sociedade & natureza

DOI: 10.14393/SN-v32-2020-43436
Received: 10 August 2018 | Accepted: 10 March 2020

Papers

The vulnerability of indigenous populations: Water quality consumed by the Maxakali community, Minas Gerais, Brazil

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Keywords:
Water physicochemical characteristics
Water microbiological characteristics
Seasonal variation
Water Resources

Abstract
Distributed in four villages with approximately 1800 individuals, the Maxakali people have the second largest indigenous population in the state of Minas Gerais, Brazil. This community's water quality is usually evaluated according to its palatability, and whether it meets certain visual criteria. Thus, a descriptive study was carried out including samples of surface and groundwater consumed in four villages. One survey was completed in each of the three seasonal periods in 2015. Hydrogen potential (Ph), turbidity, dissolved oxygen concentration, conductivity, nitrate, and total and thermotolerant coliforms were measured. The villages with the largest number of samples with values higher than tolerable were Verde Village (100%), followed by Água Boa Village (85.7%) and Pradinho (71.4%). All villages sampled showed higher-than-acceptable levels of dissolved oxygen, and total and fecal coliforms in more than 50% of the samples. The turbidity and conductivity changes were detected in three of the four villages. Thus, the water consumed by this community, untreated as per local tradition, presents a high risk for the occurrence of waterborne diseases in this population group.

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INTRODUCTION

Water quality, as well as water accessibility, are determined by a community's health and socioeconomic development. Hygiene habits, associated with access to water, increases life expectancy and decreases premature deaths. However, even though it is a basic human right, access to drinking water is still a distant reality in rural areas and needy periurban regions, leading to the search for alternative sources (often with dubious quality), further aggravating the already precarious living conditions in these places (RAZZOLINI; GÜNTHER, 2008).

Water quality can be understood as a result of natural and anthropogenic conditions relative to the water's specific intended use (home supply, irrigation, recreation, navigation, etc.). In Brazil, water quality was standardized by decree of the Ministry of Health 2914/2011 and the resolutions 357, 2005 and 396 of 2008 from National Environment Council (CONAMA - Conselho Nacional de Meio Ambiente). Despite these laws, even if a hydrographic basin is preserved, this is not, in itself, a guarantee of good quality water for consumption, due to the possibility of its contamination occurring through runoff and infiltration of undesirable contents before the water arrives at its ultimate destination (VON SPERLING, 1996). In this context, it can be understood that clean drinking water, free of chemical and microbiological contaminants, must meet chemical parameters; meeting aesthetic requirements is an inadequate measure of cleanliness (FERNANDES, 2012). Clean drinking water is still very scarce for populations that live in rural areas or villages, due to the lack of sanitation services (AMARAL et al., 2003). Although the risks of becoming ill from drinking unclean water are possible in any society, traditionally, the most vulnerable are those living in conditions of food scarcity, inadequate waste disposal, who lack sanitation infrastructure. These conditions lead to a high prevalence of parasites and malnutrition, which in turn decrease the capacity of the human physiological response when unclean water is used or consumed. One such vulnerable population is the Maxakali Indians.

The Maxakali are the second largest indigenous population in the state of Minas Gerais, with approximately 1800 individuals (BRASIL, 2013). This community is plagued with high mortality rates due to malnutrition, internal conflicts caused by the consumption of alcoholic beverages, diarrheal and respiratory diseases (LAS CASAS, 2007), in addition to the high prevalence of intestinal parasites (89%) (ASSIS et al., 2013). The Maxakali indigenous community moves between villages and consumes fresh, untreated water, which is not always abundant. In addition, the assessment of water quality for communities is limited to palatability and visual criteria, which are insufficient to guarantee the standard necessary for maintaining health. Therefore, to fill these gaps, this study aimed to scientifically characterize the conditions of the water distributed in this population group, by assessing the following: physicochemical and microbiological qualities, seasonal variation, and the origin of the source for each of the four villages studied.

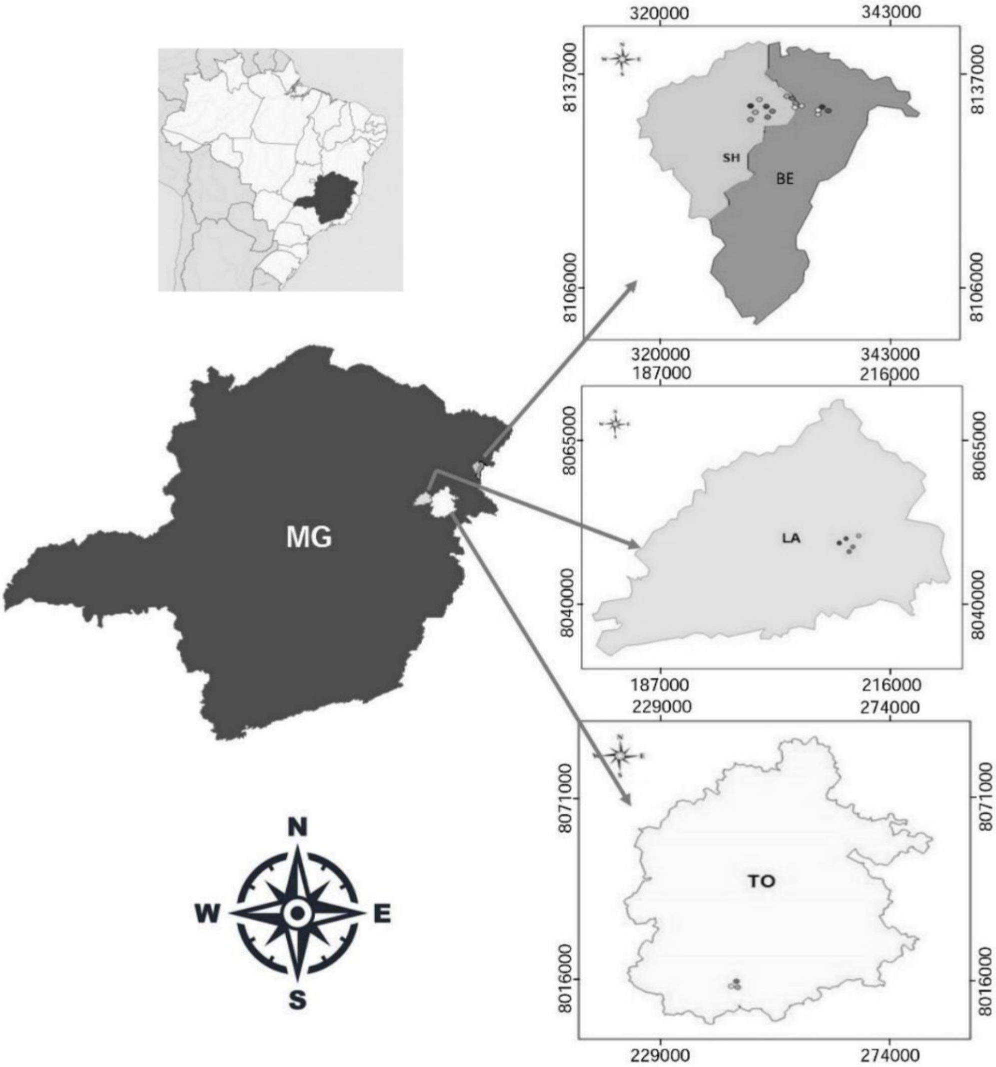
MATERIAL AND METHODS

We conducted a cross-sectional study, with water samples collected in both official water sources provided by the limited sanitation services, and unofficial sources used by the Maxakali. One survey was conducted in each of the three seasonal periods (dry, intermediate and wet) between January and July 2015. While no surveys were distributed to community members or individuals, nor was testing conducted on humans, our study was submitted to the Research Ethics Committee of the University of Vale do Rio dos Sinos-UNISINOS and approved (opinion 129/2015). Indigenous leaders and the District Special Indigenous Minas Gerais/Espirito Santo (DSEI) also gave their approval.

Study area

This study was carried out on the Maxakali indigenous land, located in the northeast region of the state of Minas Gerais. As of 2013, the local population was 1832 individuals (BRASIL, 2013). The territory is comprised of the villages of Água Boa (municipality of Santa Helena de Minas with 699 individuals), Pradinho / Vila Nova (municipality of Bertópolis with 760 individuals), Aldeia Verde (municipality of Ladainha with 308 individuals) and Aldeia Cachoeirinha / Rafael in the district de Topázio (municipality of Teófilo Otoni with 65 individuals) (Figure 1). A total of twenty-four points were mapped as sources of water consumption, the majority being artesian wells or dammed springs. We further identified a number of ponds and rivers where water was used both recreationally (bathing, leisure), as well as consumed onsite. These sites were additionally mapped (Figure 1).

Figure 1. Location of the study area with the collection points in the four Maxakali indigenous villages.



Legend: BE, Municipality of Bertópolis: Aldeia Pradinho; SH, Municipality of Santa Helena de Minas: Aldeia Água Boa; LA, Municipality of Ladainha: Aldeia Verde; TO, Municipality of Teófilo Otoni (Distrito Topázio): Aldeia Rafael. Source: Org.: by the Author, 2017.

The largest villages in territorial and population extension are the Aldeias Pradinho (Vila Nova) and Água Boa, with an area of approximately 5,305 hectares, located where Minas Gerais shares a border with Espírito Santo and Bahia. Hydrographically, these areas are located at the headwaters of the Itanhém River, in the hydrographic basin of the Itanhém River, which flows into the Atlantic Ocean. Politically and administratively they belong to the Vale do Mucuri region, Northeast region of Minas Gerais. Another of the villages sampled, Aldeia Verde, is located in the municipality of Ladainha / MG. Its 552 hectares are defined by abundant hills and low fertility soil (CARVALHO; ALVES, 2009). The final of the four villages studied, Aldeia Cachoeirinha / Rafael, in Topázio, district of Teófilo Otoni / MG, has been an incorporated townsite for less than nine years - the site consists of a farm that was acquired by the National Indian Foundation (FUNAI - Fundação Nacional do Índio). The village has little road infrastructure and lacks any basic sanitation infrastructure. Both Aldeia Verde and Rafael are located in the hydrographic basin of the Mucuri River.

Procedures for collection of water samples

The first collection took place in January 2015, during the typical rainy season. However, in this period there was no rain. The second collection was carried out in April 2015, an intermediate period in the climate calendar when temperatures were mild, still without heavy rains, but with discrete rainfall, insufficient to recharge rivers, streams and wells. The third collection took place in July 2015, when the climate calendar predicted drought; however, during our sample, there were uncharacteristically heavy rains. The climatic variations did not impact the study, since it was intended to evaluate moments of greater dilution and carrying favored by rain and of lesser dilution favored by drought. The collected samples were stored in a temperature-controlled thermal box and sent immediately for processing. Our sampling complied to the maximum limit of four hours between collection and the beginning of the analyses. Our sample collection followed the procedure recommended by the Environmental Sanitation Technology Company (CETESB, 2011), with sampling performed in 50 ml polypropylene flasks with a metal-free lid.

Determination of physicochemical parameters

The analysis of the physicochemical parameters followed the methodology described by Macêdo (2001). For the determination of pH, a potentiometer (pH meter) model DM-22 (Digimed) was used. The turbidity was determined using the nephelometric method. We used a turbidimeter device, model HI 98703-11 manufactured and distributed by the company Hanna Brazil. This instrument measures the turbidity of a sample in the range of 0 to 1000 NTU (Nephelometric Units of Turbidity). The concentration of dissolved oxygen was measured using the portable oximeter equipment, produced by the Brazilian company Digimed, model DM-4P, with measurement limits between 0 to 60 mg O_2 L^{-1}. The conduction of the electric current was measured using a conductivity meter mCA-150p distributed in Brazil by the company MS Tecnopon Equipamentos Especiais Ltda, with a reading range in waters from 0 to 200,000 µS cm^{-1}. All equipment used in this assessment was calibrated before each reading, following the manufacturer's recommendations. Nitrogen content in the form of nitrate in water was evaluated by applying selective ultraviolet light.

To remove possible interference from suspended particles, the samples were filtered. After filtration, 1.0 mL of 1 M HCl was added to each sample to prevent any interference from hydroxides or carbonates up to 1000 mg L^{-1}. Samples were then subjected to spectrophotometry using a wavelength of 220 nm to obtain the NO_3^- reading, and 275 nm to determine interference by dissolved organic matter. There was correction for non-specific absorption (e.g., from organic matter) and later comparison with the previously established standard curve. This correction was based on the absorption reading at 275 nm, where nitrate does not absorb. To prepare the nitrate stock solution (100 mg L^{-1}), 0.1629 g of potassium nitrate PA (KNO_3) (Sigma), kept at 105 ºC for 24 h, was weighed and transferred to a volumetric flask of 1000 mL and supplemented with ultrapure water (18 Ωm). For the calibration curve, standards were prepared in the range between 0.0 and 7.0 mg L^{-1} of NO_3-N in 100 mL flasks, from the stock solution, and 1 mL of 1 M hydrochloric acid with subsequent homogenization (APHA, 2012).

The microbiological analysis was obtained using the multiple tube technique to determine total and thermotolerant coliforms, as established by the Practical Water Analysis Manual of the National Health Foundation (BRASIL, 2009). For the determination of total and thermotolerant coliforms, 1 mL of each sample was diluted in saline (0.85% NaCl), totaling six decimal dilutions. For each dilution, 1 mL of the solution was removed and inoculated in culture medium Lauril Triptose Sulfate (LST) broth, stored in test tubes with inverted Duhran tubing inside. There was a total of three replicates for each dilution.

The tubes were incubated in a culture oven at 35º C for 48 hours. After incubation, all tubes that showed high turbidity of the culture medium, as well as any gas formation, were inoculated in Brilliant Green broth (VB) and Escherichia coli broth (EC), for confirmation of total coliforms and thermotolerant coliforms, respectively. For this purpose, a 100 µl aliquot was removed from each tube considered positive. These samples were then incubated at 35º C and 45º C, respectively, for 48 h. After incubation, the presence of gas and turbidity in cultured mediums were tallied as verified positives.

From the number of tubes with negative and positive reaction in the VB and EC broths, and using the Most Likely Number (NMP) table, the NMP mL^{-1} of total coliforms and thermotolerant coliforms was determined, quantifying the number of these bacteria for each millilitre of water sample.

Processing and analysis of collected data

The results were entered (with double entry and correction of inconsistencies) in SPSS (Software Statistical Package for the Social Sciences), version 22 (SPSS Inc., Chicago, IL, USA) for statistical analysis. Variables were created for each cutoff point (maximum value concerning Ministry of Health ordinances 2914/2011 (BRASIL, 2011), CONAMA 396 (BRASIL, 2008), and 357 (BRASIL, 2005) and seasonality. The Mann-Whitney non-parametric test was used to correlate results with the origin of the sample (superficial versus underground), considering that the data did not present a normal distribution (asymmetric data). All data analyses were performed concerning the point of collection, the village, seasonality (dry, intermediate, and rainy) and as to the origin of the water (superficial or underground). A complementary table with the absolute values of the analyzes and the respective reference values is available at the electronic address: https://goo.gl/EurYiT.

RESULTS

Of all metrics considered, pH levels had the lowest rate of deviation from the normal range. Dissolved oxygen, and total and thermotolerant coliforms had inadequate results in all villages with percentages greater than 50% of the samples. Turbidity and conductivity showed non-standard results for the type of destination and maximum allowed value (MPV) in three of the four participating villages; nitrate showed non-standard results in two (Table 1). The worst results concerning the items evaluated were verified in the villages Aldeia Verde (100%), followed by Aldeia Água Boa (85.7%) and Pradinho (71.4%). With the lowest percentage of change in relation to the established standards, we found Aldeia Rafael (57.1%).

Table 1. Percentage of physicochemical and microbiological changes in the water consumed in Maxakali villages.

Characteristics	Villages							
	Pradinho (n/N)	(%)	Agua Boa (n/N)	(%)	Verde (n/N)	(%)	Rafael (n/N)	(%)
pH*	-	-	-	-	02/15	13	01/09	11
Oxygen**	19/27	70	12/21	57	08/15	53	06/09	67
Turbidity	08/27	30	04/21	19	01/15	7	-	-
Conductivity	24/27	89	12/21	57	01/15	7	-	-
Nitrate	-	-	02/21	9,5	02/15	13	-	-
Total coliforms	15/27	55,5	17/21	81	09/15	60	07/09	78
Thermo coliforms	18/27	67	19/21	90	11/15	73	06/09	67

* Hydrogen potential; ** Dissolved oxygen; n, number of samples changed; N, number of samples collected; (-) with no alterations or below the maximum allowed limit.

The pH was slightly changed to the lower limit concerning Brazilian legislation (6.0 - 9.0) at two points in Aldeia Verde (AV2 and AV3) and at one point in Aldeia Rafael (AR2). This change occurred only in the samples collected during the intermediate climate period (Table 2).

Inadequate values for dissolved oxygen were considered to be those in the range below 6 mg L^{-1}. In the 72 (100%) analyzes for this parameter, 45 (62.5%) were altered. The minimum values (0.52 mg L^{-1}), (0.88 mg L^{-1}), and (0.91 mg L^{-1}), were observed at two points in Aldeia Pradinho (AP5 and AP6) and at one point in Aldeia Good Water (AB3). The intermediate period was the most critical, with 95.8% of altered samples (Table 2).

CONAMA resolutions 357/2005 and 396/2008 establish a limit lower than 40 NTU (nephelometric turbidity unit) in turbidity as a potability standard for class I water (water intended for domestic supply after simplified treatment). In the measurements made, this item was shown to be altered in 19.4% of the samples, although in 42.8% of them, the measurements showed a value between 40 and 50 NTU. Two locations in Aldeia Pradinho showed high values, reaching higher than the detection limit of the equipment at point AP6, and the value of 1000 NTU was observed at point AP5. These changes were found in the dry period.

Conductivity has a VMP for class I waters, less than 100 µS cm^{-1} (microSiemens per centimeter). In Aldeia Verde, at point AV5, the biggest change was observed in the dry period (1056 µS). In the intermediate period, the greatest change in the conductivity value was observed in Aldeia Pradinho (654 µS), at point AP3, while in the rainy season, the greatest deviation from normality was observed in the same village, at point AP1 (606 µS). In Aldeia Pradinho, only point AP4 showed water conductivity within the recommended standards. In Aldeia Água Boa, changes were present in all three seasonal periods at points AB1 to AB4. In Aldeia Rafael, conductivity was normal in all sources that had their water collected. In Aldeia Pradinho, 8 of the nine points showed altered conductivity in the three collection periods (dry, intermediate, and rainy).

Nitrate has a recommended value of less than 10 mg L^{-1} for class I waters. Two changes were found for this element in the dry period in Aldeia Água Boa (AB3 and AB4), one of them being the highest value in all analyses (160, 71 mg L^{-1}). In the rainy season, three changes were observed in Aldeia Verde (AV1, AV2 and AV4). Except for point AB4, all other values found in the samples were less than 15 mg L^{-1}. As for the evaluation for total coliforms and thermotolerants, all points showed changes at some point in the study (Table 2).

About seasonality, all the periods analyzed maintained consistent levels of alteration across qualities studied. Of the seven metrics, six were altered regardless of season, except for the pH, which only showed an alteration in the intermediate period. Dissolved oxygen presented the highest number of changes concerning the seasonal period (twenty-three of the 24 altered samples presented substandard values). For the conductivity to turbidity and nitrate, the percentage of altered samples was approximately the same in the three evaluated periods.

Table 2. Physicochemical and microbiological parameters with altered dosage, according to seasonality, at each collection point.

Villages	Points	*pH**	Oxygen**	Turb.[a]	Cond.[b]	Nitrate	Total Colif.[c]	Thermo Colif.[d]	*Total Changes*
Pradinho	AP1	-	2(I/C)	2(I/C)	3(S/I/C)	-	2(S/I)	2(S/I)	11
	AP2	-	2(I/C)	-	3(S/I/C)	-	1(S)	2(S/C)	8
	AP3	-	1(I)	-	3(S/I/C)	-	1(S)	2(S/C)	7
	AP4	-	2(S/I)	-	-	-	3(S/I/C)	3(S/I/C)	8
	AP5	-	2(I/C)	2(S/C)	3(S/I/C)	-	3(S/I/C)	3(S/I/C)	13
	AP6	-	3(S/I/C)	3(S/I/C)	3(S/I/C)	-	3(S/I/C)	3(S/I/C)	15
	AP7	-	3(S/I/C)	1(C)	3(S/I/C)	-	1(S)	1(I)	9
	AP8	-	3(S/I/C)	-	3(S/I/C)	-	1(I)	1(I)	8
	AP9	-	1(I)	1(C)	3(S/I/C)	-	-	1(I)	6
Água Boa	AB1	-	2(I/C)	1(C)	3(S/I/C)	-	2(S/I)	2(S/I)	10
	AB2	-	2(I/C)	1(I)	3(S/I/C)	-	2(S/I)	3(S/I/C)	11
	AB3	-	2(I/C)	1(I)	3(S/I/C)	1(S)	2(S/I)	2(S/I)	11
	AB4	-	2(I/C)	1(S)	3(S/I/C)	1(S)	3(S/I/C)	3(S/I/C)	13
	AB5	-	1(I)	-	-	-	3(S/I/C)	3(S/I/C)	7
	AB6	-	2(I/C)	-	-	-	2(S/I)	3(S/I/C)	7
	AB7	-	1(I)	-	-	-	3(S/I/C)	3(S/I/C)	7
Verde	AV1	-	1(C)	-	-	1(C)	3(S/I/C)	3(S/I/C)	8
	AV2	1(I)	2(I/C)	-	-	-	1(S)	2(S/C)	6
	AV3	1(I)	1(I)	-	-	-	1(C)	-	3
	AV4	-	2(I/C)	-	-	1(C)	2(S/I)	3(S/I/C)	8
	AV5	-	2(I/C)	1(S)	1(S)	-	2(S/I)	3(S/I/C)	9
Rafael	AR1	-	2(I/C)	-	-	-	3(S/I/C)	2(I/C)	7
	AR2	1(I)	2(I/C)	-	-	-	2(S/I)	2(I/C)	7
	AR3	-	2(I/C)	-	-	-	2(S/I)	2(I/C)	6
Total points with altered measurement for each item analyzed (N-72)		3	45	14	37	4	48	54	

* Hydrogen potential; ** Dissolved oxygen; a-Turbidity; b-Conductivity; c-Total coliforms; d-Thermotolerant coliforms; S-drought period; I-Intermediate period; C-rainy season; (-) Less than the maximum allowed limit or the detection limit of the equipment.

In the microbiological evaluation for coliforms, concentrations were found to be above the allowed standard in all evaluated periods. However, for total coliforms, the rainy period had a percentage below 50% of non-standard samples. The other measures for both total coliforms and thermotolerants showed a percentage of altered samples above 70%, reaching 83.3% in the intermediate period for thermotolerant coliforms (Table 3).

Table 3. Percentage of physicochemical and microbiological changes by seasonal period.

Characteristics	Dry			Intermediate			Rainy		
	Altered samples N 24	%	Max/Min	Altered samples N 24	%	Max/Min	Altered samples N 24	%	Max/Min
pH* VMP 6-9	-	-	8.13/6.2	3	12.5	6.99/5.53	-	-	8.21/6.7
Oxygen** VMP > 6 mg L^{-1}	4	16.6	21.58/1.31	23	95.8	6.77/0.52	18	75	7.63/0.88
Turbidity VMP < 40 NTU	4	16.6	>1000/1.88	4	16.6	63.7/1.31	5	20.8	318/1.35
Conductivity VMP < 100 µS	13	54.1	767/32.8	12	50	649/18.7	12	50	606/18.6
Nitrate VMP < 10 mg L^{-1}	2	8.3	160.7/0.01	-	-	2.18/0.09	3	12.5	14.48/0.08
Total Col.[a] VMP: absence in 100 mL	20	83.3	930/0	19	79.1	>11000/0	9	37.5	43/0
Thermo Col.[b] VMP: absence in 100 mL	17	70.8	2400/0	20	83.3	>11000/0	17	70.8	1100/0

* Hydrogen potential; * Dissolved oxygen; a- Total coliforms; b- Thermotolerant coliforms; (-) samples without alteration; VMP- Maximum allowed value in relation to Ministry of Health ordinances 2914/2011, CONAMA 357 and 396. Max - maximum value observed in the analyzes; Min- Minimum value observed in the analyzes.

Conductivity and nitrate showed a greater number of changes in surface water; however, the mean conductivity was significantly higher in underground water sources. Dissolved oxygen and thermotolerant coliforms showed altered concentrations in both surface and groundwater, but without statistical significance when compared to the mean values. While all sources (both surface and groundwater) have shown contamination by fecal coliforms, it is notably higher (100%) in groundwater sources (Table 4).

Table 4. Mean values for the physicochemical and microbiological variables according to the water source in the Maxakali villages.

Characteristics	VMP	Superficial versus		Underground		P-value*
		Mean	SD	Mean	SD	
pH	6-9	6.97	0.11	6.95	0.20	0.837
Oxygen	> 6 mg L^{-1}	5.86	2.02	6.34	1.75	0.639
Turbidity	<40 NTU	68.01	126.77	33.89	38.29	0.519
Conductivity	<100 µS	69.44	96.15	253.43	137.98	0.004
Nitrate	<10 mg L^{-1}	6.55	13.89	1.14	1.30	0.061
Thermo Coliforms	Absence in 100 mL	146.21	223.77	177.72	480.85	0.379

* pH, Hydrogen potential; Oxygen, Dissolved oxygen; VMP- Maximum value allowed in relation to the ordinances of the Ministry of Health 2914/2011, CONAMA 357 and 396. * P-value for non-parametric Mann-Whitney test.

DISCUSSION

Water contamination is defined as the occurrence of an element at a higher level than the basal level in a given area (PIERZYNSKI; VANCE; SIMS, 2005). It is mainly attributed to environmental pollution (GONÇALVES; ARAÚJO; FERREIRA, 2003), in the absence of policies for the environment and health education, contributing factors to the increase in parasitism rates in Brazil. Water-borne diarrheal diseases have already been responsible for several epidemic outbreaks and high infant mortality rates (BROOKS et al., 2014; MACÊDO, 2001; PELCZAR JR et al., 1996), including in the Maxakali indigenous community (ASSIS et al., 2013).

A survey carried out in the Maxakali indigenous community in 2009 (ASSIS et al., 2013), identified that there were no in place to standardize water treatment; besides, sources of water other than that collected by the villages' sanitation system were used for hygiene and consumption, with inadequate storage in all 187 homes. Regarding human waste, 139 (73.9%) of the households investigated did not have toilets. Of those that did have a toilet, 19 (10.1%) poured water from the toilet bowl into pits and 29 (15.4%) on the land itself (ASSIS et al., 2013).

Although there are several studies (AMARAL et al., 2003; GIACOMETTI, 2001; QUEIROZ et al., 2002) in Brazil evaluating the quality of water for human consumption, these are rarer in indigenous communities, despite the decreased ability of these communities to respond to health issues caused by lower water quality. It is typical in Brazilian indigenous groups for water to play a role in myths and origin stories, and water is often considered a living being that must be respected (DIEGUES, 1998). In addition, most studies that have been conducted on indigenous land have evaluated the quality of water before offering it for consumption, which presupposes the treatment recommended by the legislation in force at the time of consumption and thereby minimizes most of the identified risks. In the Maxakali Indigenous community, the fact that the offer for consumption occurs without any specific treatment is important.

The Maxakali villages occupy areas that have one of the lowest HDIs (Human Development Index) in Brazil and, even though they do not have large polluting sources, they have anthropic activities such as small livestock, which is their main productive activity (ROMERO, 2006). The secular characteristics of the mobility of this population, added to the long walks between the villages, favour the consumption of water with unsatisfactory quality during the journey, including the consumption in the villages with the worst water quality. Also, rock lithology, as well as climatic variations in this region, can largely justify most of the physical and chemical changes found in groundwater, justifying unusual patterns in the absence of anthropic activities (FERRAZ; VALADÃO, 2005).

Within the standards evaluated in this work, water pH is a major factor in the processes of coagulation, disinfection, and water softening, in the control of corrosion and the treatment of sewage. Values outside the recommended range for consumption (pH between 6 and 9), interfere with palatability, increasing the formation of crusts (VON SPERLING, 1996). Although the values that represent acidic conditions are related to probable contamination, the disinfection process is better processed with waters that have acidic pH. Our findings reveal that 50% of samples have moderate acidity (pH < 6); although associated with probable contamination, this discreet acidity favours the adoption of future disinfection processes.

Dissolved oxygen is an indicator of the oxygen concentration in the water and its pollution load (VERNIER, 1994). Dissolved oxygen was altered in samples from all villages, both in surface and underground water, with a strong predominance in the intermediate and rainy period (≤ 6 mg L^{-1}). Further, the transparency of water (that is indicative of its turbidity), depends on the concentration of suspended particulate material. Water with high turbidity is suggestive of a high suspended organic and inorganic content, which can serve as a shelter for microorganisms and decrease the efficiency of the chemical or physical treatment of water (VON SPERLING, 1996). In this study, the changes found were the same for the dry and intermediate periods, although at two points (points: AP5 and AP6), values above 1000 NTU were found in the dry period (VMP <40 NTU). These points were the same ones that showed changes concerning dissolved oxygen, strengthening the association between suspended organic and inorganic content with increased turbidity.

The ability of water to transmit electrical current is defined as electrical conductivity (EC), depending on its dissolved ion content (Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+, Cl^-, SO_4^{2-}, NO_3^-, NO_2^-, and HCO_3^-). As the temperature and the concentration of ions increases, the conductivity also increases proportionally, making it a good indicator for the assessment of mineral concentrations well as the risks that the excess concentrations of these minerals pose to health (FERREIRA, 1997; GHEYI; QUEIROZ; DE MEDEIROS, 1997). In this study, 50% of the samples were altered concerning conductivity (<100 µS) in all seasonal periods and under normal temperature conditions (average 26.2 ºC). The majority of the groundwater sources showed altered EC, strengthening the need for more sensitive studies as to the presence the dissolved salts in these sources and their relationship with the geological makeup of the soil regulating chemical conditions of the associated water.

Nitrate (NO_3^-) is the main form of nitrogen found in water. In places that are characterized by high concentrations of NO_3^- (generally higher than 5.0 mg L^{-1}), it is assumed that they have been enriched as a consequence of anthropogenic activities involving nitrogenous compounds such as soluble fertilizers, human septic systems, and/or manure from domestic animals. Our analyses found five changes for this assessment (MPV <10 µg L^{-1}), although three of them with values very close to the recommended limit. The highest value (160.71 mg L^{-1}) was observed in the dry period, which can be associated with anthropogenic activities; in this case with inadequate sanitary conditions and disposal of biological wastes on the banks of rivers and streams (ALABURDA; NISHIHARA, 1998; ASSIS et al., 2013). Due to the consumption of freshwater during moments of recreation in this stream, special attention is needed concerning nitrates during the dry season.

Determining the concentration of total and thermotolerant coliforms is important as an indicator of the possibility of pathogenic microorganisms, that are responsible for the transmission of waterborne diseases, such as typhoid fever, paratyphoid fever, bacillary dysentery, and cholera (ROITMAN; TRAVASSOS; AZEVEDO, 1988). Most of the bacteria in the coliform group belong to the genera *Escherichia*, *Citrobacter*, *Klebsiella*, and *Enterobacter*. Both total coliforms and thermotolerants were found to be above the values recommended in this study in more than 70% of the samples (absence of *E. coli* in 100 mL of the sample). Changes in these bacterial categories were observed under all climatic conditions, in all villages, and regardless of the origin of the water (superficial or underground). That 100% of underground sources are contaminated with thermotolerant coliforms, showing possible infiltration in these sources, is a major cause for concern. Runoff during the rainy season contributes the most to the microbiological changes in water quality (TALLON et al., 2005); however, our findings revealed higher contamination in the dry and intermediate periods, ruling out the idea of runoff as the only casual factor responsible for this contamination.

The Maxakali indigenous community has been suffering from repeated outbreaks of diarrhea, with a direct impact on children, and these outbreaks have been compromising morbidity and mortality indicators (BRASIL, 2013). In a cross-sectional study carried out in 2009, high levels of intestinal parasites were identified in stool samples (89%) with polyparasitism rates above 70% and a high presence of E. coli, especially among individuals under 12 years old age in this group (ASSIS et al., 2013). As reported in other studies (BEVILACQUA et al., 2002; TEIXEIRA et al., 2014), inadequate hygiene habits, defecation in forests and margins near water sources, and inadequate waste disposal are factors that compromise the potability of water in all villages, justifying previous findings of parasites in the same population and region (ASSIS et al., 2013).

The possible limitations of the present study are that all analyses performed for the investigated parameters were not evaluated in duplicate.

CONCLUSIONS

The waters in the Maxakali Indigenous villages presented physicochemical and microbiological conditions that make them unfit for consumption, and will likely cause illness when consumed. Thus, the lack of sanitation, as well as the lack of knowledge or the non-acceptance of simple disinfection processes for the use of water mainly for consumption, has placed the Maxakali community in a situation of vulnerability to illness due to water-borne diseases. Hence, there is a great need for new studies aimed at continuing the monitoring and evaluation of the quality of the water currently used by this community, as well as the need for planning and implementing a sanitation service in the villages to guarantee minimum drinking standards. The adoption of filtration processes or conventional treatments that do not affect palatability are potential effective measures that can be adopted.

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