

Physical-chemical and microbiological evaluation of mine waters in the Municipality of Caratinga - MG

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Abstract — *Water coming from mines to be destined for human consumption must comply with Ordinance No. 888 of May 4, 2021 of the Ministry of Health. the standard of potability of water for human consumption. The objective of this study was to evaluate, through physical-chemical and microbiological variables, the quality of mine waters that are being exposed to consumption by the population of the municipality of Caratinga-MG, using the parameters referred to by Ordinance No. 888 of 2021. The methodologies used for the analysis of physicochemical and microbiological parameters followed the protocols of the Standard Methods For the Examination of Water and Wastewater, 23rd edition. The results of the physical-chemical analyzes of all water collection points are within the potability standards required by Ordinance No. 888 of 2021, and the results found referring to microbiological analyzes demonstrated that there is no contamination by fecal coliforms, and that It is an excellent index, and makes us think about applying the simple chlorination process, which can contribute to the disinfection process and maintain water quality. Consuming quality water is a right of every citizen, therefore, actions to adapt mine waters used by the population for consumption, or any other sources, are essential, and therefore, it is recommended to continue monitoring water quality of the mines studied in the municipality of Caratinga-MG.*

I. INTRODUCTION

The water mine is formed when the aquifer, that is, the subterranean sheet reaches the surface and, thus, the water stored underground surfaces on the surface of the land, and is popularly known as spring, mine, water hole, headboard, spout or fountain.

Water from mines to be destined for human consumption must comply with Ordinance No. 888 of 2021 of the Ministry of Health. This ordinance describes all the physical-chemical and microbiological parameters necessary for the standard of potability and human consumption, being o except applied only in mineral water source, natural or water added with salts intended for consumption after bottling, which are subject to the

microbiological guidelines of Resolution (RDC) No. 274 of 2005 (BRASIL, 2005).

The characteristics found in groundwater are due to physical, chemical and biological processes that determine a wide variety of substances present in the water, and can also be affected by anthropogenic activities, such as domestic and industrial polluting loads, which can also influence the quality of water underground.

Normally groundwater is less prone to contamination, because, during the path in which water percolates between the pores of the subsoil and rocks, it is purified through a series of physicochemical and bacteriological processes, which naturally modify the characteristics of the water, making it more suitable for

consumption human (SILVA and ARAÚJO, 2003; PEIXOTO et al., 2017, PEIXOTO, 2020).

The use of groundwater can be advantageous when it is free from contaminants, however, Costa et al., (2012) reports that this water resource can have the potential for transmitting diseases caused by pathogenic microorganisms, which may come from feces of humans and animals, or through chemical substances in concentrations outside the standards allowed by Ordinance No. 888 of 2021, therefore, it is essential to verify and monitor their potability for human consumption.

Assuming that groundwater may somehow have the potential for contamination by microorganisms and at the same time for spreading disease (Costa et al., 2012, Peixoto et al., 2017, Peixoto, 2020), the need is reinforced to verify the physical-chemical and microbiological standards of groundwater, and the service for consumption in accordance with Ordinance No. 888 of 2021.

The aim of this study was to evaluate, through physical-chemical and microbiological variables, the quality of water from mines that are exposed to consumption by the population of the municipality of Caratinga-MG, and thus verify whether these water mines are used for human supply, reach the standards of Ordinance No. 888 of 2021 and are free of contaminants or if they need any type of treatment.

It is also reinforced that the municipality of Caratinga has an average infant mortality rate of 21.03 for every 1,000 children born alive, representing the position 171 out of 853 of the municipalities in the State of Minas Gerais (IBGE, 2017). And that many hospitalizations due to diarrhea are possibly linked to the consumption of water that is not properly treated.

II. MATERIALS AND METHODS

2.1. Study area and sample collection

This work was carried out in the municipality of Caratinga, which is located in the interior of the State of Minas Gerais, in the Vale do Rio Doce. According to the latest edition of the IBGE of 2010, the city has a population of 85.239 inhabitants, with an estimated 91.503 inhabitants in 2018 (IBGE, 2020).

The city's water and sewage treatment is the responsibility of the State Joint Company, Minas Gerais Sanitation Company (COPASA), headquartered in Belo Horizonte. The city's water supply system has a production capacity of 207.9 liters of water per second. The water reaches their properties along 167,114 meters of distribution networks (COPASA, 2018).

The water supply service provided to the municipality of Caratinga has a service percentage of

89.87% of the population and a coverage rate of 100% (ARSAE, 2016).

Collections were carried out in three water mines in the municipality, which are commonly used for supply and human consumption. These mines have the following geographic coordinates: -19.7909907, -42.1364616.1025, in the Santa Zita district; -19.785404, -42.1484615.512 (called collection point 1), mine located in the Anápolis district, at Street José Alves Pereira, and - 19.717815, -42.128485 (called collection point 2), mine located at BR 116, at (called collection point 3).

At collection point 1, there is a tap installed to facilitate the collection of part of the mine's water by people. At point 2, in the Anápolis neighborhood, the residents made a kind of pipe with a pipe to supply and consume water from this mine. And finally, at collection point 3, at Km 520, BR 116, there is a pipe with water that runs constantly in a faucet, both placed by residents for the mine's consumption.

2.2. Collection and processing of mine water samples

Collections were carried out in the three mines in triplicate and the transport of samples was carried out in accordance with the guidelines of the Standard Methods 23rd edition and the National Guide for the Collection and Preservation of Samples (ANA, 2011).

For the realization of the physical-chemical parameters, the collections were made in plastic containers with a capacity of 250 mL sterile. And for the analysis of microbiological samples, sterilized glass containers were used, with a capacity of 125 mL, sterilized at 180 °C for 1:30 h. The collected samples were placed in a Styrofoam box with ice for transport and taken to the COPASA - Caratinga laboratory, where they were refrigerated at approximately 6 °C until the analysis was carried out. Chlorine and temperature analyzes were performed in loco.

2.3. Physicochemical analysis of mine water samples

The physical-chemical analyzes performed were: pH, turbidity, chlorine, color, fluorine and conductivity, defined in accordance with Ordinance No. 888 of 2021. The temperature measurement of the samples was performed with a digital thermometer.

The methodologies for analyzing the physicochemical parameters were carried out in accordance with the Standard Methods For the Examination of Water and Wastewater, 23rd edition (APHA, AWA, WEF, 2017). The pH analysis is performed by the electrometric method by a digital device known as potentiometric, which measures the activities of hydrogen ions present in water.

And later the turbidity analysis used the nephelometric method, in a digital device that measures the deviation of light when passing through any particle in the water. And for color analysis, the photolorimetric method was applied, in a digital device, which measures the wavelength of color absorption.

Chlorine analyzes were performed using the DPD colorimetric method, in which the device measures the wavelength in the absorption of colors caused by the DPD reagent in the presence of chlorine in water. Fitting the fluoride (or fluoride ion) analyzes performed by the selective ion electrode reading by electrode method, in which after adding a solution called TISAB, where the various ions present in the water complex with one of its constituents, leaving the ions of free fluorine to be measured. And finally, the conductivity analyzes performed by an electrometric method using an electrode sensitive to all ions present in water (APHA, AWA, WEF, 2017).

2.4. Criteria for carrying out microbiological analysis of water

For microbiological analyses, the presence/absence control for total coliforms and *Escherichia coli* (*E. coli*) was performed, using qualitative methodology, and also the measurement performed by the most probable number (MPN) of coliforms in 100 ml of sample, by quantitative methodology.

For the analysis of total coliforms and *E. coli*, the chromogenic substrate was used, which can be accounted for the presence of total coliforms in 24 hours in the oven at 35° C, which have a yellowish color, which after being placed in a dark room with a lamp ultraviolet, if the samples are fluorescent, they will be considered positive for *E.coli*,

all methodology followed the Standard Methods For the Examination of Water and Wastewater, 23rd edition (APHA, AWA, WEF, 2017).

2.5. Suggested alternative for simplified treatment for mines in the municipality of Caratinga-MG.

As a suggestion for the proposal for treatment in the mines of this study, an alternative for installing simple chlorinators was presented, citing a project developed by the Brazilian Agricultural Research Corporation (Embrapa), which is linked to the one linked to the Ministry of Agriculture, Livestock and Supply (EMBRAPA, 2021).

III. RESULTS AND DISCUSSION

3.1. Physicochemic alanalysis

The temperature measurements of the samples were carried out in loco, and presented values ranging from 19°C to 21°C, which are considered within the normal range for groundwater and without interfering with water quality (FAVARIN, 2017).

The results regarding the pH (hydrogenionic potential) are within the potability standards and within the recommended range of 5.5 to 8.0, which corroborate the work carried out by CERQUEIRA, (2014).

The pH is defined as the negative logarithm of the concentrations of hydrogen ions, ranging from 0 to 14. Values less than 7 (seven) acidity, and the lower, the more acidic. Values from 7 to 14 indicate increased alkalinity, and the more alkaline the closer it is to 14 FRITZSONS et al., (2009). According to FEITOSA et al., (2008), the pH of groundwater can generally vary between 5, 5 and 8.5, in agreement with the results found in this work.

Table 1 - Results of the physicochemical analyzes of water from the mine in point 1.

Collection point 1	pH	Chlorine (mg/L)	Fluoride (mg/L)	Turbidity (NTU)	Color (uH)	Conductivity (µS/cm)
Collection 1	7.7	0	0.17	0.37	5.9	256
Collection 2	7.7	0	0.16	0.28	2.7	256.1
Collection 3	7.7	0	0.13	0.38	6.0	256.3

Source: Authors (2021).

With respect to fluoride ions, these presented values below expectations, ranging from 0.13 mg/L to 0.17 mg/L, as can be seen in table 1. The fluoride content in groundwater, values that can vary between <1 to 25 mg/L, depending on the geological and physicochemical factors of the area where the water mine is located (NETTO, et al., 2016).

According to the Ordinance 888 of 2021, the fluoride ion in drinking water needs to be less than 1.5 mg/L, which is in accordance with the results found in this work, presented in table 1. It is noteworthy that the absence of this chemical compound does not characterize a water as non-potable, but the controlled addition of this ion is one of the most important caries prevention measures. Some

groundwater has this compound naturally (BRASIL, 2009b).

The turbidity results, presented in the samples are below 1.0 NTU 3, as shown in table 1. A turbidity is a parameter of great importance in physicochemical and bacteriological controls and the Ordinance No. 888 of 2021 defines that in at least 95% of the analyzed samples the turbidity needs to be up to 1.0 NTU (turbidity unit).

The WHO international standards of water for human consumption recommend maximum levels of up to 5 NU of turbidity, if this parameter appears higher than this value, there may be material suspended in the water, and these contribute by fixing the pathogens, making the action difficult of simple treatments, such as the use of chlorine over them for water disinfection (SCHWARTZ et al., 2000).

Regarding the parameter of colors observed in the samples in table 1, they are below 15 uH, the values found are in accordance with what was determined by the Ordinance No. 888 of 2021 (BRASIL, 2021).

Also in table 1, the conductivity values result in TDS lower than 1,000mg/L, corroborating the values already found by FEITOSA et al., (2008), and also in relation to the chlorine compound, it was observed that it was not found in the samples from this location, however, the Ordinance No. 888 of 2021, establishes a minimum of 0.2 mg/L and a maximum of 5.0 mg/L, for water that is treated and used for human consumption.

Finally, regarding the values related to electrical conductivity, it is important that it is between 50 to 1500

$\mu\text{S}/\text{cm}$ in drinking water. The quantification of the conductivity parameter is important due to the excess of dissolved particles in the water be harmful to health (SANTIAGO et al., 2007; FEITOSA et al., 2008). It can also be observed in table 1, that in the water samples from this point 1, this parameter was kept within the allowed values, ranging from 256 ($\mu\text{S}/\text{cm}$) to 256.3 ($\mu\text{S}/\text{cm}$).

In the analyzes performed at collection point 2, the pH results are all within potability standards and within the recommended range of 5.5 to 8.5 (CERQUEIRA, 2014) for groundwater, as shown in table 2. table, it can be noted that the chlorine had the expected content, since it is water without prior chlorination (BRASIL, 2016a)

Fluoride ions had values equal to 0.08 mg/L, as shown in table 2. This content is expected for groundwater without fluoridation. According to Ordinance 888 of 2021, the fluoride ion must be below 1.5 mg/L. The fluoride content in groundwater can vary between <1 to 25 mg/L, depending on the geological and physicochemical factors of the area where the water mine is located (NETTO, et al., 2016).

And with regard to the turbidity results, these also showed values below 1.0 NTU, which is recommended by Ordinance 888 of 2021 and the same occurred with the color patterns found, as can be seen in table 2 (BRASIL, 2017).

The conductivity values found result in TDS lower than 1,000mg/L, corroborating FEITOSA et al., (2008) and presented values equal to 244.4 ($\mu\text{S}/\text{cm}$).

Table 2 - Results of the physical-chemical analyzes of water from the mine in point 2.

Collection point 2	pH	Chlorine(mg/L)	Fluoride (mg/L)	turbidity (NTU)	Color (uH)	Conductivity($\mu\text{S}/\text{cm}$)
Collection 1	5.9	0	0.08	0.20	3.1	244.4
Collection 2	5.8	0	0.08	0.14	3.5	244.4
Collection 3	5.9	0	0.08	0.12	<2.5	244.4

Source: Authors (2021).

In the physicochemical analyzes carried out in point 3, the pH results were between 5.2 and 5.3, these values being slightly below the recommended range, which is 5.5 to 8.5 for groundwater (CERQUEIRA, 2014), as can be seen in table 3. It was also observed in table 3 that the samples did not contain chlorine, as expected, as it is not treated water (BRASIL, 2016).

And with respect to fluoride ions, presented in table 3, the values were equal to 0.08 mg/L, content is

expected for groundwater without fluoridation. The turbidity results are below 1.0 NTU, with values equal to 0.30 NTU and 0.34 NTU, as recommended by Ordinance No. 888 of 2021. The colors have values below 15 uH, being in accordance with the determined by the Ordinance (BRASIL, 2021). The conductivity values found result in TDS lower than 1,000mg/L, which is in agreement with the work carried out by FEITOSA et al., (2008) (Table 3).

Table 3 - Results of the physicochemical analyzes of water from the point 3 mine.

Collection point 3	pH	Chlorine (mg/L)	Fluoride (mg/L)	Turbidity (NTU)	Color (uH)	Conductivity (µS/cm)
Collection 1	5.2	0	0.08	0.33	<2.5	74.8
Collection 2	5.3	0	0.08	0.34	3.1	74.9
Collection 3	5.2	0	0.08	0.30	<2.5	77.4

Source: Authors (2021).

3.2. Microbiological analysis

All microbiological analyzes of point 1, referenced in table 4, showed presence for total coliforms, and absence for *E. coli*. Total coliforms are mostly not pathogenic, but they can pose health risks, as well as deteriorate water

quality, causing unpleasant odors and tastes, while *E. coli* bacteria are part of this group and their origin is essentially fecal (FUNASA, 2013). The probability of finding pathogenic bacteria in water is greater the greater the number of coliforms in this water (DEMAE, 2001)

Table 4 - Results of microbiological analyzes at collection point 1.

Collection point 1	Total coliforms	Total coliforms (NMP)	<i>E. coli</i>	<i>E. coli</i> (NMP)
Collection 1	Presence	1989,3	Absence	0
Collection 2	Presence	866.4	Absence	0
Collection 3	Presence	866.4	Absence	0

Source: Authors (2021).

The microbiological analyzes of point 2, represented in table 5, showed presence for total coliforms, and absence of for *E. coli*. Total coliforms are used as evidence of contamination and the *E. coli* species is

considered the best indicator of fecal contamination, and can be found in sources other than feces (FUNASA, 2013), the fact that it is not found in the samples in this study, is already a good sign of water quality.

Table 5 - Results of microbiological analyzes at collection point 2.

Collection point 2	Total coliforms	Total coliforms (NMP)	<i>E. coli</i>	<i>E. coli</i> (NMP)
Collection 1	Presence	14.6	Absence	0
Collection 2	Presence	19.5	Absence	0
Collection 3	Presence	24.9	Absence	0

Source: Authors (2021).

Only collection 2 from this point 3 showed 1 NMP of bacteria from the total coliform group, the others absent for total coliforms and *E. coli*.

According to Ordinance No. 888 of 2021, water for human consumption must present absence of fecal coliforms. All water samples are adequate in this regard, and in accordance with this ordinance.

Table 6 - Results of microbiological analyzes at collection point 3.

Collection point 3	Total coliforms	Total coliforms (NMP)	<i>E. coli</i>	<i>E. coli</i> (NMP)
Collection 1	Absence	0	Absence	0
Collection 2	Presence	1	Absence	0
Collection 3	Absence	0	Absence	0

Source: Authors (2021).

The group of coliforms are classified into total coliforms and thermotolerant coliforms and are considered indicators of contamination most used to monitor the sanitary quality of water (SCURACCHIO, 2010). The presence of total coliforms in water is not necessarily indicative of fecal contamination or occurrence of enteropathogens, it may be related to the presence of *E.coli* (BORELI et al., 2014).

3.3. Suggested installation of a tablet chlorinator for water treatment in Mines in the municipality of Caratinga-MG.

According to Ordinance No. 888 of 2021, for the use of any water for human ingestion, it is necessary to undergo at least a simplified treatment such as disinfection; this is because, only with the disinfection process (the most common chlorine) will water be safer for human consumption.

Some even resist the presence of chlorine in treated water and often assimilate its characteristic smell and taste as something undesirable, or even toxic SILVA & VALENTINI (2020) and LUCAS & BOHNE (2015).

The disinfection of water can be carried out by different physical or chemical processes, and even a combination of them is possible. Historically, the most used oxidizing agent in water treatment processes has been chlorine, in the form of gaseous chlorine (Cl_2), sodium hypochlorite ($NaOCl$) and calcium hypochlorite ($Ca(OCl)_2$). Its disinfectant power is high, easily acquired on the market, and its antibacterial action is mainly due to its atomic structure with a tendency to gain electrons, and

high oxidizing power. Thus, chlorine can penetrate the cell wall of microorganisms that are predominantly negatively charged, and inhibit the oxidation of glucose, which is vital for bacterial growth (BRASIL, 2006), thus leaving the water free of microorganisms.

Thinking about water supply and consumption in small communities without access to water treated by sanitation companies, it was developed in 1978, in a partnership between COPASA and the Minas Gerais State Education Department, the tablet chlorinator, which aims to improve the potability of water distributed in several schools in the state education system in the metropolitan region of Belo Horizonte, however, it should be noted that there are several models of tablet chlorinators, but basically their operating mechanism is the same. The tablets usually have the composition of calcium hypochlorite, which gradually releases the chlorine ions into the water needed for water disinfection (BRASIL, 2006).

The average duration of the tablets must be defined through the residual chlorine control, which needs to be between 0.2 to 5.0 mg/L. For this it is essential that this content is analyzed frequently. Currently, there are laboratory equipment on the market for chlorine analysis of various models, as well as visual and digital methodologies (SOARES et al, 2016).

The tablet chlorinator model developed by Embrapa (Brazilian Agricultural Research Corporation), shown in Figure 1, is simple to make and inexpensive, in addition to having an easy-to-understand booklet, which is freely accessible on the company's website. It follows the model chlorinator of inserts assembled by EMBRAPA (2014; 2021).

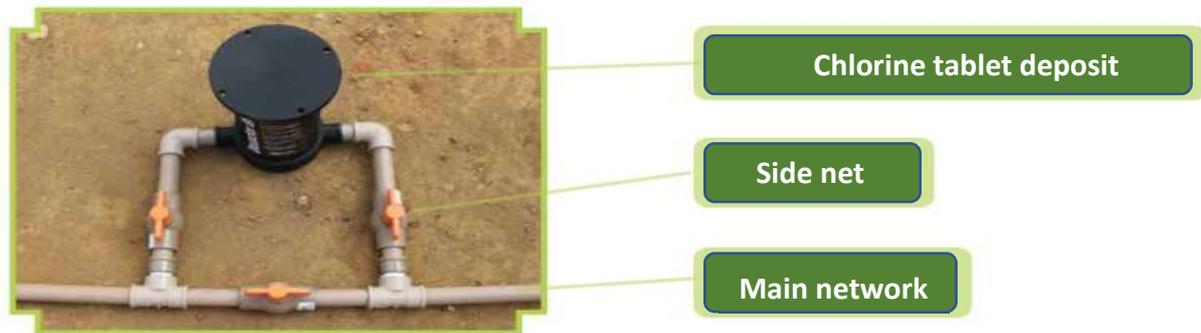


Fig.1: Chlorinator suggestion model for communities without access to treated water.

Source: Embrapa (2014).

As the water mines in this work are small flows, the consumption of pellets will probably be small, and you will be able to apply this model in each of the points where water is collected for human consumption. It is noteworthy that in the booklet, there are also instructions on how to perform the chlorine content analysis using a visual methodology with the “measuring kit” that are easily found in stores specializing in swimming pool treatment.

The suggestion made in this work, with the application of a simple chlorinator system, aims to keep the water consumed by the local population in perfect potability. The installation of chlorination processes can be elaborated by the local residents or by the public authorities, being still necessary the control and monitoring of these waters, to guarantee its potability.

IV. CONCLUSION

The physicochemical analyzes found at all collection points are within the potability standards required by Ordinance No. 888 of 2021. And with regard to microbiological analyzes, these showed that there is no contamination in the samples by fecal coliforms, and this is an excellent index, and that makes us think that a simple chlorination system that can be applied at the points of collection and human consumption, and it aims to contribute so that the water from these mines will guarantee the quality within the desired standards.

Water quality is perennial, its controls and care must be frequent, as well as maintenance of cleanliness and asepsis of sources, pipes and connections. This work assumes, with the analyzes carried out, that the water being chlorinated will be suitable for consumption and will be able to meet the parameters recommended by Ordinance No. 888 of 2021.

Consuming quality water is a right of every citizen, therefore, actions to adapt or improve quality are always a

way of trying to guarantee the desired standard of human consumption so that they do not have problems with the ingestion of disease-causing pathogens. And it would be of interest in these localities to study the continuity of water quality monitoring, for a greater guarantee of water consumption within the recommended standards.

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