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Research paper

Microbiological and physico-chemical quality of water from beveragers of Uberlândia Federal University, Campus Santa Mônica

Qualidade microbiológica e físico-química da água de bebedouros da Universidade Federal de Uberlândia, Campus Santa Mônica

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ABSTRACT: This study evaluated the water quality of drinking fountains in the buildings 1B and 5RA at the Santa Mônica campus, Federal University of Uberlândia, monitoring that is part of the institution's Water Safety Plan. The water quality was investigated through bacteriological analysis and physicochemical parameters. The analyses were during 12 weeks in a total of 72 samples. In the bacteriological analysis, none of the samples showed growth of coliforms, being this parameter in accordance to the legislation. In the physicochemical analysis, an average pH of 5.62 and 5.44 was obtained in 1B and 5RA buildings, respectively. In 1B, the color showed an average of 6.85 uC, with six samples showing values slightly above the limit. The other parameters were in accordance to the standards, with average values for block 1B of: turbidity - 0.18 NTU, conductivity - 64.55 us cm^{-1} and dissolved solids - 43.89 mg L^{-1} and for 5RA were of: color - 2.10 uc, turbidity - 0.14 NTU, conductivity - 52.70 us cm^{-1} and dissolved solids - 35.84 mg L^{-1}. Regarding metals, only one sample from 1B presented values of iron, chromium and nickel above the limit. The results indicate the potability and the security of the evaluated water in terms of microbiological, toxicological and organoleptic indicators.

Keywords: Water quality; potability; coliforms; physicochemical parameters.

RESUMO: *Este estudo avaliou a qualidade da água dos bebedouros de dois edifícios da Universidade Federal de Uberlândia, do campus Santa Mônica, monitoramento que faz parte do Plano de Segurança da Água da Instituição. A qualidade da água foi investigada através de análise bacteriológica e parâmetros físico-químicos durante 12 semanas, totalizando 72 amostras. Na análise bacteriológica, nenhuma amostra apresentou crescimento de coliformes, estando em conformidade com a legislação. Na análise físico-química, obteve-se média de pH de 5,62 e 5,44, nos blocos 1B e 5RA, respectivamente. No bloco 1B, o parâmetro cor apresentou média de 6,85 uC, sendo que seis amostras apresentaram valores ligeiramente acima do limite. Os demais parâmetros estavam de acordo com as normas, com valores médios para o bloco 1B de: turbidez - 0,18 NTU, condutividade - 64,55 us* cm^{-1} *e sólidos dissolvidos - 43,89 mg* L^{-1} *e para o bloco 5RA de: cor - 2,10 uc, turbidez - 0,14 NTU, condutividade - 52,70 us* cm^{-1} *e sólidos dissolvidos - 35,84 mg* L^{-1}*. Quanto aos metais, somente uma amostra do bloco 1B apresentou valores de ferro, cromo e níquel acima do limite. Os resultados indicam a potabilidade e asseguram a qualidade da água que abastece a comunidade, quanto aos indicadores microbiológicos, toxicológicos e organolépticos.*

Palavras-chave*: Qualidade da água; potabilidade; coliformes; parâmetros físico-químicos.*

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INTRODUCTION

According to Federal Law N°. 9,433/1997, which instituted the National Water Resources Policy and the National Water Resources Management System, the access to quality water is a right of all the generations (BRASIL, 1997). Basic sanitation, a fundamental right for the development of citizenship, deals with measures that aim to protect or restore the environmental conditions, in order to promote the health of the population and disease prevention (TRATA BRASIL, 2012; FAXINA et al., 2019). The availability, sustainable management of water and basic sanitation for all are part of the Sustainable Development Goals, established by the United Nations (UN), as part of the 2030 Agenda. This Agenda is a global pact for sustainable development signed during the United Nations Summit in 2015, by 193 countries (CABRAL; GEHRE, 2020).

In 2019, according to the National Sanitation Information System (SNIS) and the Water Quality Surveillance Information System for Human Consumption (SISAGUA), 83.7 % of the Brazilian population were served by Water Supply, with 85-90 % in the Southeast, South and Midwest regions and 73.9 and 58 % of the population in the Northeast and North regions, respectively (BRASIL, 2019; OLIVEIRA JÚNIOR et al., 2019). Regarding to water quality, 1.3 and 2.1% of the population receives untreated water, and in the North region, this index increases to 7.2 %, which may represent a health risk (ARAUJO et al., 2022). According to the Brazilian Institute of Geography and Statistics (IBGE), around 11,000 people die each year in the world due to lack of basic sanitation, usually due to microbial agents from fecal contamination in water (IBGE, 2021).

To be potable, the water must meet microbiological, physical and chemical parameters in order to avoid risks to collective health (ARAUJO et al., 2020). The risks associated with the quality of drinking water can be due to chemical pollutants or the presence of biological agents. Among the main reasons of contamination of water resources are the discharge of untreated sewage into rivers and lakes, landfills, use of pesticides that affect groundwater and dry pits in homes, or even supply networks such as cisterns, water tanks, taps and drinking fountains, whose maintenance and cleaning are not adequate (ALMEIDA; COTA; RODRIGUES, 2020). Treated water that contains bacteria of fecal origin may also be related to the integrity of the distribution system due to the accumulation of sediments and organic matter, promoting the development of microorganisms (CASTELLO BRANCO et al., 2022).

In view of the importance of water quality for human consumption, its monitoring is indispensable. The analysis permits the verification if the water distributed to the population is free of pathogens and harmful substances, meeting the potability standards. Among the waterborne pathogens with the greatest impact on public health, the bacteria *Escherichia coli*, *Salmonella typhii*, *Shigella spp*. and *Pseudomonas aeruginosa* and *hepatitis A virus*, rotavirus, adenovirus and enterovirus (PRADO; MIAGOSTOVICH, 2014). The high circulation of these microorganisms can be due to the inefficient sanitary conditions, including the absence of coverage of services or ineffectiveness of water and sewage treatment technologies. Therefore, microbiological analyzes are fundamental, since in several regions of Brazil, the water contamination is still a frequent adversity, and the monitoring is a preventive measure to contribute to public sanitation policies (OLIVEIRA et al., 2020).

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One of the methods to ensure the water quality for human consumption is to verify the presence of bacteria from the coliform group, employed as bioindicators of contamination (VALIATTI et al., 2021). According to the "Standard Methods for the Assessment of Water and Wastewater" (APHA), the coliform group can be defined as: "all aerobic or facultative anaerobic bacteria, Gram negative, non-sporulating and bacilliform, which ferment the lactose with gas formation in 48 hours at 36 ºC" (APHA, 2012). In addition to microbiological indicators, physical-chemical parameters are also analyzed, such as pH, turbidity, color, dissolved solids, metals, residual chlorine, among others (SOUZA; GASTALDINI, 2014). Such analyzes follow the Water Safety Plan (PSA), recommended by Ministry of Health Ordinance No. 888 of 2021, which aims to ensure water safety through monitoring and management plans for water resources, in order to prevent contamination in the system of distribution and storage (BRASIL, 2021).

However, even ensuring these essential steps, operational and maintenance problems in the system, clandestine release of effluents and penetration of contaminants can interfere with the water potability. Therefore, caution must be taken with the internal facilities and the cleaning and conservation of the reservoirs to maintain their quality. In public places, such as educational institutions, which behave like small urban centers due to the amount of floating population, drinking fountains can become an indirect source of contamination, due to the conditions of use and hygiene (BRITO et al., 2021; SOUZA et al., 2021). Thus, the monitoring and maintenance of drinking fountains in these institutions are essential to guarantee water quality to consumers (MARTINS et al., 2016). In this context, the present study evaluated the water quality of drinking fountains at the Federal University of Uberlândia, on the Santa Mônica campus, through physical-chemical and microbiological parameters, with the objective of verifying whether the water consumed by the university community is in compliance with potability standards defined by Ordinances of the Ministry of Health PRC No. 05 of 2017 (BRASIL, 2017) and Annex XX PRT No. 888 of 2021 (BRASIL, 2021).

MATERIAL AND METHODS

Sample collection

The study was carried out in two buildings (buildings 1B and 5RA) on the Santa Mônica campus of the Federal University of Uberlândia, located in Uberlândia, MG. The buildings 1B and 5RA are composed by classrooms with high circulation of people, whose drinking fountains are used by a floating population of about 1000 people daily, in each buildings. To collect the samples from the drinking fountains, the water was allowed to drain for 1 minute and, subsequently, collected in 45 mL falcon tubes, previously sterilized in an autoclave at 121°C and 1.2 atm for 20 minutes. The tubes were identified and immediately assayed. Samples were collected weekly for 12 weeks and analyzed in triplicates, totaling 36 samples for each building.

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Bacteriological analysis

Microbiological analyzes were performed using the Standard Multiple Tube Method (APHA, 2012), by counting the Most Probable Number (MPN) of coliform bacteria in three stages: presumptive, confirmatory and complete tests, according to PRT-MS No. 888 (BRASIL, 2021). In the presumptive assay, the water samples were homogenized and diluted in test tubes containing lactose broth as the only carbon source and inverted Durhan tubes. For each series of three tubes containing lactose broth, three 10mL aliquots of water sample in tubes containing 10 mL of lactose broth at double concentration (sample without dilution), three 1mL aliquots in tubes containing 9 mL of broth lactated broth at normal concentration (10x dilution) and three 0.1mL aliquots in tubes containing 9.9 mL of lactated broth at normal concentration (100x dilution) were aseptically transferred. The samples were incubated at ±36°C for 48 hours. Afterwards, the samples were evaluated for gas production and the presence of turbidity in the tubes indicated the presence of lactose fermenting bacteria.

In the confirmatory assay, 100 µL aliquots from the tubes with a positive result in the presumptive test were transferred to 15 mL falcon tubes containing 5 mL of 2% Green Bile Brilliant Broth. After the incubation at 36ºC for 48 hours, the presence of gas and turbidity was evaluated to confirm the presence/absence and calculate the MPN of total coliforms in the samples. Aliquots of 100 µL of samples with a positive result in the presumptive test were also transferred to tubes containing EC broth and incubated for 24 hours at 45ºC to evaluate the presence of thermotolerant coliforms. Subsequently, the tubes that presented microbial growth and gas formation were counted to obtain the MPN.

Physical-chemical parameters

The physical-chemical parameters pH, conductivity, color, total dissolved solids, turbidity and trace metals were analyzed according to PRT-MS nº 888 (BRASIL, 2021). For pH determination, the potentiometric method was used through the ®MS Tecnopon mPA-210 benchtop pHmeter equipment. The pH meter was calibrated with standard pH 4.0 and 7.0 buffer solutions before reading the weekly samples. The reading was performed by immersing the clean and dry electrode in the water sample until the pH stabilized.

The conductivity was analyzed in a HACH - HQ40d multiparameter equipment by the conductimetry method, which is based on the intensity of the electric current in the water, with the result expressed in µS cm^{-1}. The conductivity meter electrodes were immersed in the sample and the result was obtained by the intensity of the electric current passing through them. The determination of total dissolved solids was also carried out in the multiparameter equipment, through the conversion based on the electrical conductivity of the water (Electrical conductivity = K * dissolved solids), with a multiplication factor (K) recommended between 0.55 and 0.75. Thus, in the present study, the value of 0.680 was used for the multiplication coefficient based on the measured electrical conductivity. The concentration of chemical constituents dissolved in water was expressed in mg L^{-1}, and the VMP in water for human consumption is 500 mg L^{-1} (FELIPPE; de ALMEIDA NETO, 2019).

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For turbidity, the turbidimetric method was employed, which consists of measuring the interference in the passage of light due to the presence of suspended particles in the water. For this purpose, the ®PoliControl Turbidimeter AP2000 equipment was used, consisting of a light source (tungsten filament) and a photoelectric detector that measures the scattered light and the turbidity unit expressed in uT. The water sample was inserted into a colorless and transparent cuvette that was introduced into the turbidimeter for reading. For the color parameter, the spectrophotometric method was used using the ®PoliControl AquaColor equipment, which measures the intensity of color in water. The water sample was placed in a colorless glass cuvette and the color of the sample was determined.

For the analysis of trace metals, the atomic emission spectrometry with inductively coupled plasma was used, in ICP-OES/5100 ®Agilent equipment, for the determination of metals (Al, Ba, Cd, Pb, Cu, Cr, Fe, Mn, Ni, Na and Zn). This technique is based on the detection of electromagnetic radiation emission by electrons, atoms, ions or molecules in their excited state, or emission states, which can have their concentration determined through the use of light intensity or specific wavelength (DUARTE, 2020).

RESULTS AND DISCUSSION

Bacteriological analysis

After 12 weeks of monitoring, the bacteriological analysis of the drinking water in 1B and 5RA buildings did not detect the presence of coliforms in the samples (MPN = 0), as total coliforms as Escherichia coli during the evaluated period. Total coliforms are microbiological indicators of hygiene conditions, which help in evaluation the integrity of the system and water quality (BRITO et al., 2021). The presence of thermotolerant coliforms, represented by *E. coli*, indicates the occurrence of fecal contamination. Thus, the results showed that the water from the drinking fountains of 1B and 5RA buildings did not present contamination (**Figure 1**), indicating that the hygiene conditions and integrity of the system are in accordance with the current legislation (BRASIL, 2021). Sampaio and Silveira (2021) analyzed the water of 96 public schools in the municipality of Uberlândia using the chromogenic substrate method and observed that in 23 schools there was microbiological contamination, representing an opposite scenario of the present study. This study showed that the water that reaches schools is of good quality, indicating that contamination occurs after supplying the schools, which may be due to lack of maintenance and cleaning of water reservoirs and filtering systems of drinking fountains. Thus, to ensure the water potability, as recommended by legislation, the maintenance and cleaning of water reservoirs must be carried out at intervals of a maximum of six months to avoid contamination, in accordance with Resolution no. 216, of the National Health Surveillance Agency (ANVISA, 2004).

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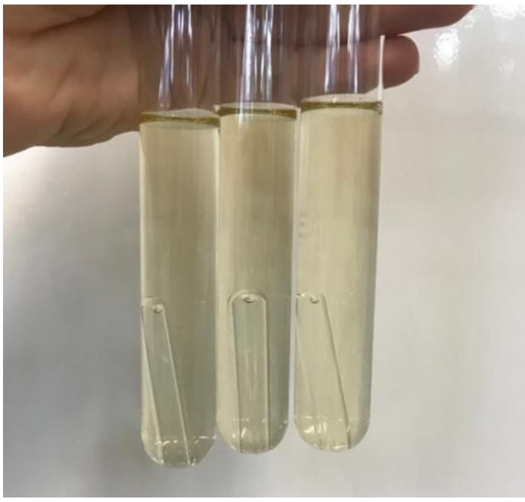
Figure 1. Example of presumptive test indicating the absence of total coliforms in 1B building, according to Ordinance MS 888/2021. Results expressed as the mean of triplicates



Physical-chemical parameters

The physical-chemical analysis showed that all the parameters, except pH and color, were in compliance with the legislation (BRASIL, 2021). For the pH, some samples from few weeks showed small changes, with values slightly below the required for the potability standard, which should range from 6.0 to 9.5 (**Figure 2A**). The pH is an important water quality parameter, which may be related to the presence of metals, and low values can cause corrosion of distribution system pipes (SILVA; LOPES; AMARAL, 2016). The water acidity can trigger problems and affect its quality, since low pH can neutralize agents that are used to remove microorganisms (ARAÚJO; ANDRADE, 2020).

In addition, acidity has an indirect long-term effect on the precipitation of metals that can influence other parameters such as color. In this work, the average pH value was 5.81 and 5.44 in buildings 1B and 5RA, respectively. These pH values below the established minimum value may be due to oxidative processes, as the building's pipes are made of iron and are very old. Water acidity may also be associated with chlorine stability, which may affect disinfection efficiency, compromise flavor and cause pipe corrosion, justifying its monitoring (BRITO et al., 2021).

However, in this study the pH values are close to the range determined for consumption and do not offer potential risks to the human health. For the color parameter, the maximum allowed value (MPV) for drinking water is up to 15 uc, according to Ordinance MS No. 888/2021 (BRASIL, 2021). For the 5RA building, the average value found was 2.10 uc, in compliance with the legislation (**Figure 2B**). For building 1B, the overall average was 13.10 uc; however, six samples showed values slightly above the MPV at weeks 1, 4, 6 and 8 (**Figure 2B**). After the 9th week, a drop in value was observed in relation to the previous weeks, which coincided with the increase in pH. As previously mentioned, this increase in pH may be associated to the oxidative processes and, consequently, to the decrease in the value of the color parameter.

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Figure 2. Values of pH (A) and apparent color (B) of the drinking water of the buildings 1B (■) and 5RA (●). Value required for pH: 6.0 - 9.5 and VMP for color units (uc) < 15.0 (Ordinance MS 888/2021). Results expressed as the mean of triplicates

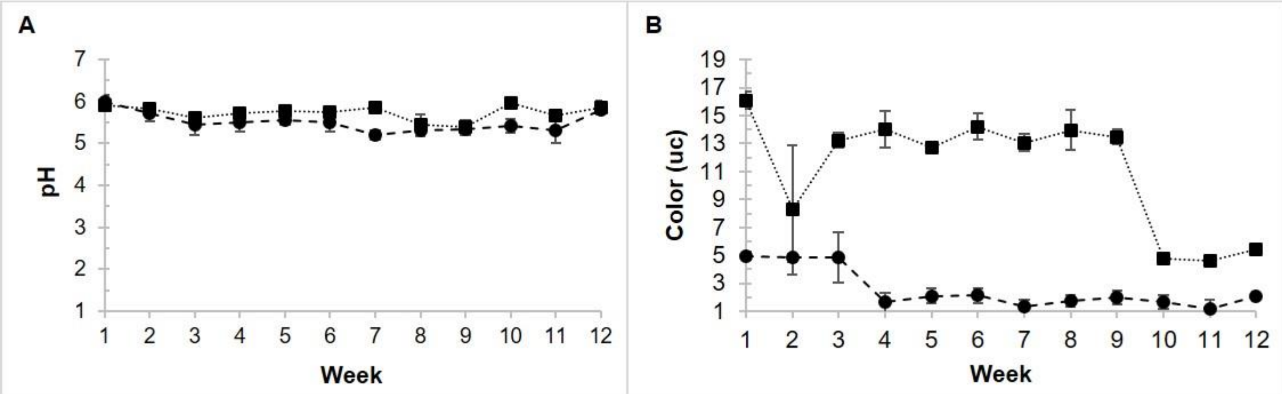
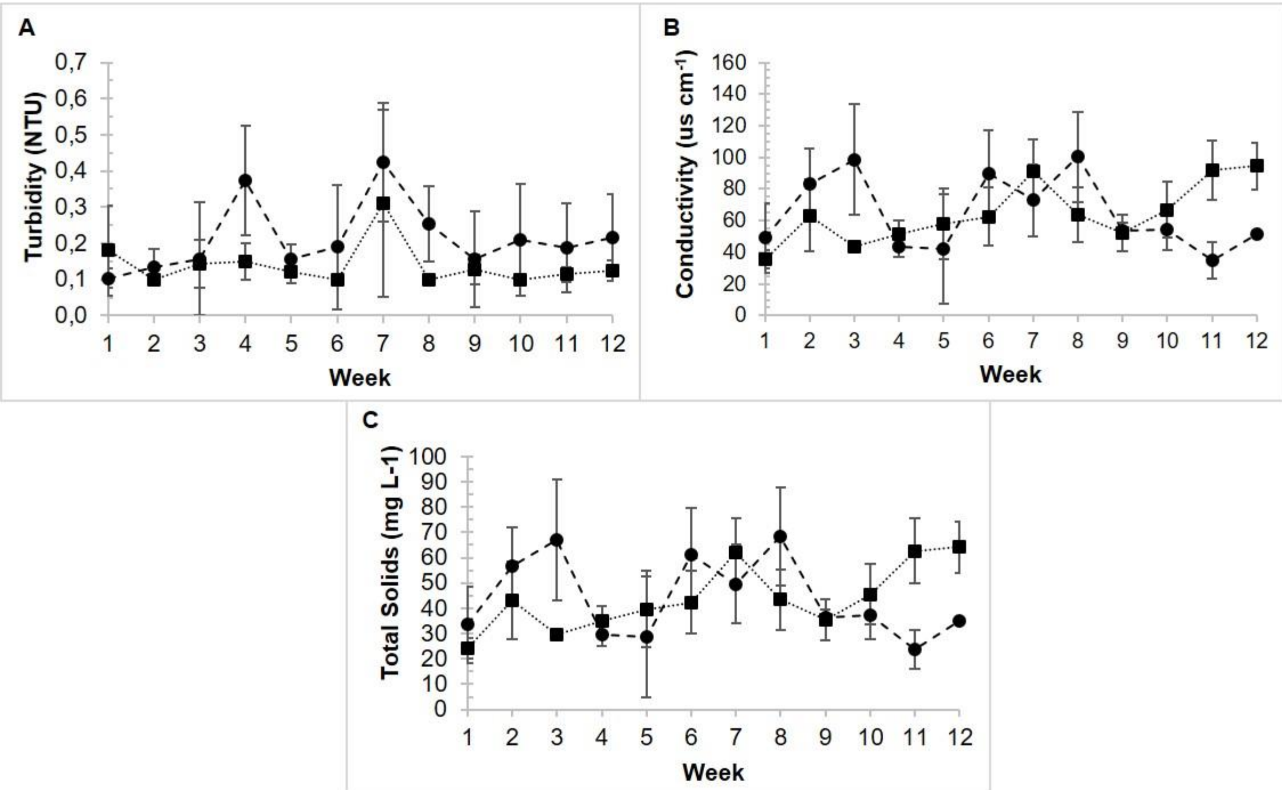


Figure 3. Turbidity (A), conductivity (B) and dissolved solids (C) of drinking water in buildings 1B and 5RA. VMP for NTU < 5.0 and SD < 1000.0 mg L^{-1} (Ordinance MS 888/2021). Results expressed as means of triplicates



This relationship was also observed by Araújo and Andrade (2020), in a literature review about the water quality in drinking fountains in educational institutions. This result may be due to the removal of the water tanks from building 1B, which started to be supplied directly by the central tank of the campus from the 9th week of analysis, the same week in which the alteration of the color and pH parameters was evidenced. The color indicates the

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presence of dissolved or colloidal organic and inorganic substances in the water. The increase in color may be related to the age of the piping material and be due to the high concentration of some elements, such as iron or manganese, or due to the decomposition of organic matter (TELLES, 2013). Even so, color is considered an aesthetic characteristic that does not pose a direct risk to health.

The other parameters presented results according to the potability standard, with average values for building 1B of: turbidity - 0.10 NTU, conductivity - 53.65 us cm^{-1} and total dissolved solids - 36.48 mg L^{-1}, demonstrating good water quality (**Figure 3A, B** and **C**, respectively). For the 5RA building, the average results found were: turbidity - 0.14 NTU, conductivity - 52.70 µs cm^{-1} and total dissolved solids - 35.84 mg L^{-1} (**Figures 3 A, B** and **C**), demonstrating that the water from the drinking fountains in this building also complies with the legislation. In general, the results obtained indicated that the analyzed water is of good quality. However, periodic monitoring is recommended, observing the expiry date of the filters and the condition of the water fountain hoses that supply the community.

Metal quantification

According to Annexes 9 and 11 of Ordinance MS 888/2021 (BRASIL, 2021), the maximum permitted values (MPV) of trace metals in water for human consumption are shown in **Table 1**.

For 1B building, alterations were observed in the values of Cr, Fe and Ni in the 4th week of analysis, with values above the MPV (**Table 2**). Chrome compounds, in high concentrations, can result in problems in the respiratory system, kidneys and liver, in addition to dermatitis, diarrhea and hemorrhages, and high concentrations of Ni can affect cardiac and respiratory nerves and also cause dermatitis (AGUILLAR et al., 2020).

Table 1. MPV for metals, according to Annexes 9 and 11 of Ordinance MS 888/2021

Parameter	MPV* (mg L^{-1})	QL***(mg L^{-1})
Al	0,2	0,0040
Ba	0,7	0,0005
Cd	0,003	0,0005
Pb	0,01	0,0080
Cu	2	0,0005
Cr	0,05	0,0005
Fe	0,3	0,0050
Mn	0,1	0,0005
Ni	0,07	0,0020
Na	200	0,0100
Zn	5	0,0020

*MPV Maximum Permited Value. ***QL Quantification Limit. Source: Ordinance MS 888/2021.

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Table 2. Quantification of Metals (mg L^{-1}) in 1B building. Results expressed as the mean of triplicates, with standard deviation $p<0.05$. E: chemical element

	Week											
E	1	2	3	4	5	6	7	8	9	10	11	12
Al	0,0954	0,1460	0,1378	0,0611	0,0689	0,0543	0,0569	0,1221	0,0779	0,0877	0,0752	0,1021
Ba	0,0177	0,0134	0,0134	0,0339	0,0167	0,0163	0,0130	0,0220	0,0157	0,0131	0,0125	0,0160
Cd	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	0,0003
Pb	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080
Cu	0,0025	0,0011	0,0009	0,0020	0,0013	0,0011	0,0011	0,0018	0,0021	0,0015	0,0020	0,0625
Cr	0,0037	0,0044	0,0058	0,0685	0,0035	0,0040	0,0044	0,0056	0,0054	0,0030	0,0043	0,0123
Fe	0,1204	0,0352	0,0629	0,3663	0,0814	0,0672	0,1167	0,0795	0,0954	0,1366	0,0834	0,0816
Mn	0,0042	0,0031	0,0040	0,0091	0,0045	0,0044	0,0106	0,0067	0,0105	0,0127	0,0078	0,0240
Ni	0,0056	0,0065	0,0085	0,0409	0,0054	0,0044	0,0035	0,0041	0,0042	0,0045	0,0035	0,0125
Na	0,9617	1,4178	2,5888	1,3901	0,9484	0,8250	0,6953	1,7705	1,3345	4,3973	4,3452	4,5295
Zn	0,0199	0,0105	0,0130	0,0229	0,0177	0,0180	0,0215	0,0256	0,0304	0,0255	0,0234	0,1002

According to Marcelino et al. (2017), Fe can impart color and flavor to water, presenting aesthetic problems and can also cause encrustation and corrosion in pipes, allowing the appearance of ferruginous bacteria. Therefore, these parameters must be constantly monitored. The Fe concentration at point B3 in the 4th week of analysis was 0.9443 mg L^{-1}, a value that would indicate some coloration of the water, which was not evidenced in the results of the color parameter of the same sample. Since only one sample among 36 samples showed alteration in the values of the metals Cr, Fe and Ni, it was considered that some experimental or instrumental error had occurred and the alteration was disregarded. For the 5RA building, the results obtained for trace metals were all in accordance with the legislation, indicating that the water is qualified for human consumption, according to this parameter (**Table 3**).

Table 3. Quantification of Metals (mg L^{-1}) in 5RA building. Results expressed as the mean of triplicates, with standard deviation $p<0.05$. E: chemical element

	Week											
E	1	2	3	4	5	6	7	8	9	10	11	12
Al	0,0488	0,0823	0,0665	0,0590	0,0571	0,0480	0,0895	0,0283	0,0876	0,0689	0,0465	0,0865
Ba	0,0131	0,0165	0,0173	0,0177	0,0131	0,0152	0,0174	0,0123	0,0104	0,0133	0,0130	0,0169
Cd	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	0,0002
Pb	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080	<0,0080
Cu	0,0042	0,0023	0,0021	0,0023	0,0016	0,0014	0,0017	0,0007	0,0011	0,0032	0,0037	0,0017
Cr	0,0034	0,0040	0,0029	0,0026	0,0035	0,0039	0,0043	0,0130	0,0081	0,0009	0,0018	0,0087
Fe	0,0513	0,0757	0,0477	0,0409	0,0649	0,0442	0,0975	0,0572	0,0868	0,0428	0,0409	0,0618
Mn	0,0136	0,0173	0,0108	0,0080	0,0103	0,0061	0,0141	0,0061	0,0082	0,0240	0,0247	0,0240
Ni	0,0039	0,0044	0,0035	0,0037	0,0030	0,0150	0,0026	0,0035	0,0046	0,0066	0,0071	0,0111
Na	2,8512	2,3293	2,2701	1,5236	1,9805	1,8576	1,7319	4,7649	4,8616	4,0473	4,0416	4,5094
Zn	0,0207	0,0223	0,0232	0,0202	0,0182	0,0188	0,0228	0,0139	0,0111	0,0384	0,0357	0,0519

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CONCLUSIONS

After 24 weeks of monitoring, the present study presented satisfactory results in respect to the water quality of the drinking fountains at the Federal University of Uberlândia, indicating the absence of contamination by bacteria of the coliform group. However, it is important to prevent cross-contamination of drinking fountains, avoiding proximity to bathrooms and performing periodic cleaning and maintenance of both reservoirs and filtering systems. The physical-chemical parameters turbidity and dissolved solids are in accordance with the potability standard; however, pH and color showed small changes. For trace metals, a point change for Cr, Fe and Ni was observed in a single sample. Such changes do not offer potential risks to human health. The results indicated the potability of the water analyzed and reinforce the importance of monitoring water in educational institutions, as well as maintaining reservoirs and drinking fountains, to ensure the availability, sanitation and sustainable management of water for the entire community, in accordance with the SDG 6.

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