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EVALUATION OF MICROBIOLOGICAL DATA FROM THE SANITARY SURVEILLANCE OF WATER CONSUMED IN QUIRINÓPOLIS, GOIÁS

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ABSTRACT

Water is essential for human survival and health and microbiological monitoring of the water supply is a practice used to control fecal contamination and prevent diseases. The objective of this study was to evaluate data on the parameters Total coliforms and *Escherichia coli* (*E. coli*) in the water supply for human consumption in the city of Quirinópolis, Goiás, observing the standards recommended by Ordinance GM/MS No. 888/2021 of the Ministry of Health. The secondary data provided by the Health Surveillance were evaluated and mapped in the period from 2021 to 2023. A total of 524 water samples were collected in 34 neighborhoods. The results showed annual microbiological percentages above the allowed standard with the presence of total coliforms in the samples collected during the three years. And for the E. *coli bacterium* in 2021 and 2022, with the exception of 2023, noting an evolution in the microbiological quality of the water. The mapping showed the central region as the most contemplated with water sample collections and with the highest number of presences for total coliforms in the three years and *E. coli* in 2021 and 2022. Although the microbiological quality of the water improved in relation to *E. coli*, the same did not happen with total coliforms in 2023. For this reason, it is suggested that there is a need for in-depth investigation and additional monitoring, with an increase in the frequency of sampling in the most compromised neighborhoods, so that it can predict vulnerabilities in the supply and specific preventive actions, meeting the recommendations of the current legislation in Brazil.

Keywords: Drinking Water. Contamination. Water Distribution. *Escherichia coli*. Public health.

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INTRODUCTION

Water is a primordial natural resource for human survival and the growth in the global demand for quality and quantity for human consumption has faced serious challenges, such as poor quality due to environmental pollution of various origins, which is associated with the transmission of diseases and direct threats to the health of thousands of people worldwide (Lin; Yang; Xu, 2022; Gomes *et al*., 2018).

Poor water quality is related to contamination by indiscriminate discharge of wastewater into the environment with minimal or no prior treatment, from industries, agriculture, domestic sewage, among other types of waste (Lin; Yang; Xu, 2022; Nabeela *et al*., 2014). As a result, globally, more than 80% of diseases, representing more than 50 types, cause about 50% of infant deaths, which are associated with poor drinking water quality (Lin; Yang; Xu, 2022). Worldwide, approximately 2 million people die annually from diseases such as diarrhea acquired by water unfit for consumption (Ahmed *et al*., 2020; Odonkor; Mahame, 2020).

Despite compliance with potability requirements and the quality of treated water, the occurrence of contamination by fecal material in distribution networks, reservoirs and consumption points remains a significant challenge for public health. Several studies, such as those by Danieli, Gastaldini and Barroso (2006) and Palmeira *et al*. (2019), show factors that can compromise water quality after treatment.

One of the main problems is the entry of fecal pollutants, mainly by microorganisms, into the distribution system, if the path taken by the water has been contaminated by intrusion, openings in storage tanks, ruptured plumbing, cross-connections between a sewage source and a water line, or even failures in the maintenance of the residual disinfectant (United States Environmental Protection Agency, 2006). Thus, the analysis of drinking water for the presence of indicator microorganisms becomes a fundamental method to determine microbiological quality and ensure public health safety (Saxena *et al*., 2015).

In Brazil, the control of the quality of water for human consumption follows Consolidation Ordinance No. 5 of 2017, Annex XX, amended by Ordinance GM/MS No. 888/2021, which specifies the requirements on the standard of potability and quality of water for human consumption. In addition to determining the obligations and responsibilities of concessionaires and the health sector for control and strict monitoring based on the set of recommended parameters and values, with the objective of providing

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drinking water, free of contamination, free of risks to public health, that is, safe and fit for human consumption (Brasil, 2021).

This Brazilian regulation determines that drinking water must be within the microbiological standard allowed as a guarantee of the safety of water made available for human consumption (Brasil, 2021). In this bias, microbiological contamination by bacteria of the coliform group represents one of the several threats and one of the main causes of gastrointestinal and diarrheal diseases (Seo; Lee; Kim, 2019). Coliforms originate in the intestines of warm-blooded animals and are bacteria that indicate fecal contamination (Libânio, 2016). Although, there are other subgroups of coliforms, water quality monitoring is based on the presence of total coliforms and *E. coli*, both of which pose health risks (Nabeela *et al*., 2014).

Total coliforms are bacteria found naturally in the environment and in the human intestine, and can be of fecal origin and, therefore, in water tests, they inform the general sanitary conditions of a water supply (United States Environmental Protection Agency, 2006; Nabeela *et al*., 2014). Therefore, once detected, they show deficiency or failures in water treatment. Although they are not directly associated with biofilms, they signal problems with the growth of microorganisms in the pipeline. These bacteria are associated with the efficiency of the water treatment process and should be absent in treated water (United States Environmental Protection Agency, 2006).

E *. coli* is the main species of the group of fecal coliforms, considered the most accurate indicator of fecal contamination accepted worldwide, capable of predicting a great potential of pathogenic organisms. This bacterium is one of the main causes of diarrheal diseases and its presence in water poses disease risks and health threats, and can generate high rates of morbidity and mortality, especially in children (Fernández *et al*., 2022).

Thus, the monitoring of coliforms in water is crucial to maintain their quality, as they are bacteria that can impact human health causing serious diseases through microorganisms such as the gastroenteritis virus type A, the hepatitis virus, pathogenic protozoa such as *Giardia sp*., *Estamoeba sp., Cryptosporidium* that causes gastrointestinal diseases, which affect the intestinal mucosa with consequences such as dehydration, weight loss and dysentery, almost always fatal, in addition to worms and parasites found in waters polluted by untreated sewage, septic tanks and other means of contamination (Seo; Lee; Kim, 2019; Tundisi; Matsumura-Tundisi, 2020).

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In view of the above, this study aimed to evaluate secondary data on the microbiological quality parameters, total coliforms and *E. coli*, of the water supply for human consumption in the city of Quirinópolis, Goiás, based on the standards recommended by the Ministry of Health.

METHODOLOGY

FIELD OF STUDY

The municipality of Quirinópolis, Goiás (Figure 1) is located in the South Goiano Mesoregion, belonging to the Microregion of Quirinópolis (Municipal Plan for Basic Sanitation of the Municipality of Quirinópolis, 2018), latitude 18º24'48" S, longitude 50º48'24" W and urban area with altitude above 460 meters reaching up to 590 meters above sea level (Figure 1). It has a territorial area of 3,786.026 km² and has a population of 48,447 inhabitants (Brazilian Institute of Geography and Statistics, 2022).

The data used in this study were derived from water samples obtained from the Sanitary Surveillance of Quirinópolis, Goiás. Figure 1 shows the map of location, hypsometry and geographic division of the 42 neighborhoods that covers the urban area, including the 34 neighborhoods where water samples were collected to evaluate the parameters of total coliforms and *E. coli*.

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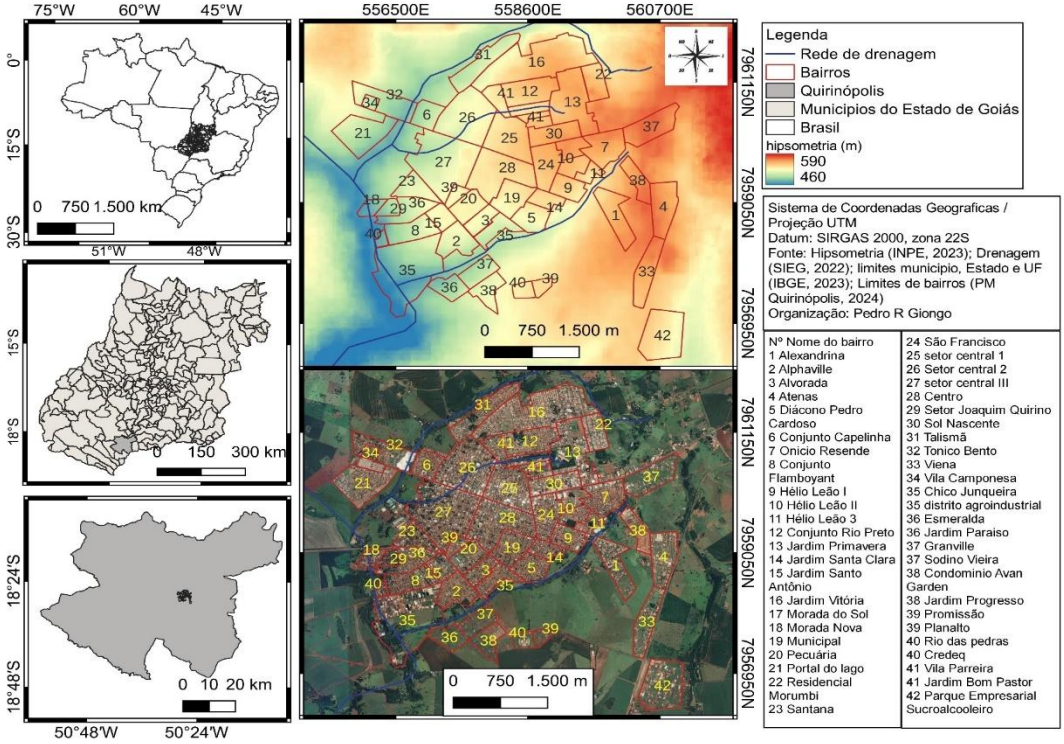
Figure 1 - Map of location, hypsometry and geographic division of the neighborhoods of Quirinópolis, Goiás.



Source: *Google Earth* (2024); National Institute for Space Research (2023); State Geoinformation System (2022); Brazilian Institute of Geography and Statistics (2023); Quirinópolis City Hall (2024). Organization: Pedro R. Giongo (2024).

WATER SUPPLY OF QUIRINÓPOLIS

The water supply of the municipality of Quirinópolis is captured from the surface source, Ribeirão das Pedras and pumped to the Water Treatment Plant (ETA), where it is treated and distributed (Water and Sanitation Institute, 2020; Municipal Basic Sanitation Plan of the Municipality of Quirinópolis, 2018) by the state sanitation company of Goiás S/A - SANEAGO, responsible for the water supply and quality control system. In 2022, the population supplied with treated water in the urban area of Quirinópolis was 45,588 people (National Sanitation Information System, 2022), corresponding to 94.1% of the current population, which, according to the Brazilian Institute of Geography and Statistics (2022) is 48,447 inhabitants.

OBTAINING AND PROCESSING SECONDARY DATA

The secondary data of the parameters of total coliforms and *E. coli* were provided by the Sanitary Surveillance of Quirinópolis and refer to the monitoring of the period from 2021 to 2023, which are expressed in absences and presences. The data totals 524 water samples collected from the supply network and are distributed in 165 water samples in

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2021, 175 in 2022 and 184 in 2023. In addition, Ordinance GM/MS No. 888 of May 4, 2021, was also used as a normative instrument to compare the conformities or possible non-conformities of these parameters.

Soon after the water is collected, the samples of the physical-chemical parameters are analyzed in the Sanitary Surveillance's own laboratory. Another batch of samples for examination of total coliforms and *E. coli* is packed in a thermal box with recyclable ice to preserve the samples below 8 ºC, to be transported to the Dr. Giovanni Cysneiros State Public Health Laboratory of the state of Goiás, LACEN-GO, in Goiânia, in order to be analyzed, reported and made available to the municipality's Health Surveillance.

For the purposes of potability of water for human consumption, Ordinance GM/MS No. 888 of May 4, 2021, determines as a microbiological quality standard, the absence of total coliforms in 95% of the 100 ml of water samples analyzed per month in water supply systems from 20,000 inhabitants. In this case, as Quirinópolis has a population of 48,447 inhabitants (Brazilian Institute of Geography and Statistics, 2022), it is possible to detect presences in up to 5% of the samples examined per month. Above this percentage, the maximum level of total coliform presence in the water is violated (Brasil, 2021).

Regarding E. *coli* bacteria, according to Ordinance GM/MS No. 888 of May 4, 2021, its presence is not tolerated in water distribution systems for human consumption, as it is an accurate indicator of fecal contamination (Brasil, 2021).

Secondary data were extracted from reports provided by the Sanitary Surveillance and organized in electronic Excel spreadsheets , tabulated by year and month, number of samples, presence and absence of total coliforms and *E. coli* and calculations for the preparation of thematic maps of the neighborhoods contemplated with water samples. In addition, the absolute and relative frequencies of the samples analyzed in the distribution system were calculated in order to synthesize, interpret and present the results of each parameter by means of a table.

The data were mapped using the Geographic Information System (GIS). To this end, the data were imported into the *Q-Gis software,* version 3.28, to generate the thematic maps of the urban area of Quirinópolis. And thus, allow the spatial and temporal visualization of the data in each neighborhood, where the water samples occurred for analysis of the parameters of total coliforms and *E. coli* in three consecutive years. Once this was done, the data were analyzed on an annual and monthly scale, observing each microbiological parameter in relation to each neighborhood.

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RESULTS AND DISCUSSION

The results with the counts of the microbiological parameters of total coliforms and *E. coli* of the treated water in Quirinópolis are described in Table 1, with their respective total collections, absolute and relative frequencies in relation to the presence and absence of these microorganisms in the water samples, in the period from 2021 to 2023.

If, on the one hand, there was an increase in the number of collections and a reduction in the number of samples with the presence of *E. coli*; on the other hand, there was an increase in the amount of total coliforms present in the water distributed at the points of consumption in 2022 and a decrease in 2023 compared to the previous year. Therefore, there should be no bacteria in drinking water that indicate fecal contamination, as they harm human health and can cause various diseases (Brasil, 2021; Kings; Beloved; Benvenuti, 2023).

As can be seen in Table 1, in 2023 there was no presence of *E. coli* in the water samples analyzed. Therefore, all samples collected to investigate these bacteria during the year were in compliance with Ordinance GM/MS No. 888/2021, which determines the absence of 100 mL of water samples so that it can be considered suitable for human consumption (Brasil, 2021).

Regarding the number of samples analyzed, in 2021, 2022 and 2023 they totaled 165, 175 and 184 respectively, for the parameters of total coliforms and *E. coli* (Table 1). Thus, the minimum amount of samples required monthly for bacteriological control of water is provided for in the National Guideline of the Sampling Plan for Surveillance of the Quality of Water for Human Consumption and is based on the population range of the municipality (Brasil, 2016). In this case, as Quirinópolis has a current population of 48,447 inhabitants (Brazilian Institute of Geography and Statistics, 2022), it falls into the range between 10,001 and 50,000, with the obligation to collect a monthly minimum of 8 samples (+ 1) for every 7.5 thousand inhabitants (Brasil, 2016).

Table 1 - Total samples, absolute and relative frequencies in relation to the presence and absence of total coliforms and *E. coli* in the water distributed in Quirinópolis, Goiás in the period from 2021 to 2023.

Periods	Total collections	Total coliforms (%)		*Escherichia coli* (%)	
		Absent	Present	Absent	Present
2021	165	145 (88%)	20 (12%)	156 (95%)	9 (5%)
2022	175	147 (84%)	28 (16%)	171 (98%)	04 (2%)
2023	184	161 (88%)	23 (13%)	184 (100%)	0 (0%)

Source: Sanitary Surveillance of Quirinópolis, Goiás (2021; 2022; 2023).

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Based on the number of inhabitants and considering the minimum amount of water samples collected monthly, the Sanitary Surveillance of Quirinópolis complied with the determinations of the National Guideline of the Sampling Plan for the Surveillance of the Quality of Water for Human Consumption, with an average of 14 monthly analyses, in 2021 and 15 in 2022 and 2023. Overall, he obtained an average of 15 samples in the period analyzed. Such samples come from the water distribution system, collected directly from the network, from taps before reservation, in different neighborhoods and varied places such as schools, Basic Health Units (UBS), among others, as determined by the National Program for Surveillance of the Quality of Water for Human Consumption (VIGIAGUA), as it is the responsibility of the municipalities through the Secretariats of Health to exercise water quality surveillance through this Program (Brazil, 2021).

The National Guideline of the Sampling Plan for the Surveillance of the Quality of Water for Human Consumption advises that monitoring be carried out in the distribution system, both for total coliforms and for *E. coli*, because even receiving adequate treatments and eliminating pathogenic bacteria, the water can deteriorate along the route within the distribution network or even due to inadequate conditions in the reserve (Brasil, 2016).

Figures 2 to 7 show the thematic maps of the 34 neighborhoods of Quirinópolis contemplated in the water sample script of the Sanitary Surveillance, containing the number of samples per neighborhood in the legend with the colors and the number of presences for the parameters of total coliforms and *E. coli* within the polygons, for the twelve months of the years 2021, 2022 and 2023, which allows us to visualize the spatio-temporal variability of the data under study.

In general, Figure 2 shows that in 2021, the parameter Total coliforms was analyzed in eleven months and only in January there were no water samples collected in the neighborhoods of Quirinópolis. During this period, the monitoring of neighborhoods took place in 64% (11/7) of the months (February, April, June, July, August, November and December) in the east, north and northwest regions of the city. The central region was the only one contemplated with water sample collections in all months of the year, except January. This fact may have occurred due to the Health Surveillance prioritizing places with greater circulation of people as established by Ordinance GM/MS No. 888/2021. And as these neighborhoods, in addition to the population residing in the place, also have school institutions, Basic Health Units and hospitals as spaces that circulate and agglomerate a

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large number of people, the Health Surveillance follows the requirements of the aforementioned Ordinance.

Although most neighborhoods have between one and two water samples (dark colors), many did not detect the presence of total coliforms. Of the total number of neighborhoods sampled in March, 23% (3/13) confirmed the presence of total coliforms in a single water sample. On the other hand, in the eastern region of the city, it was found to be present in the months of June, July and August in 9% (1/11), 9% (1/11) and 14% (1/7) of the neighborhoods, respectively. Likewise, in the central region of the city, the presence of these microorganisms was also found in the months of August, October, and November in 14% (1/7), 17% (1/6), and 9% (1/11) of the neighborhoods, respectively (Figure 2).

The number of samples confirming the presence of total coliforms may probably be a reflection of intermittences in the distribution network, because when the water pressure is low or the pipes are empty or even when there are water interruptions, they can favor the entry of contaminants into the pipes (Kumpel; Nelson, 2013). And consequently, compromising the microbiological quality of the water that arrives at the taps and if consumed under these conditions, affects human health, since pathogenic agents can be carried and cause diseases such as diarrhea (Castro; Cruvinel; Oliveira, 2019). The presence of total Coliform bacteria in raw water does not necessarily imply contamination. However, in public water supply it is a worrying factor because it may contain other types of microorganisms such as antibiotic-resistant bacteria in the water, for example, heterotrophic bacteria (Bortoloti *et al*., 2018).

It is reiterated that, in 36% (4/11) of the months (August, September, October and November) of monitoring carried out by the Health Surveillance, there was the presence of total coliforms in 2021. Although the presence of these bacteria can also be related to the rainy season, there were months with proof outside this period. The month of March obtained records in three neighborhoods, however, the highest confirmation of cases occurred in the eastern and central regions of the city, in the months of September, October and November. Considering March, October and November, this fact may be related to the rainy season, as Quirinópolis has two well-defined seasons, winter and summer, in which the lowest incidence of rainfall occurs in the winter that goes from June to September and the highest rainfall occurs in the summer that occurs in the period from October to March (Municipal Plan of Basic Sanitation of the Municipality of Quirinópolis, 2018).

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This association was also reported by Santos *et al*. (2023) when they evaluated data from water samples obtained through the National Program for the Surveillance of the Quality of Water for Human Consumption in 21 municipalities in the north of Paraná and found that 1,268 (10.95%) of the water samples collected in the trestle hydrometer were contaminated by total coliforms, with the presence correlated with rainy periods. Also according to Santos *et al*. (2023) rainfall is a risk factor that impacts water quality, increases turbidity and microbiological contamination, and negatively affects water treatment.

In this case, the occurrence of these bacteria is probably associated with the rainy season. However, regardless of climatic events, they are bacteria that cannot be ignored, as they encompass a wide range of microorganisms found in the environment and are of fecal origin (Libânio, 2016). That is why they are used as indicators of the efficiency of the water treatment process to verify the removal of environmental and fecal contaminants, since they are present in the soil, in the intestines of animals and initially in the raw water collected. And for this reason, they are analyzed at the exit of the water treatment plant to ensure its quality (Macêdo, 2016).

In view of the results found in this study, Reis; Amado and Benvenuti (2023) explain that the total coliforms individually identified in water have limited sanitary value. However, when there is joint confirmation with *E. coli*, control measures must be provided immediately to adapt the water to the quality standard for human consumption.

In the context of the city of Quirinópolis, it is possible to see through the thematic maps that during the year 2021 there was a maximum number of nine confirmed analyses for *E. coli* in the central region of the city, while in the months of August and September they indicated a sample, respectively. Meanwhile, in October there was the presence of these bacteria in four analyzes and in November in three analyzes in the same region. Although the central region was contemplated with the largest number of water samples for analysis of microbiological parameters, it was also the one with the highest number of confirmed presence of *E. coli* in the water samples (Figure 3).

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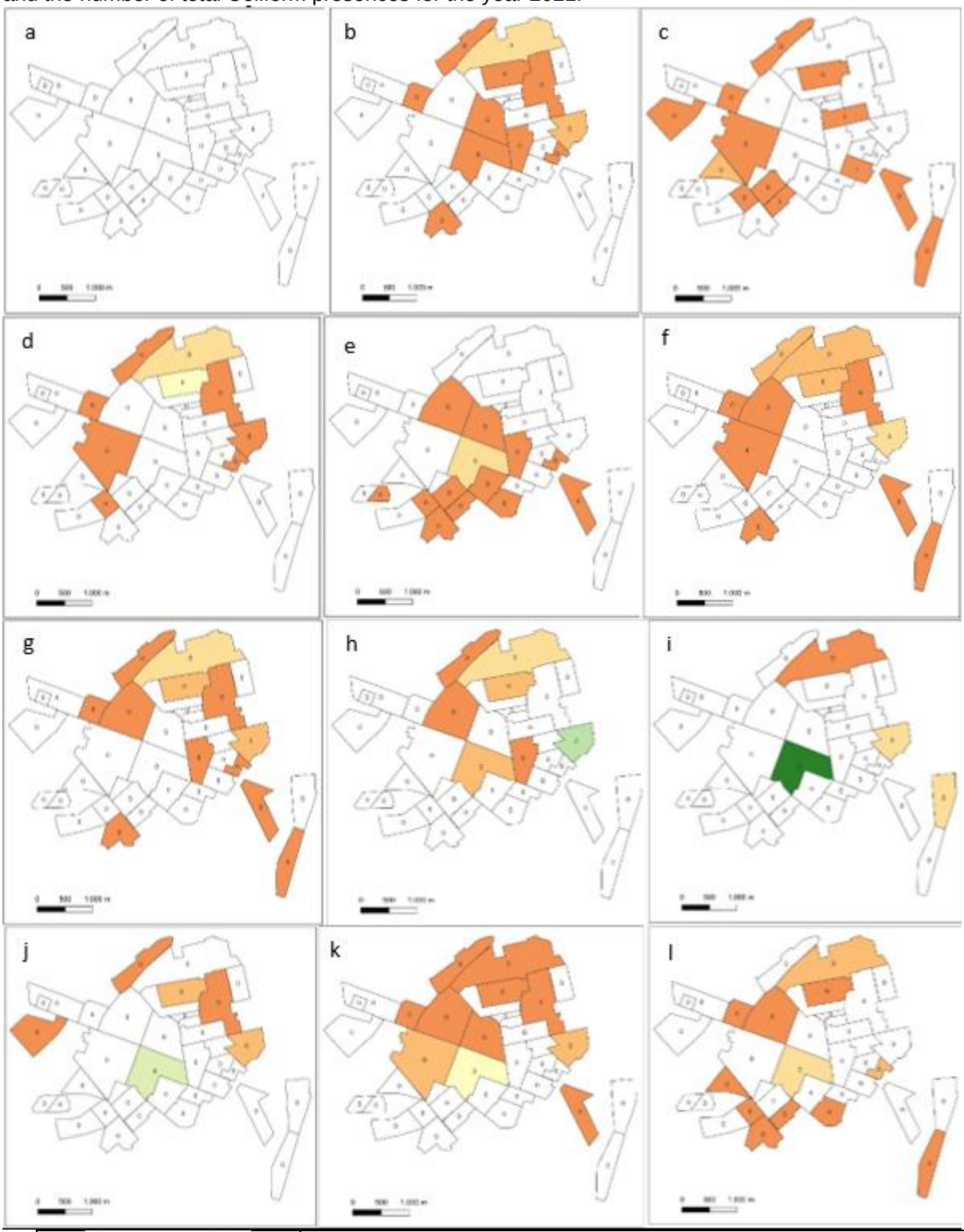
Figure 2 - Thematic maps of the neighborhoods of Quirinópolis, Goiás such as the number of water samples and the number of total Coliform presences for the year 2021.



Thematic maps of the neighborhoods of Quirinópolis – GO, such as the number of water samples (legend with colors) and the number of samples with the presence of total coliforms (number in the polygon) for the months of January (a), February (b), March (c), April (d), May (e), June (f), July (g), August (h), September (i), October (j), November (k), (December (L), for the year 2021.

Source: Sanitary Surveillance of Quirinópolis, Goiás (2021). Organization: The authors (2024).

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Figure 3 - Thematic maps of the neighborhoods of Quirinópolis, Goiás such as the number of water samples and the number of attendances of *E. coli* for the year 2021.

Thematic maps of the neighborhoods of Quirinópolis – GO, such as the number of water samples (legend with colors) and the number of samples with the presence of *E. coli* (number in the polygon) for the months of January (a), February (b), March (c), April (d), May (e), June (f), July (g), August (h), September (i), October (j), November (k), (December (L), for the year 2021.

Source: Sanitary Surveillance of Quirinópolis, Goiás (2021). Organization: The authors (2024).

Figure 3 shows that, in 2021, most neighborhoods located in the south and southwest regions of the city, especially the peripheral ones, had insufficient water

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sampling coverage in several months. On average, only 10 neighborhoods (29% of the total) were sampled per month, while 24 neighborhoods (71%) did not have their water collected for analysis. This gap in sample collection is worrisome, as it prevents the detection of possible problems in the quality of the water supplied to these neighborhoods. Considering that regular monitoring of water quality is essential to identify and correct irregularities and prevent risks to the health of the population, as highlighted by Brasil (2016), the situation evidenced in Figure 3 deserves special attention.

Therefore, the presence of *E. coli* in the water represents a strong indication of human or animal fecal contamination and the possibility of enteric pathogens present. And because they are bacteria with a short lifespan, when detected in the water supply, they indicate contamination of a recent point source, probably due to the occurrence of intrusion, burst pipes, cross-connection between sewage wastewater and water lines or even septic tanks (United States Environmental Protection Agency, 2006).

In 2022, there was a spatial distribution of samples in the neighborhoods of Quirinópolis in the twelve months of the year, except October, with samples concentrated in only seven neighborhoods in the central region (Figure 4). It is noted that the remote neighborhoods located further south and northwest of the city, mainly in the vicinity of Ribeirão das Pedras, the Sewage Treatment Plant and the Agroindustrial District, were not collected during 2022, except in two neighborhoods (Figure 4). Regarding the neighborhoods without collections, attention is suggested as reference points to intensify monitoring with an increase in water samples, as they are close to the city's capitation source and with possibilities of generating point sources of contaminants and producing effects on the receiving body (Rio das Pedras) and resulting in impacts on the quality of the water collected for supply, make treatment more expensive and raise costs for consumers (Paula, 2011), making people opt for unsafe alternative sources of water, which can have strong implications for human health (Libânio, 2016).

It should be noted that in the first half of 2022, sampling occurred repeatedly in neighborhoods located in the north and central regions of the city and sporadically in the east and south regions. In this period, January had 100% of the neighborhoods with water samples free of the presence of total coliforms. However, the presence of these bacteria was identified in the water samples in the months of February, March, April, May and June in 11% (1/9), 8% (1/13), 20% (2/10), 25% (2/8) and 9% (1/11) of the neighborhoods, respectively (Figure 4).

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Figure 4 - Thematic maps of the neighborhoods of Quirinópolis, Goiás such as the number of water samples and the number of total Coliform presences for the year 2022.

Thematic maps of the neighborhoods of Quirinópolis – GO, such as the number of water samples (legend with colors) and the number of samples with the presence of total coliforms (number in the polygon) for the months of January (a), February (b), March (c), April (d), May (e), June (f), July (g), August (h), September (i), October (j), November (k), December (L), for the year 2022.

Source: Sanitary Surveillance of Quirinópolis, Goiás (2022). Organization: The authors (2024).

The occurrence of total coliforms in the water suggests the existence of factors that compromise the quality of the water during the supply and such factors may be related to intermittences, negative pressures, high turbidity, low chlorine concentration, interruptions

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due to repairs, biofilms adhered to the internal walls of the pipes that can detach and alter the quality of the water in the supply, as well as occasional rains with sewage overflows, which in turn force pollutants into the pipe, or even the age of the water and high temperatures can contribute to the proliferation of these microorganisms (Kumpel; Nelson, 2013).

In the second half of 2022, water sample collections carried out in Quirinópolis with the presence of total coliforms were more frequent, in the months of July, August, and September in 14% (1/7), 17% (1/6), and 11% (1/9) of the neighborhoods, respectively. In the months of October, November and December, the presence of these microorganisms was found in 43% (3/7), 33% (3/9) and 67% (6/9) of the neighborhoods, respectively. It is important to note that, although other regions had occurrences, the central region was the most affected by total coliforms (Figure 4).

As total coliforms attest to the bacteriological quality of the water, one of the concerns is related to Acute Diarrheal Diseases (ADD) which consist of a syndrome caused by bacteria, viruses and parasites. And these microorganisms and parasites can be transmitted by food and even by contaminated water, causing diseases such as cholera, hepatitis, gastroenteritis, worms, and others (Alves *et al*., 2016).

Despite this, the state of Goiás has recently registered cases of outbreaks of Acute Diarrheal Diseases (ADD) in 74 municipalities, totaling 12,205 notifications and showing an increasing trend. The State Health Department is issuing alerts to the population about the importance of drinking treated water and adopting hygiene and sanitation practices. While continuing to monitor the situation, the presence of *E. coli* has been confirmed in contaminated water samples from irregular private wells. The main causes of the disease are related to rotavirus and norovirus, with cases already predicted for the months of August and September (Goiás, 2024).

In the same direction, the presence of total coliforms in water samples does not seem to be a problem found only for Quirinópolis, according to Alves *et al*. (2016) using secondary data of the parameters of total coliforms and *E. coli* obtained through the Information System for the Surveillance of the Quality of Water for Human Consumption (SISAGUA) and the Laboratory Environment Management System (GAL) of LACEN, in twenty-one municipalities of the state of Goiás, verified the presence of total coliforms in twenty municipalities that managed the treatment of public water supply in 2014.

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In the case of Quirinópolis, the results with a predominance of total coliforms during the collection period may have a probable cause of water stagnation inside the pipe or various dirt near the taps that are exposed and unprotected from animals, since the water is also collected in external places, close to vegetation (grasses). And because of this, even following the correct procedure for disinfection and draining tap water at the time of collection, contamination can occur during water sampling.

Referring to Figure 5, in 2022, in the central region, four water samples were found with the presence of *E. coli* for three months.

This time, studies have confirmed the microbiological contamination of the water through secondary data such as the research by Alves *et al*. (2016) on the Information System for Surveillance of the Quality of Water for Human Consumption, finding in municipalities of Goiás in 2014, with water treatment managed by public administration, the presence of *E. coli* in sixteen municipalities, with only four free of these bacteria. Another study by Faria *et al*. (2021) with data from the Information System for the Surveillance of the Quality of Water for Human Consumption (SISAGUA) identified 14.9% (343/2,302) of samples positive for *E. coli* in municipalities of Rio de Janeiro and found a high prevalence of protozoa in regions affected by coliforms.

Contamination by *E. coli* has been reported in research such as the one carried out by Moreira; Kopp and Nardocci (2021) found that in the thirty collection points of shallow wells used as a source of water supply and water supply, in a residential neighborhood in Goiânia, Goiás, consisting of a water supply network destined for a black tank, there was the detection of high levels of total coliforms and *E. coli*, without meeting potability standards.

Figure 5 shows that the occurrence of samples with the presence of *E. coli* bacteria was recurrent and punctual in the central region. This finding raises the hypothesis that there is a problem in this area because, although it was the region with the highest number of collections, it was also the area with the highest percentage of these microbial contaminants. This fact represents a warning for this region because *E. coli*, once found in the water, signals fecal contamination and the presence of microorganisms such as protozoa or other pathogens in the water. Some strains cause serious gastrointestinal problems and, most of the time, are responsible for outbreaks of waterborne diseases (Libânio, 2016).

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In this sense, the presence of *E. coli* becomes a problem when it comes to water for human consumption because it indicates recent fecal contamination, makes the use of water unfeasible and poses health risks (Bortoloti *et al*., 2018). The consequences of this are the transmission of acute diarrheal diseases and hepatitis A, which are associated with the quality of the water consumed (Castro *et al.*, 2019).

Figure 5 - Thematic maps of the neighborhoods of Quirinópolis, Goiás such as the number of water samples and the number of attendances of *E. coli* for the year 2022.

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Thematic maps of the neighborhoods of Quirinópolis – GO, such as the number of water samples (legend with colors) and the number of samples with the presence of *E. coli* (number in the polygon) for the months of January (a), February (b), March (c), April (d), May (e), June (f), July (g), August (h), September (i), October (j), November (k), December (L), for the year 2022.

Source: Sanitary Surveillance of Quirinópolis, Goiás (2022). Organization: The authors (2024).

It is worth clarifying that the effective treatment of drinking water can inactivate more than twenty waterborne pathogens, such as *pathogenic* E. coli bacteria, *Shigella*, *Campylobacter*, viruses that cause hepatitis A and E, norovirus and rotavirus, and parasites such as Giardia and *Cryptosporidium* (World Health Organization, World Bank Group, Unicef, 2022).

Thus, the monitoring of the water supply network as carried out in Quirinópolis by the Sanitary Surveillance, can positively reflect on the health of the population when corrective measures are taken. As well as open complaint channels between consumer and concessionaire, at times of maintenance and supply cuts can be useful to optimize the safe supply of water (Castro *et al.*, 2019)element.

Regarding the year 2023, Figure 6 shows the thematic maps with the spatiotemporal distribution of the water samples of the Total Coliforms parameter in the neighborhoods under study, during the twelve months. In general, it is possible to identify the collection of water samples covering the neighborhoods of all regions of the city of Quirinópolis.

In this context, in January, water samples were collected in twelve neighborhoods, of which 58% (7/12) showed the presence of total coliforms and in most of them in the only sample of the month. In the months of February, April and May, the presence of these bacteria was confirmed in 18% (2/11), 8% (1/12) and 50% (3/6) of the neighborhoods, respectively. These bacteria were also found in the months of July, October and November in water samples equivalent to 29% (2/7), 40% (4/10) and 8% (1/12) of the neighborhoods, respectively. And, finally, in December, 10% (1/10) of the neighborhoods proved the presence of these microorganisms in the water samples (Figure 6).

Another possibility that this problem is persisting would be due to the lack of a minimum content of free residual chlorine in the water that arrives in these neighborhoods. According to Danieli, Gastaldini and Barroso (2006), water can react with chemical and microbiological species during runoff and lose residual chlorine content. This situation was verified in a water distribution sector in a neighborhood of Santa Maria in Rio Grande do

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Sul, with a tendency to lose residual chlorine at the end points of the network and for this not to occur it would be necessary to have higher concentrations to reach any distribution point with the minimum allowed (0.2 mg/L) by the legislation (Brazil, 2021).

In 2023, the percentages varied between 8% and 50% of the neighborhoods with the presence of total coliforms, where the highest incidence was found in the months of May (50%) and October (40%). A similar fact was also found by Alves *et al*. (2017) using historical monitoring data of the physicochemical and microbiological parameters of the monitoring of public water supply analyses in the State of Ceará from 2014 and 2015, found the presence of total coliforms in all months of the years. In 2014, the presence of these bacteria ranged from 7 to 48%, with a higher percentage in June. And in 2015 there were percentages ranging from 2 to 25%, with a higher percentage found in the samples analyzed in April.

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Figure 6 - Thematic maps of the neighborhoods of Quirinópolis, Goiás such as the number of water samples and the number of total Coliform presences for the year 2023.

Thematic maps of the neighborhoods of Quirinópolis – GO, such as the number of water samples (legend with colors) and the number of samples with the presence of total coliforms (number in the polygon) for the months of January (a), February (b), March (c), April (d), May (e), June (f), July (g), August (h), September (i), October (j), November (k), December (L), for the year 2023.

Source: Sanitary Surveillance of Quirinópolis, Goiás (2023). Organization: The authors (2024).

Although these results are worrying for Quirinópolis, the finding of total coliforms alone does not indicate contamination of the water by feces, as they are bacteria from the

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natural environment (Alves *et al*., 2017). However, when detecting any non-conformity in the water distribution system, corrective measures are immediately provided, such as stopping the treatment and maintenance of the water supply systems, cleaning of the reservoirs and the distribution network. The monitoring of water quality is carried out through daily analyses according to the standards of the Ministry of Health (Saneago, 2022).

Figure 7 shows the spatialization of the neighborhoods where water samples were collected by the Quirinópolis Health Surveillance during the twelve months in 2023. In general, there was no presence of *E. coli* in the water samples.

It should be noted that, in the three consecutive years, although the central region of the city was contemplated with the highest number of water samples taken per month in relation to the other regions, it was also the one that presented the highest number of samples with total coliform bacteria and *E. coli*. Based on this, it is inferred that the greater number of samples in relation to the other regions is probably due to the large concentration of institutions located in this region such as schools, public buildings, commerce, hospitals, homes, and other establishments (Brasil, 2021).

Similar to the results observed in this study in 2023, the research by Costa *et al*. (2022) carried out in São José dos Quatro Marcos in the state of Mato Grosso, verified at the end of the distribution network, the absence of *E. coli,* verifying the absence of pathogenic microorganisms in the treated water. In another study conducted by Morais *et al*. (2016), in three neighborhoods of the city of Rio Verde, Goiás, on the sanitary quality of the water distributed for public supply, also found the absence of total coliform bacteria and *E. coli* in the 36 water samples analyzed.

Thus, water intended for human consumption requires greater satisfaction of quality requirements. And for this reason, this type of supply is considered the noblest use of water (Sperling, 2005). Among the criteria required as a quality parameter, the coliform *E. coli* is extensively used worldwide as an accurate indicator of the microbiological quality of water (Libânio, 2016).

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Figure 7 - Thematic maps of the neighborhoods of Quirinópolis, Goiás with the number of water samples and the number of water samples. *E. coli* for the year 2023.

Thematic maps of the neighborhoods of Quirinópolis – GO, such as the number of water samples (legend with colors) and the number of samples with the presence of *E. coli* (number in the polygon) for the months of January (a), February (b), March (c), April (d), May (e), June (f), July (g), August (h), September (i), October (j), November (k), December (L), for the year 2023.

Source: Sanitary Surveillance of Quirinópolis, Goiás (2023). Organization: The authors (2024).

Based on the results for the year 2023, there was no evidence of the presence of *E. coli* in the water samples in the Quirinópolis supply (Figure 7), confirming the

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microbiological quality in the water distributed for consumption by the population. Similar results were obtained in a previous study conducted by Borges *et al*. (2023), when analyzing the quality of the treated water distributed by Saneago in the city of Anápolis, Goiás, in sixteen neighborhoods in eight different regions, found through a confirmatory test for total coliforms that the water in all the neighborhoods analyzed was in compliance with potability standards, proving the efficiency in the city's water treatment.

The presence of total coliforms or *E. coli* is a sign of inefficient treatment or fecal recontamination during distribution (Brasil, 2016). These bacteria can enter and proliferate in public water distribution and supply systems, resulting in a reduction in the microbiological quality of water (Santos *et al*., 2023). In view of their occurrence in the supply system, corrections are recommended until normality is restored (Brasil, 2016). In this case, new samples should be taken immediately on successive days, resulting in a recollection and two extra samples, until the microbiological quality of the water is restored (Brasil, 2021).

According to the World Health Organization, like total coliforms, *E. coli* is a parameter traditionally used to monitor the microbiological quality of drinking water, which should not contain any indication of fecal contamination so that the safety of the water is guaranteed for human consumption (World Health Organization, 2017; Guidelines for Drinking-Water Quality, 2022). *E. coli* is a bioindicator for detecting fecal contamination and its presence is associated with waterborne diseases (Odonkor; Mahame, 2020). It is conclusive proof of fecal contamination (Sharma *et al*., 2023) and indicates the existence of microorganisms transmitted by feces, which cause diseases such as cholera, typhoid, diarrhea, hepatitis, and other contamination infections in drinking water (Odonkor; Mahame, 2020; Nabeela *et al*., 2014).

The monitoring of water for human consumption must fully comply with the standards of total coliforms and *E. coli*, as determined by Ordinance GM/MS No. 888/2021 in force in Brazil, which follows the Guidelines for the Quality of Drinking Water of the World Health Organization (Table 2).

As the supply system of Quirinópolis has less than 50,000 inhabitants, total coliforms are tolerated in only 5% of the 100 mL water samples analyzed per month. As for *E. coli,* it is not tolerated, it is required absence in water intended for human consumption (Brasil, 2021; 2014).

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In this regard, the group of total coliforms are free-living bacteria, found naturally in soil, water and plants and may not have any relationship with water pollution by feces (Brasil, 2016). However, they are bacteria that can never be neglected when it comes to the quality of water for human consumption, since positive results indicate possible deficiencies in the disinfection process or in the distribution system, and, in this case, it is recommended to investigate and carry out actions with corrective measures (Brasil, 2016; United States Environmental Protection Agency, 2006).

Table 2 - Standards of Ordinance GM/MS No. 888/2021 and Of Guidelines for the Quality of Drinking Water.

Parameters	Brazil - Ordinance GM/MS No. 888/2021	Guidelines for Drinking-Water Quality
Total coliforms	Absence/100 mL (treatment output) 95% in systems that supply from 20,000 inhabitants	Absence / 100 mL
Escherichia coli	Absence / 100 mL	Absence / 100 mL

Source: Brazil (2021); Guidelines for Drinking-Water Quality (2022).

In order to verify the presence of total coliforms in treated water samples, specific analysis for *E. coli is required* (Brasil, 2016). It is worth noting that *E. coli* is an indicator of the microbiological quality of water treated for human consumption and a signal of the efficiency and integrity of the distribution system for the potability of water (Libânio, 2016). However, this bacterium is considered the most accurate indicator of water contamination by fecal matter and its presence represents the indication of the occurrence of contamination by pathogenic microorganisms (Brasil, 2016; Morais *et al*., 2016).

In studies by Waideman *et al*. (2020) analyzed water samples from drinking fountains and taps in Curitiba in the State of Paraná and found the presence of total Coliforms in 6.6% in the ninety samples analyzed, even with adequate free residual chlorine content, according to them, this fact may be related to the resistance capacity of microorganisms to chlorine, which allows survival and persistence in the distribution system, even after cleaning and disinfection procedures have been carried out.

Also in Paraná, the investigation by Santos *et al*. (2023) using data from analyses of water samples obtained from the National Program for the Surveillance of the Quality of Water for Human Consumption in 21 municipalities in the state in the period from 2013 to 2021, found that in urban areas, 1,268 (10.95%) of the samples analyzed were contaminated by total coliforms and 293 (2.53%) in the form of *E. coli* and concluded that

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microbial contamination in water supply systems in northern Paraná may be associated with rainfall factors or insufficient concentrations of free residual chlorine.

According to the recommendations of the World Health Organization, the World Bank, Unicef and Ordinance GM/MS No. 888/2021, in force in Brazil, for water to be compliant for human consumption, that is, free of contamination, *E. coli* must be absent in samples of 100 ml of water examined (Brasil, 2021; World Health Organization; World Bank Group; Unicef, 2022). Otherwise, the water does not meet the standard of potability for human consumption, as recommended in Annex 1 of the aforementioned Ordinance (Brasil, 2021).

In addition, *E. coli* is a bacterium found in human and animal feces, which has been used as an indicator of fecal contamination in water and is related to gastrointestinal diseases (United States Environmental Protection Agency, 2006), once found, it is considered that the water is unfit for human consumption, posing risks to the health of the population (Brazil, 2021).

Although, not all strains of *E. coli* bacteria are offensive, some are pathogenic and can cause serious illness (Nabeela *et al.*, 2014). Like the one found in a study using the Polymerase Chain Reaction technique, carried out by Saima *et al*. (2023) in *East Arichpur*, *Dhaka*, *Bangladesh,* they reported pathogenic *E. coli* types in 22% (38/169) of drinking water samples at consumption points. According to these researchers, even detected in small concentrations, it is worrying because it can compromise water quality and cause serious infections.

According to Morais *et al*. (2016), when the absence of E. coli bacteria is verified, indicates that the water distributed meets the bacteriological quality standard. To this end, it is necessary to consider that this type of bacteria inhabits the intestine of mammals and its absence in water supply indicates that it is not contaminated by fecal matter and can be consumed. This guarantee is obtained by maintaining free residual chlorine at adequate levels within the water supply system, as insufficient concentrations increase the incidence of microbiological indicators (Santos *et al*., 2023).

Therefore, total coliforms and *E. coli* are fundamental parameters to be considered in relation to the surveillance and control of the microbiological quality of water, characterizing potability and bacteriological safety for public supply (Brasil, 2021). In this sense, the monitoring of the water supply for human consumption, through microbiological evaluative parameters to monitor the potential of pathogens, present or absent in the

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water, such as total coliforms and *E. coli*, is essential to keep the water safe for consumption (Morais *et al.,* 2016). Traditionally, *E. coli* is the most widely used parameter in the world to detect fecal contamination, in addition to being a reliable and rigorous way to control and maintain the quality of water supplied for public supply (World Health Organization; World Bank Group; Unicef, 2022; Soares *et al*., 2020; Sperling, 2005).

In view of the results found in this study, it is suggested that there is a need for more careful investigation in neighborhoods with samples outside the potability standard, since the hypothesis of the possibility that hydraulic installations are being fed by other sources of water other than the public supply cannot be ruled out, as specified in article 26 of Ordinance GM/MS No. 888/2021, treated water from the distribution system cannot be added with water from other sources (Brazil, 2021).

In general, regarding the results that were in disagreement with the legislation, it is suggested that there should be a more in-depth investigation and greater rigor in carrying out additional monitoring, with an increase in sampling at the points of consumption to predict vulnerabilities and provide more punctual corrective actions in the supply systems as a whole. After all, the role of managers, administrators of the treated water supply company and authorities in public health surveillance is fundamental for the management and identification of risks associated with bacteriological contamination of water for human consumption.

CONCLUSION

It is concluded that the evaluated data presented results exceeding the normative standards of microbiological parameters in two consecutive years. In 2021 and 2022, both presented contamination together, both for total coliforms and *for E. coli*. During the 2023 monitoring, no *E. coli bacteria* were detected and the same did not occur for total coliforms.

The evaluation of the data on the microbiological parameters showed that the water supply of Quirinópolis was in disagreement with the standards required in Ordinance GM/MS No. 888/2021 for total coliforms in three consecutive years and *E. coli* in 2021 and 2022. However, this Ordinance recommends the absence of total coliforms in 95% of the 100 ml water samples analyzed per month in systems that supply from 20,000 inhabitants and no tolerance for *E. coli*. As the population of Quirinópolis has about 48,447 inhabitants, a present sample of the total samples examined in the month is already sufficient to

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exceed the acceptable limit of 5% for the presence of total coliforms. As for the E*. coli bacterium*, as it is an indicator of fecal contamination, its presence is not allowed in supply water for human consumption because it violates the potability standard of the Ministry of Health.

The mapping of the data through the Geographic Information System (GIS) allowed us to identify in the urban area of Quirinópolis, the central region of the city as the most sampled and with the greatest impairment in relation to the other regions, with the occurrence of the presence of total coliforms and *E. coli* in the period analyzed. In addition, the use of GIS enabled the graphic presentation, spatial analysis and dynamic reading of the data of the microbiological parameters.

Therefore, this discovery needs further investigation to better understand what justifies the contamination in the water distributed in the public supply of Quirinópolis.

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