actions to depolluting the basin, aiming at the recovery of natural conditions and the restoration of water quality.

For both rivers, municipal laws based on the principles of environmental protection-recipient and polluter-payer laws should be established. These laws may be applied for individuals or legal entities, to avoid contribution of anthropic pollution to the waters. In addition to non-structural measures, the possibility of institution of structural actions, such as the improvement of rain drainage and the implementation of linear parks on the banks of rivers, should be analyzed. This last option is already taking place in springs of the Pinhalzinho Second, which remained channeled for years, whose site had been transformed into a multi-sport complex. Currently, the site undergoes remodeling and implementation of a linear park in the first stretches of the river, Ipês Park.

Considering the analyses of the urban rivers of Portugal, the Douro, Ave and Leça rivers have a Hydrographic Region Management Plan, assuming the same criteria for validity for the three rivers. However, the management plan in the Douro is more efficient. Therefore, that the Leça and Ave need depollution actions and preservation plans.

Finally, water quality is conditioned by natural variables and anthropic impacts, so more effective water resource management actions based on water monitoring become increasingly necessary. An efficient management plan of water resources, obtaining adequate indicators, reflects in the good state of conservation of rivers and ecosystems in its surroundings.

5 ACKNOWLEDGEMENTS

The authors thank the scholarship provided by the Pro-Rectory of Extension, Research, Graduate and Innovation of the Instituto Federal do Paraná (IFPR) by Internal Notice No. 10/2018; and the Instituto Superior do Porto (ISEP), especially professors Cristina Maria Fernandes Delerue Alvim de Matos and Sonia Adriana Ribeiro da Cunha Figueiredo.

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