

Water from alternative supply sources in Paraná State: potability and map of vulnerable groups

Águas de fontes alternativas de abastecimento no Paraná: potabilidade e mapeamento de grupos vulneráveis

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ABSTRACT: The present study describes a survey based on data provided by the National Program of Water Quality Surveillance for Human Consumption, also known as *Vigiagua*, carried out between January 2020 and December 2022. Great challenges were observed in nine municipalities composing the 4th Health Regional of Paraná State. In total, 35.75% of all 2,078 analysis reports presented registration mistakes. Imbituva, Mallet and Rio Azul were the municipalities mostly affected by this issue. Quality of water significantly varied among municipalities; it showed high indices of both inconclusive or not-recorded reports in Inácio Martins, Teixeira Soares and Guamiranga. Fernandes Pinheiro was the municipality accounting for the largest number of non-compliant reports about water turbidity and contamination by *Escherichia coli*. The availability of Information about quality of water in alternative supply sources was limited, despite the large number of analyzed samples - some municipalities did not meet the standards set for *E. coli* presence. Based on cluster analysis, rural areas, and traditional peoples and communities, such as *faxinalenses* and indigenous peoples, are the most vulnerable ones.

Keywords: Quality of water; Environmental justice; Vigiagua.

RESUMO: O presente estudo realizou um levantamento de dados do Programa Nacional de Vigilância da Qualidade da Água para Consumo Humano (*Vigiagua*) de janeiro de 2020 a dezembro de 2022 e foram observados grandes desafios nos nove municípios que compõem a 4^a Regional de Saúde do Paraná. Dos 2078 laudos de análise da água registrados, 35,75% apresentaram erros no cadastramento, com municípios como Imbituva, Mallet e Rio Azul sendo os mais afetados. A qualidade da água variou consideravelmente, com altos índices de laudos inconclusivos ou não registrados em alguns municípios, como Inácio Martins, Teixeira Soares e Guamiranga. Em relação à turbidez e *Escherichia coli*, o município de Fernandes Pinheiro liderou em laudos fora do padrão. A disponibilidade de informações sobre a qualidade da água de fontes alternativas de abastecimento foi limitada, apesar do grande número de amostras analisadas, alguns municípios não atenderam aos padrões para *E. coli*. Conforme análise de agrupamento conclui-se que as áreas rurais e povos e comunidades tradicionais, como *faxinalenses* e povos indígenas, apresentaram maior vulnerabilidade.

Palavras-chave: Qualidade da água; Justiça ambiental; Vigiagua.

INTRODUCTION

Water is a fundamental element for life existence and maintenance; therefore, it plays key role in ecosystems' conservation, mainly for humans, since it is essential for their health and well-being, as well as for vital biological functions. High-quality water intake is paramount to ensure the conditions, and to protect individuals from different diseases, mainly from the water-associated ones, since they can be avoided. Although the Sanitation Legal Framework (Law 14.026/2020) ensured universal access to sanitation - i.e., the right of all citizens to have this service available, with quality and equity -, Brazil remains far from the adequate standards linked to this topic. Approximately 16% of the population does not have access to water supply services. This rate drops down to 4.6% in Paraná State; however, access to potable water in this state's municipalities is not leveled. Some municipalities in Paraná State, such as Rio Azul and Prudentópolis, which are in the state's Central-Western region, still have 40% of their population lacking access to water supply system.

Access to high-quality water in rural areas is even worse, due to issues related to distance to and lack of water resources in them. Alternative consumption sources, such as water springs, dug and artesian-flow wells, have been used by the population for water consumption purposes. It is so because treated water does not reach residences and other buildings. Ordinance n. 888/2021 classified alternative supply solutions into two classes: collective and individual. Alternative collective solution is a collective supply modality aimed at supplying drinking water without distribution networks. The alternative individual solution, in its turn, focuses on human consumption: it must supply water to residences housing a single family.

Quality of water can be expressed by several parameters capable of translating its main physical, chemical and biological features. One of the main water-pollution aspects regards hygiene factors associated with waterborne diseases. Bacteria belonging to the group of coliforms are used as fecal contamination indicators - species *Escherichia coli* is a reliable indicator, since it sets water potability standards for human consumption. Inappropriate sanitary sewage disposal is the main water-contamination source. Approximately 2.1 million people die every year due to intake of sewage-contaminated water - at global scale, approximately 1.8 billion individuals use water sources exposed to fecal microorganisms due to their supply needs, and 1.1 billion of them face mild contamination risk and 10% of the total consume high-risk water.

Potability recorded for the sources, mainly in rural regions, can reach alarming numbers - more than 70% of samples can be non-compliant with standards provided by law (Brasil, 2021). It is essential pointing out that, according to data provided by *Instituto Trata Brasil* [Treat Brazil Institute] (2019), women are the most affected individuals, because 1 in 4 women do not have access to potable water. This same study also showed that broad access to water and sanitation could take approximately 635 thousand women out of the poverty line, most of them black and young. Accordingly, *Trata Brasil* data evidenced that women who are self-declared brown, indigenous and black are the Brazilian population groups most suffering with damage caused by sewage-access inequities and by human-consumption water.

Studies about equal access to safe and high-quality water substantiate the efforts by the UN's General Assembly, which issued Resolution 64/292, from 2010, acknowledging access to potable water and basic sanitation as essential, fundamental and

universal human right, because it is indispensable for a dignifying life. This resolution opened room for at least three analysis fronts about the potable-water/human-dignity association. The first front points towards a management profile to access-to-water public policies based on equity and universality requirements. Universal access to safe water is a right of all, regardless of social class, race, ethnicity, gender, age, among other social markers. The second front regards potable water distribution and access, and it must follow risk stratification assumptions and the vulnerability of certain populations. The third front identifies water security shortage as one of the main human life precariousness indicators.

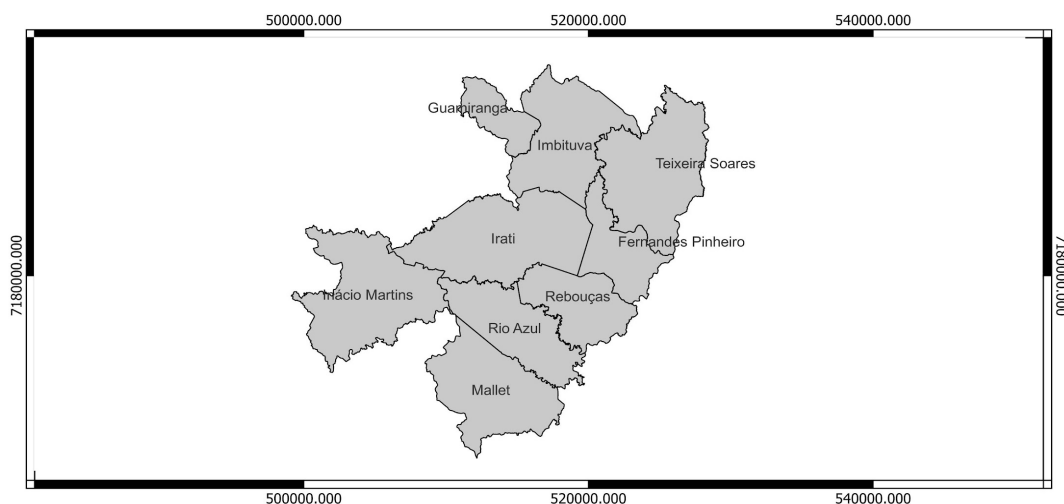
United Nation's guidelines (2010) are essential to the so-called Environmental Justice Social Movements, mainly when it comes to unbalanced distribution of both environmental impacts and access to natural resources. Assumingly, environmental justice is a democratic management movement that must include all social groups in decision-making about access and use of natural resources, regardless of their origin, income, social class, sex, race, or ethnicity. Environmental justice must mainly ensure that potential environmental damage does not stay limited to vulnerable populations. The concept of vulnerability implies thinking about acknowledging the interface of interrelated multiple individuals, social and programmatic/institutional variables in Brazil. Race and ethnicity, and gender issues are entangled to social determinants that, in their turn, feature vulnerable populations.

Accordingly, the aim of the present research was to map the potability of alternative water supply sources and the population consuming water from them in municipalities composing the 4th Health Regional in Paraná State.

MATERIALS AND METHODS

The following municipalities form the 4th Health Regional of Paraná State and were selected for the present study: Fernandes Pinheiro, Guapiranga, Imbituva, Inácio Martins, Irati, Mallet, Rebouças, Rio Azul and Teixeira Soares (**Figure 1**). Potability data and population features (sex and race/skin color) were collected in each municipality to map their water-access vulnerabilities.

Figure 1. Study site location.



Data about the potability of alternative water supply sources, as well as about the presence of total fecal coliforms, *Escherichia coli* (*E. coli*) and water turbidity were collected from the Panel for Water Quality Surveillance for Human Consumption, based on the January-2020/December-2022 timeframe.

Variables, such as sex and race/skin color of individuals living in each of the selected municipalities, were collected from IBGE's (2010) database.

Data analysis

The set of information about quality of water, gender, race-skin color, and violence against women was subjected to cluster analysis based on an algorithm, on PAM and on spatial analysis, according to Moran's Index. It was done to assess whether different clusters are formed due to municipalities, and to find what racial and gender groups are related to water samples that were non-compliant with potability standards. These analyses were carried out in Rstudio software.

RESULTS AND DISCUSSIONS

The National Program of Water Quality Surveillance for Human Consumption (Vigiagua) comprises a set of actions taken by public health authorities to ensure water access to the population at sufficient amounts and quality in compliance with potability standards provided by the legislation in force. Vigiagua System recorded 2,078 water-analysis reports from the herein assessed municipalities between January 2020 and December 2022. In total, 743 (35.75%) of these 2,078 reports presented registration mistakes: at least 1 of the parameters was not described in the report available in the database. Among municipalities recording the largest number of registration mistakes, one finds Imbituva, with 92% (only 21 samples out of 281), Mallet and Rio Azul (69% and 41% lack of registration, respectively), Rebouças (23%), Fernandes Pinheiro (17%), Irati (10%), Teixeira Soares (3%), Guamiranga (2%) and Inácio Martins with less than 1% registration (25 recorded reports out of the 35 issued ones).

The number of samples ranged from 35 (in Teixeira Soares) to 371 (in Fernandes Pinheiro). This finding is somehow explained by the size of the assessed territories and by their number of inhabitants, which is significantly different from one study site to another.

Overall, the assessed municipalities presented high heterogeneity in the number of samples contaminated with *E. coli*. The only standard observed in the collected data regards inconclusive or non-registered (mistaken) reports. Inácio Martins, Teixeira Soares, Mallet and Guamiranga municipalities presented more than 90% inconclusive or non-registered reports; Rebouças recorded 76%, i.e., more than half of municipalities presented inconclusive or non-registered reports. Irati and Fernandes Pinheiro recorded approximately 35% inconclusive or non-registered reports, whereas Imbituva reached 8% inconclusive or non-registered samples for *E. coli*. Thus, it is worth highlighting that impairments and mistakes linked to the process to record reports' results are common among municipalities joining Vigiagua Program, as well as mistakes related to surveillance of both water supply facilities and geo-referencing instruments, to lack of temporal reports and to poor integration between Vigiagua and Epidemiological Surveillance professionals.

Based on turbidity results, it is possible stating that the number of reports lacking results or presenting incorrect registrations (inconclusive) is significantly smaller than that

recorded for *E. coli*. Guamiranga, Inacio Martins and Teixeira Soares municipalities stood out for presenting lack-of-reports rate higher than 90%. Fernandes Pinheiro recorded the highest rate of non-compliant reports (32%).

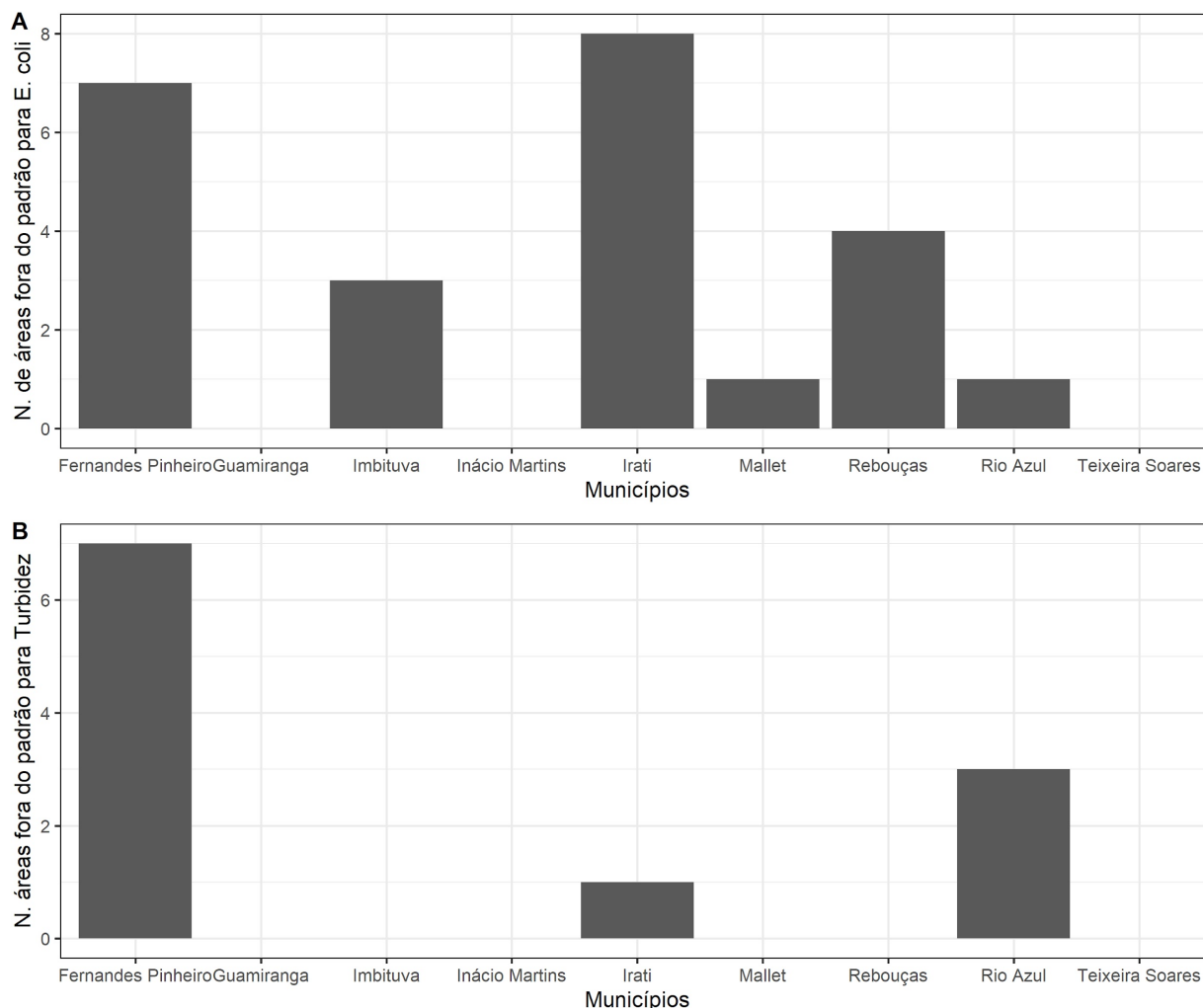
Based on the scenario depicted in **Table 1**, one can see that information about the quality of water from alternative sources in the herein assessed municipalities was low during the 2020-2022 timeframe, although the number of analyzed samples was significant.

Table 1. Mean rates recorded for the reports: inconclusive, absent, non-compliant and compliant. Parameters: *Escherichia coli* and turbidity in municipalities composing the 4th Health Regional of Paraná State.

Parameters	Counties	Inconclusive	Absent	Inappropriate	Adequate
<i>E. coli</i> (%)	Fernandes Pinheiro	20.63	16.27	44.65	18.45
	Guamiranga	90.98	1.23	2.46	5.33
	Imbituva	6.10	1.71	24.80	67.39
	Inácio Martins	98.62	0.19	0.00	1.19
	Irati	23.84	0.00	56.01	20.16
	Mallet	42.42	53.64	0.30	3.64
	Rebouças	67.24	12.92	6.96	12.88
	Rio Azul	9.65	34.62	19.54	36.20
	Teixeira Soares	99.05	0.00	0.00	0.95
Turbidity (%)	Fernandes Pinheiro	2.16	20.96	32.39	44.49
	Guamiranga	1.09	92.76	0.00	6.15
	Imbituva	91.77	7.38	0.00	0.85
	Inácio Martins	0.00	98.81	0.00	1.19
	Irati	13.37	23.84	1.74	61.05
	Mallet	23.18	71.21	0.00	5.61
	Rebouças	2.55	70.56	0.00	26.89
	Rio Azul	3.79	10.01	2.93	83.27
	Teixeira Soares	6.67	92.38	0.00	0.95

Figure 2 shows non-compliant samples for *E. coli* – it was recorded at least twice a month. They were classified as contaminated, based on GM/MS Ordinance n. 888/2021, according to which, only one sample among the assessed ones (in 1-month timeframe) can be positive to the presence of this group of bacteria. Guamiranga, Teixeira Soares and Inácio Martins were the only municipalities that did not report contamination by these bacteria. Teixeira Soares and Inácio Martins are also among municipalities that did not register these results or that have registered inconclusive results in more than 90% of samples. Guamiranga accounts for three reports about diarrhea caused by contaminated-water supply within the herein adopted timeframe.

Figure 2. Bar charts showing the number of sites contaminated by *Escherichia coli* and non-compliant turbidity in municipalities forming the 4th Health Regional of Paraná State.



Fernandes Pinheiro, Rio Azul and Irati are the municipalities showing non-compliant reports for *E. coli* and Turbidity. Contaminated sites are all rural; they belong to recently regulated communities or settlements. It is also important pinpointing an environmental protection area in the region that houses a *faxinal*.

Mendonça et al (2019) analyzed water microbiological quality in Bambuí City /Minas Geras State and found that mandatory assays were not carried out, just as it happened in the current study. Rios (2012) observed in his undergraduate thesis, back in 2022, that 70% of alternative individual solution and 27% of alternative collective solution in municipalities in Northwestern Rio Grande do Sul State were not in compliance with microbiological parameters.

Malheiros et al (2009) observed that 76% of the 212 samples analyzed in a study about water bacteriological quality in Western Santa Catarina State were inappropriate for human consumption – 95% of them presented total coliforms and 71% were contaminated with thermotolerant coliforms. Results in the current research showed low water quality,

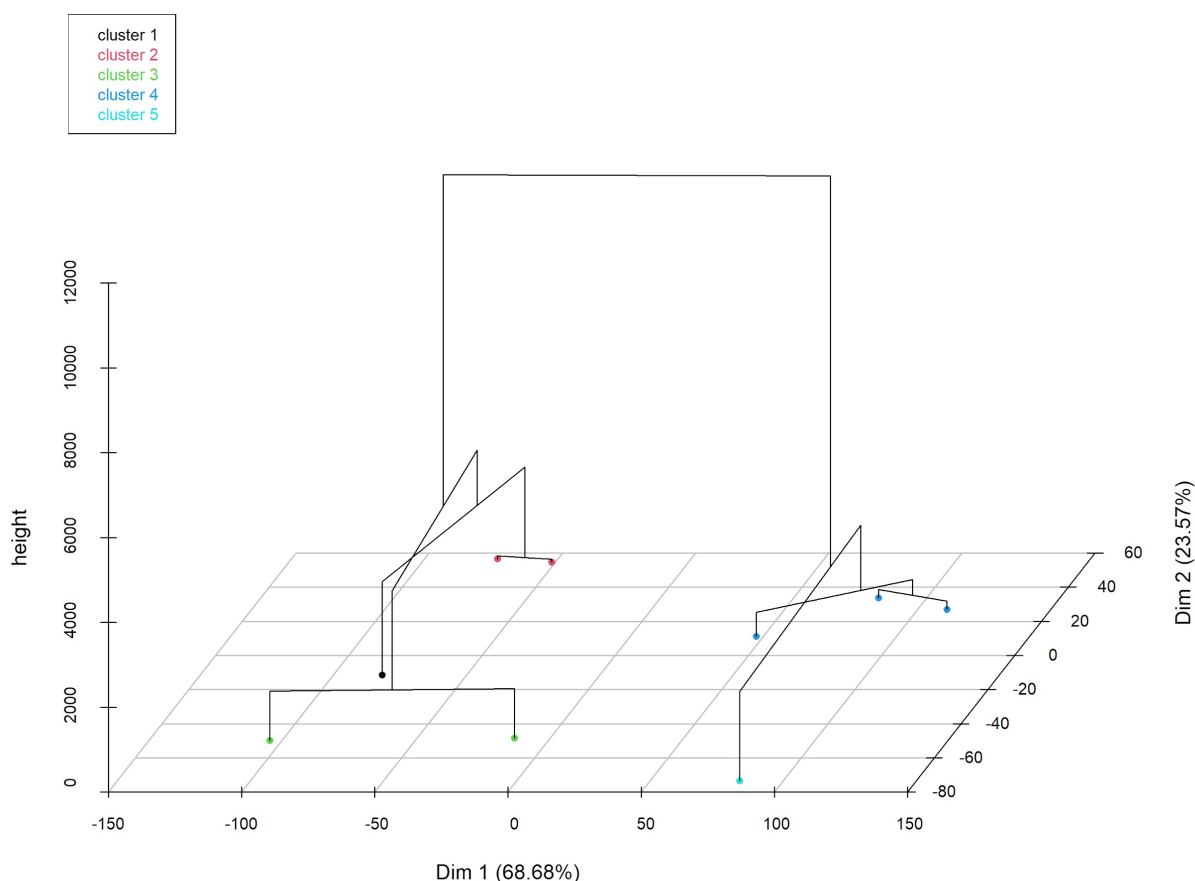
and hard time monitoring and recording data. This finding points towards the need of improving monitoring systems due to risk posed on the population's health.

Cardoso (2022) also carried out a data survey between 2014 and 2019 about the 4th Health Regional of Paraná State to assess water microbiological quality in municipalities that have joined his study. He found that most water samples collected in the assessed municipalities were non-compliant with the legislation in force. Furthermore, almost 60% of them were contaminated with *E. coli*.

Municipalities' clustering – based on quality of water reports and on variables linked to residents' race/skin color and sex – met study sites in 5 vulnerable groups (clusters). This finding was in compliance with the heterogeneity observed among the assessed municipalities (**Figure 3**).

Figure 3. Cluster analysis applied to municipalities composing the 4th Health Regional of Paraná State, based on the matrix of quality of water reports recorded for alternative sources and on socio-demographic and race-skin color data.

Hierarchical tree on the factor map



The first cluster comprised one single municipality: Imbituva (3), which is featured by homogeneous socio-demographic values and quality of water reports in comparison to the data set; cluster 2 comprises Inácio Martins and Teixeira Soares (4 and 9), and it is featured by the presence of indigenous populations, mainly of indigenous women, and by inconclusive reports for *E. coli* and Turbidity; cluster 3 encompasses Fernandes Pinheiro

and Rio Azul, and it is featured by the highest rates of non-compliant reports for turbidity. The fourth cluster comprised Mallet and Guamiranga (2 and 6), and these municipalities are featured by lack of turbidity data. Finally, the last cluster encompasses Irati municipality, which accounted for the highest rate of supply water contaminated with *E. coli*. Variables mostly influencing the clusters were 'indigenous women population' (= 0.91; $p < 0.1$), non-compliant reports for *E. coli* and turbidity ($r = 0.89$; $p < 0.01$) and inconclusive samples for *E. coli* and turbidity ($r = 0.88$; $p = 0.01$).

Based on the cluster analysis, the population of indigenous women faces vulnerable conditions when it comes to access to potable water.

Silva (2022) highlights that socio-environmental aspects have stronger impact on women, girls and feminized bodies than on men.

One can observe that women, due to their social gender accountabilities, which derive from the sexual division of labor, and to those reproduced by the contemporary capitalist society, in a contradictory way - entangled to social class relationships, and to racial and ethnic relationships – emerge as high vulnerability group because of precarious access to water and to its consumption (SILVA, 2022, p. 157).

Historically, women were prepared to the domestic environment; therefore, access to water significantly influences their lives. Black, indigenous, *quilombola*, peripheral women under vulnerability condition are the groups mostly affected by lack of access to good-quality water. Data about the herein assessed region corroborate such information. It is also important observing that, according to the present study, the female population, mainly that of indigenous women, is the one suffering with the strongest impact of environmental degradation and social injustice.

CONCLUSIONS

The analysis applied to Vigiagua Program in municipalities composing the 4th Health Regional of Paraná State, between 2020 and 2022, showed significant challenges for quality of water management. Registration mistakes were common in its municipalities, a fact that affected data reliability, mainly in Imbituva, Mallet and Rio Azul. There was broad variation in contamination by *E. coli* – inconclusive reports prevailed in Inácio Martins, Teixeira Soares, Mallet and Guamiranga. Turbidity values were also concerning, mainly in Fernandes Pinheiro. The availability of information about alternative water supply sources was limited. Based on results in the current study, only few municipalities have met the standards set for *E. coli*. Rural areas, and traditional and indigenous populations, were the ones mostly prone to deal with water contamination. Improving Vigiagua Program's management, correcting registration mistakes and ensuring high-quality water supply is essential for public health in Brazil.

Although most cases presented inconclusive results, it was possible observing gender and race-skin color-related issues. It is relevant approaching access to potable water as State duty and fundamental human right to reduce vulnerability, as well as to achieve environmental justice and gender equity.

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