



Evaluation of water quality and sanitation of reservoirs used in field activities of a military unit in the state of Rio de Janeiro

ARTICLES doi:[10.4136/ambi-agua.2573](https://doi.org/10.4136/ambi-agua.2573)

Received: 06 May 2020; Accepted: 22 Jun. 2020

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ABSTRACT

In the Armed Forces' campaign activities, large troops may be exposed to serious health risks even before war itself. In 2010, for example, the Brazilian Army sent nearly 2,000 men to join the United Nations peacekeeping mission in Haiti, which was experiencing a cholera epidemic. This work therefore investigated the water quality and sanitation of the various types of reservoirs used in four field-training activities of a Brazilian Army Unit located in the state of Rio de Janeiro. Physicochemical and microbiological analyses of the water were carried out, and visual inspections and swab samples were collected from the inner surface of these reservoirs for counting coliform bacteria and counting mesophilic aerobic microorganisms. Physicochemical and microbiological analyses of water from different types of reservoirs revealed a lack of conformity with American Public Health Association and Ordinance Number 518, of 03/25/04, of the Brazilian Ministry of Health. It was observed that 50% of the collective and individual reservoirs did not have the desirable minimum levels of Free Residual Chlorine. In addition, in 35.7% of the total collective and individual reservoirs evaluated there was growth of coliform group bacteria and in 28.57% of them the number of heterotrophic bacteria exceeded the maximum recommendation. According to the swabs performed on the inner surfaces, results of the total viable mesophilic aerobic counts were above the recommended levels in 78.57% of the total evaluated reservoirs. Besides that, in the Lyster bags of activities 1 and 2, there was growth of coliforms, or 14.28% of the total evaluated reservoirs. It was concluded that there were failures in the management of multiple barriers during storage and / or distribution, as well as in the maintenance of disinfection to prevent or eliminate microbial contamination, indicating the need for corrective measures.

Keywords: armed forces, drinking water, reservoir.



Avaliação da qualidade da água e da higienização dos reservatórios utilizados nas atividades de campanha de uma unidade militar no estado do Rio de Janeiro

RESUMO

Nas atividades de campanha das Forças Armadas, grandes tropas podem ser expostas a sérios riscos à saúde antes mesmo da ação militar propriamente dita. Em 2010, por exemplo, o Exército Brasileiro enviou quase 2.000 homens para participar da missão de manutenção da paz das Nações Unidas no Haiti, que estava passando por uma epidemia de cólera. Este trabalho teve como objetivo investigar a qualidade da água e o saneamento dos vários tipos de reservatórios utilizados em quatro atividades de treinamento em campo de uma Unidade do Exército Brasileiro, localizada no estado do Rio de Janeiro. Foram realizadas análises físico-químicas e microbiológicas da água, além de inspeções visuais e amostras de swab da superfície interna desses reservatórios, para contagem de bactérias coliformes e microrganismos aeróbios mesófilos. Análises físico-químicas e microbiológicas da água de diferentes tipos de reservatórios indicaram um desacordo com as recomendações da Associação Americana de Saúde Pública e da Portaria número 518, de 25/03/04, do Ministério da Saúde. Observou-se que 50% dos reservatórios coletivos e individuais não apresentavam os níveis mínimos desejáveis de cloro residual livre. Além disso, 35,7% do total de reservatórios coletivos e individuais avaliados apresentaram crescimento de bactérias do grupo coliforme e em 28,57% delas o número de bactérias heterotróficas excedeu a recomendação máxima. De acordo com as swabs realizados nas superfícies internas, os resultados das contagens aeróbicas mesofílicas viáveis totais ficaram acima dos níveis recomendados em 78,57% do total de reservatórios avaliados. Nos sacos Lyster das atividades 1 e 2, houve crescimento de coliformes, ou seja, 14,28% do total de reservatórios avaliados. Concluiu-se que houve falhas no gerenciamento de múltiplas barreiras durante o armazenamento e / ou distribuição, bem como a manutenção da desinfecção para prevenir ou eliminar a contaminação microbiana, indicando a necessidade de medidas corretivas.

Palavras-chave: água potável, forças armadas, reservatório.

1. INTRODUCTION

The Armed Forces deal with extreme situations, which lead thousands of men and women away from situations considered ideal for the health protection of so many people. Under these conditions, large troops may be exposed to serious health risks even before war activities themselves.

The warning from American researchers of the importance of strict control over the origin of water, especially when troops are away from their headquarters, is irrefutable proof of the importance of water in the context of field sanitation operations. During Operation “Desert Storm” in the first Gulf War, the US military used water from a few local sources that were closely monitored by troops (US, 2008).

Another example of an operation involving great concern with drinking water was during the United Nations Mission for Stabilization of Haiti (MINUSTAH), where more than 30 thousand military personnel from the Armed Forces, especially from the Brazilian Army, participated. In 2010, cholera spread to the Haitian population, whose health situation was even worse after earthquakes that occurred in that same period. The United Nations has been held responsible for the approximately 10,000 deaths and 820,000 cases of the disease recorded between 2010 and 2018 (De Andrade-Lima, 2019).

The guarantee of safe drinking water poses challenges for an army, since the treatment equipment used by conventional troops is very heavy and operationally complex to deploy in remote stations (Koban and Gibson, 2017). Thus, in situations where a soldier is far from a safe point to refill his canteen, he must be able to disinfect the water for his own consumption (Brasil, 2019). Individual water treatment can be done by iodine tablets, chlorine ampoules or boiling. Besides that, the water containers should be inspected and residual chlorine must be monitored in water supply units (US, 2016). Residual disinfection is used to provide partial protection against low contamination and growth in the distribution network (WHO, 2008; Dion-Fortier *et al.*, 2009).

Water reservoirs are also important, as they may compromise water quality. Surfaces in contact with water can form the basis for bacterial biofilm formation. These microbial complexes are not removed during normal cleaning procedures and may be a continuous source of contamination (Joseph *et al.* 2001). Biofilms are more resistant to cleaning and disinfection processes (Shia and Zhu, 2009).

In addition, aquatic reservoirs have the ability to drastically alter the quality of water that previously had a free-flowing system. Problems encountered include oxygen depletion, nitrogen supersaturation, excessive nutrient and sediment loading, and uncontrolled growth of algae and aquatic plants (US, 2008). Reservoirs must be adequate, capped, leak-free, and stored at a mild temperature (US, 2016).

Physicochemical and microbiological analyses are performed in order to control the water quality. Bacteria of the coliform group are among the main indicators of the suitability of water for domestic, industrial and other uses. The density of this group, especially thermotolerant coliforms or *E. coli*, is an important criterion of sanitary quality. The importance of the tests and the interpretation of the results are well validated and have been used as the basis for bacteriological water supply quality standards. Heterotrophic counts, on the other hand, provide a centesimal enumeration of the total viable bacteria that can provide useful information on water quality and provide supporting data on the significance of total coliform test results. Heterotrophic counting is also useful in evaluating the efficiency of various treatment processes (APHA *et al.*, 2005).

It is also worth mentioning that, currently, multivariate statistical analyses have been used to assess pollution in aquatic sediments such as principal component analysis / factor analysis (PCA/ FA), hierarchical cluster analysis (HCA) and Pearson's correlation relationship (ICP). These analyzes are useful as they establish relationships between the investigated data, determine their sources and still classify them according to their characteristics. The PCA and the HCA are useful tools for the effective management of water resources (Ustaoğlu and Tepe, 2019; Ustaoğlua and Islam, 2020). In addition, Gu *et al.* (2016) reports that results indicated that integrated application of multivariate methods may serve as an operational analysis tool for reservoir water quality assessment.

The goal of this work, therefore, was to evaluate water quality and sanitation of the supplies used for water transportation and storage in the field training activities of a military unit of the state of Rio de Janeiro. The collective reservoirs used in these activities were water trucks with 10,000 liters of water, tank trailers of up to 1,500 liters and Lyster bags of 100 liters of water. In addition, each military man carried a canteen with a capacity of 950 ml for individual use.

2. MATERIAL AND METHODS

The study was conducted through a partnership between the Federal Rural University of Rio de Janeiro (UFRRJ) and a military unit located in the state of Rio de Janeiro. This is a cross-sectional, descriptive and exploratory study. The area in which the study was carried out is around 26.2 km² (Figure 1).



Figure 1. The area in which the study was carried.

Four field training activities were followed during 2010, as shown in Table 1. In these activities, water samples were collected from reservoirs available for microbiological and physicochemical analysis, and swab samples were collected for analysis from the internal surface of these reservoirs.

Table 1. Description of campaign activities.

Activity	Camp 1	Camp 2	Camp 3	Camp 4
Activity start	Jun 23 2010	15 Set 2010	Out 19 2010	Nov 15 2010
Place	A	B	C	D
Stay in campaign	4 days	4 days	4 days	15 days
Participating troop	650 military	546 military	330 military	400 military
Number of meals a day	2,600	2,184	1,320	1,600
Volume of drinking water used per day	3,000 to 4,000 L	3,000 a 4,000 L	4,000 L	3,000 to 4,000 L
Source of drinking water	Municipal Water Park	Municipal Water Park	Municipal Water Park	Municipal Water Park

Each activity included a water truck, some trailer tanks (Figure 2) and some Lyster Bags (Figure 3), as well as canteens for individual use. In each activity, the same types of reservoirs were used; however, they belonged to different sections of the military unit, and it was not possible to collect samples from the same reservoir in the different camps. Therefore, the collection was made by choosing a reservoir of each type, randomly.

Water samples were also collected from the city's Water Park. This source was used to supply the water truck, which subsequently supplied the trailer tanks and Lyster bags.

The samples were obtained under aseptic conditions and were transported to the Food and Beverage Analytical Laboratory (LAAB) of the Federal Rural University of Rio de Janeiro, respecting the maximum period of 24 hours between collection and the beginning of the analyses.



Figure 2. Trailer tank.
Source: the author.



Figure 3. Lyster bag.
Source: the author.

2.1. Physicochemical analysis

Physicochemical analyses were performed for apparent color, taste, odor, appearance, pH, turbidity, total dissolved solids, organic matter, sulfates, hardness, chlorides and iron according to the Standard Methods for the Examination of Water and Wastewater (APHA *et al.*, 2005). Samples were collected in previously washed 1.5L polypropylene flasks. Turbidity was determined by the Nephelometric method using MS Tecnonon turbidimeter - model TB 1000. The pH was determined using a Lutron portable pHmeter - Model pH 206. Total dissolved solids were determined using the MS Tecnonon conductivity meter - Model MSM 150.

2.2. Microbiological analyzes

From the water samples, total and thermotolerant coliforms (fecal coliforms) counts were performed by the multiple-tube technique, and heterotrophic bacteria counts were also performed according to the methodology of the Standard Methods for the Examination of Water and Wastewater (APHA *et al.*, 2005). Samples were collected using 500 ml glass bottles, previously washed with non-toxic detergent, rinsed with ordinary water and distilled water (last rinse), autoclaved for 15 minutes at 121°C, added with 0.1 ml. (2 drops) 10% sodium thiosulfate.

Results of coliform counts were expressed as MLN (most likely number) per 100 milliliter sample and heterotrophic bacteria in CFU (Colony Forming Units) per milliliter sample. The interpretation of results followed the recommendations of MS Ordinance No. 518 (Brasil, 2004), which, although repealed, had the same microbiological parameters required by the current Consolidation Ordinance No. 5 of September 28th 2017 (Brasil, 2017). The determination is the absence of coliforms in 100 ml, and results <2.0 / 100 mL of sample by the multiple tube technique can be considered as ABSENCE in 100 ml. Regarding the count of heterotrophic bacteria, a maximum of 5 x 10² CFU / ml is recommended.

2.3. Microbiological analysis of the inner surface of water reservoirs

Swab sample collection was performed for microbiological analysis of the inner surfaces of the reservoirs. Then the swabs were transferred to the neutralizing solution tubes. These tubes were transported in ice-containing Styrofoam boxes (for low temperature maintenance) to the laboratory where total counts of viable aerobic mesophilic microorganisms and coliform bacteria were counted.

The results of aerobic mesophilic counts (AMC) were expressed in CFU / cm² and were interpreted according to APHA (2001) and Harrigan (1998). Counts ≤5 / cm² were considered satisfactory; 5 to 25 / cm², as counts which require investigation; and >25 / cm², as totally unsatisfactory requiring immediate corrective action. As for coliforms, complete absence is recommended, being obligatory absence on surfaces that come into contact with heat-treated foods.

3. RESULTS AND DISCUSSION

With the analyses being performed in the LAAB, it was possible to verify that, according to the analyzed parameters, water samples taken from the Resende City Water Park were in accordance with Ordinance No. 518, of the MS (Brasil, 2004).

Regarding the inspection performed on the water reservoirs, it was observed that the Lyster Bag covers did not fit perfectly to them, allowing rainwater and dirt to enter. In addition, some bags had holes that were sealed with tape. According to reports from those responsible for the maintenance of these materials, the Lyster Bags were already in the process of being disposed of, because they were deemed unserviceable and their recovery was not economically viable.

Water reservoirs should be inspected periodically for cracks, signs of use for the storage of products other than water, such as petroleum, gasoline or diesel derivatives (US, 2016). In addition, in places with treated water, attention should be paid to the regular cleaning of the reservoirs, including water tanks, gallons and canteens themselves (Brasil, 2019).

When measuring the free-residual chlorine (FRC) of the reservoirs, it was observed that 50% of the collective and individual reservoirs did not have the desirable minimum levels of FRC, as listed in Table 2. According to Ordinance No. 518, after disinfection, the water must contain a minimum FRC content of 0.5 mg / L and a minimum of 0.2 mg / L must be maintained at any point in the distribution network (Brasil, 2004).

Table 2. Reservoir Physicochemical analysis of water during the campaign activities.

Reservoir	Analysis performed	Legislation parameters	1	2	3	4
Water truck	Odor	Odorless	Odorless	Odorless	Odorless	Odorless
	Color	Colorless	Colorless	Colorless	Colorless	Colorless
	pH	5 to 10	7.5	6.08	8.16	7.8
	^a FRC	0.2 to 2 mg/L	1.0	0.2	---	---
	Hardness	Max 500 mg/L	42.0 mg/L	58.7 mg/L	34.20 mg/L	44.0 mg/L
	Chlorides	Max 250 mg/L	8.14 mg/L	---	---	6.68 mg/L
	Organic matter	---	2.56 mg/L	1.89 mg/L	---	2.47 mg/L
	Turbidity	5 NTU	3.95 NTU	3.26 NTU	3.85 NTU	2.88 NTU
	Total solids	Max 1000 mg/L	90.0 mg/L	---	122 mg/L	81.0 mg/L
	Sulfates	Max 250 mg/L	20.0 mg/L	0	0	26.1 mg/L
Iron	Max 0.3 mg/L	0.2 mg/L	0.12 mg/L	0.2 mg/L	0.2 mg/L	
Tank	Odor	Odorless	Odorless	Odorless	Odorless	Odorless
	Color	Colorless	Colorless	Colorless	Colorless	Colorless
	pH	5 to 10	7.60	6.53	7.52	7.56
	^a FRC	0.2 to 2 mg/L	0.5	1.0	0.14	0.3
	Hardness	Max 500 mg/L	38.0 mg/L	69.1 mg/L	11.07 mg/L	13.59 mg/L
	Chlorides	Max 250 mg/L	7.09 mg/L	5.68 mg/L	---	11.59 mg/L
	Organic matter	---	2.89 mg/L	1.59 mg/L	---	3.49 mg/L
	Turbidity	5 NTU	3.95 NTU	1.03 NTU	2.78 NTU	5.50 NTU
	Total solids	Max 1000 mg/L	77.0 mg/L	150 mg/L	---	83 mg/L
	Sulfates	Max 250 mg/L	3.0 mg/L	10.0 mg/L	5.0 mg/L	15.0 mg/L
Iron	Max 0.3 mg/L	0.2 mg/L	0.04 mg/L	0.18 mg/L	0.36 mg/L	
Lyster bag	Odor	Odorless	Odorless	Odorless	Odorless	Odorless
	Color	Colorless	Colorless	Colorless	Colorless	Colorless
	pH	5 to 10	7.79	6.15	7.37	7.56
	^a FRC	0.2 to 2 mg/L	0.0	0.1	0.12	0.2
	Hardness	Max 500 mg/L	38.0 mg/L	60.4 mg/L	10.40 mg/L	21.95 mg/L
	Chlorides	Max 250 mg/L	8.25 mg/L	4.20 mg/L	---	12.72 mg/L
	Organic matter	---	2.12 mg/L	2.0 mg/L	---	2.98 mg/L
	Turbidity	5 NTU	4.22 NTU	1.84 NTU	3.19 NTU	5.03 NTU
	Total solids	Max 1000 mg/L	81 mg/L	142 mg/L	---	85.33 mg/L
	Sulfates	Max 250 mg/L	18 mg/L	5 mg/L	5 mg/L	20.0 mg/L
Iron	Max 0.3 mg/L	0.2 mg/L	0.10 mg/L	0.13 mg/L	0.30 mg/L	
Canteen	Odor	Odorless	Odorless	Odorless	Odorless	Odorless
	Color	Colorless	Colorless	Colorless	Colorless	Colorless
	pH	5 to 10	---	6.32	7.40	7.58
	^a FRC	0.2 to 2 mg/L	0.0	0.0	0.09	0.2
	Hardness	Max 500 mg/L	---	---	6.40 mg/L	14.98 mg/L
	Chlorides	Max 250 mg/L	---	---	---	---
	Organic matter	---	---	1.77 mg/L	---	---
	Turbidity	5 NTU	---	2.25 NTU	2.36 NTU	5.21 NTU
	Total solids	Max 1000 mg/L	---	---	---	---
	Sulfates	Max 250 mg/L	---	---	5.0 mg/L	25.0 mg/L
Iron	Max 0.3 mg/L	---	---	0.13 mg/L	0.27 mg/L	

Standards of ordinance number 518, of March 25, 2004, of the Ministry of Health of Brazil. ^a Free Residual Chlorine.

An important issue in this type of activity that must be considered is the exposure of the reservoirs to the sun. Bondank *et al.* (2018) emphasize that summer temperatures increase the reaction rates between organics and disinfectants in water, increasing the formation of total trihalomethanes (TTHM). Another concern is the constant relationship of drop in chlorine residual with temperature.

FRC must be monitored throughout the procurement process, including the source and all collective reservoirs. Water should be chlorinated when the supply source has no FRC, when the FRC is below the required level, and when a raw (untreated) or unapproved (US, 2016)

source of water should be used as necessary.

Regarding the other physicochemical parameters (odor, color, pH, hardness, chlorides, organic matter, turbidity, total solids, sulfates and iron) the results were in accordance with Ordinance No. 518 of the MS (Brasil, 2004) in all camps.

As shown in Table 3, the source water (Water Park) was within the microbiological parameters required by legislation. However, in 35.7% of the total collective and individual reservoirs evaluated there was growth of coliform group bacteria and in 28.57% of them the number of heterotrophic bacteria exceeded the maximum recommendation provided by Ordinance No. 518 of 2004 (Brasil, 2004).

Table 3. Microbiological analyses of water during the four campaign activities.

RESERVOIR	PARAMETERS	1	2	3	4
Water park (source)	^a Thermotolerant Coliforms (NMP/100 mL)	Absence	Absence	Absence	Absence
	^a Total coliforms (NMP/100 mL)	Absence	Absence	Absence	Absence
	^b Heterotrophic bacteria (UFC/ mL)	< 25	< 25	< 25	< 25
Water truck	^a Thermotolerant Coliforms (NMP/100 mL)	Absence	Absence	----	----
	^a Total coliforms (NMP/100 mL)	Absence	Absence	----	----
	^b Heterotrophic bacteria (UFC/ mL)	< 25	< 25	----	----
Tank	^a Thermotolerant Coliforms (NMP/100 mL)	Absence	Absence	Absence	Absence
	^a Total coliforms (NMP/100 mL)	Absence	Absence	2	Absence
	^b Heterotrophic bacteria (UFC/ mL)	7.3x10 ²	2.7x10 ²	8.2x10 ²	25
Lyster bag	^a Thermotolerant Coliforms (NMP/100 mL)	Absence	Absence	Absence	Absence
	^a Total coliforms (NMP/100 mL)	170	Absence	30	Absence
	^b Heterotrophic bacteria (UFC/ mL)	7.2x10 ³	45	3.5x10 ²	< 25
Canteen	^a Thermotolerant Coliforms (NMP/100 mL)	Absence	Absence	Absence	Absence
	^a Total coliforms (NMP/100 mL)	30	Absence	2	Absence
	^b Heterotrophic bacteria (UFC/ mL)	1.1x10 ²	1.8x10 ²	2.5x10 ³	1.3x10 ²

^a MLN / 100ml = Most Likely Number per 100 milliliter of sample; ABSENCE of coliforms is considered a result <2.0 / 100 mL of sample by the multiple tube technique.

^b CFU / ml = colony forming units per milliliter of sample. Heterotrophic Bacterial Count: Recommended maximum 5 x 10².

It is important to mention that traditional culture methods used to detect environmental and pathogenic microorganisms are generally not very sensitive and still seem to underestimate the microbial load present. Furthermore, it is already recognized that the absence of traditional bacterial indicators does not guarantee the absence of more resistant forms such as *Mycobacterium* spp., *Clostridium* spp., viruses, protozoa, etc. Thus, promising analytical techniques are available for microbiological and viral monitoring of water quality, such as microbial identification by mass spectrometry and molecular techniques. These non-cultural methods are of high yield and detect bacterial indicators and non-cultivable pathogens, in addition to consuming less time. However, it should be noted that these new technologies are not yet included in the standards and guidelines and have not yet been applied as to their performance characteristics (Bonadonna *et al.*, 2019).

According to the swabs performed on the inner surfaces of the reservoirs, it was concluded that sanitation was not adequate. Results of the total viable mesophilic aerobic counts (Table 4) were above the recommended levels in 78.57% of the total evaluated reservoirs. In addition, in the Lyster bags of activities 1 and 2, there was growth of coliforms in 14.28% of the total evaluated reservoirs.

Table 4. Reservoir swab results during the 4 campaign activities.

RESERVOIR	PARAMETERS	1	2	3	4
Water truck	^a Total Mesophilic Aerobic Count (CFU/cm ²)	2	Absence	----	----
	^b Coliform Group Bacteria (CFU/cm ²)	Absence	Absence	----	----
Tank	^a Total Mesophilic Aerobic Count (CFU/cm ²)	4.6x10 ²	2.5x10 ²	1.2x10 ²	85
	^b Coliform Group Bacteria (CFU/cm ²)	Absence	Absence	Absence	Absence
Lyster bag	^a Total Mesophilic Aerobic Count (CFU/cm ²)	1.8x10 ³	2.5x10 ³	1.5x10 ³	1.3x10 ³
	^b Coliform Group Bacteria (CFU/cm ²)	> 2.5x10 ²	16.2	Absence	Absence
Canteen	^a Total Mesophilic Aerobic Count (CFU/cm ²)	53	2.9	80	1.3x10 ²
	^b Coliform Group Bacteria (CFU/cm ²)	Absence	Absence	Absence	Absence

^a Total count of viable mesophilic aerobic: ≤5 / cm² (satisfactory); 5 - 25 / cm² (requires investigation); > 25 / cm² (totally unsatisfactory requiring immediate corrective action);

^b Absence of coliforms recommended, being obligatory absence on surfaces that come into contact with heat-treated foods.

Microorganisms that inhabit biofilms in drinking-water distribution systems (DWDS), are involved in degradation of disinfectant residual, changes in water organoleptic characteristics, discolouration, sheltering pathogens, production of toxins and virulence factors and in transformation of metals involved in corrosion (Douterelo *et al.*, 2018). This last bacterial action makes it highly worrying in relation to the water truck and tank used in this experiment, since they contained several points of corrosion inside.

Another major concern of these field activities should be the exposure of the reservoirs to the sun, especially the water tanks and Lyster bags. According to Liu *et al.* (2016), an initial binding of bacteria to the surface and the growth rate of biofilms is affected by temperature fluctuations. In the case of growth rate, ammonia oxidizing bacteria, for example, grow biofilms more quickly at a typical summer temperature of 22°C compared to 12°C in the fall, unlike what happens with the pathogenic *Vibrio cholerae*.

Liu *et al.* (2016) reports that control of biofilms must be done by removing organic and inorganic nutrients and treatment with disinfectants. Biomass sensors and biomolecular analyses have been developed to allow more frequent and complete assessments of the characteristics of biofilms. Research is indispensable, considering the known prevalence of antibiotic resistant bacteria and antibiotic-resistant germs in drinking water.

4. CONCLUSIONS

The source water was within potability standards, according to current legislation; however, the results of the physicochemical and microbiological analysis of the water of the various types of reservoirs were in disagreement. It can be concluded that there are failures in managing multiple barriers during storage and / or distribution, together with maintaining disinfection to prevent or eliminate microbial contamination.

Considering that the group participating in these activities comprises a large community, and that in limited situations this group may be more susceptible to diseases, interventions are recommended with regard to water quality in campaign activities, based on compliance with good hygienic-sanitary practices and existing regulatory requirements. From this perspective, the joint effort of the authorities responsible for coordinating these activities to ensure water safety and to promote the health of their herds becomes essential.

5. REFERENCES

- APHA. **Compendium of Methods for the Microbiological Examination of Foods**. 4. ed. Washington, 2001.
- APHA; AWWA; WEF. **Standard Methods for the Examination of Water and Wastewater**. 21. ed. Washington, 2005.
- BONADONNA, L.; BRIANCESCO, R.; LA ROSA, G. Innovative analytical methods for monitoring microbiological and virological water quality. **Microchemical Journal**, v. 150, p. 104160, 2019. <https://doi.org/10.1016/j.microc.2019.104160>
- BONDANK, E. N.; CHESTER, M. V.; RUDDELL, B. L. Water Distribution System Failure Risks with Increasing Temperatures. **Environmental Science & Technology**, v. 52, n. 17, p. 9605-9614, 2018. <https://doi.org/10.1021/acs.est.7b01591>
- BRASIL. Ministério da Defesa. Exército Brasileiro. Departamento de Educação e Cultura do Exército Brasileiro. **Manual de Ensino Higiene e Saneamento em Campanha (EB60-ME-17.401)**. 1. ed. Brasília, 2019.
- BRASIL. Ministério da Saúde. Portaria n. 05, de 28 de setembro de 2017. Consolidação das normas sobre as ações e os serviços de saúde do Sistema Único de Saúde. **Diário Oficial [da] União**: seção 1, Brasília, DF, n. 190, supl. p. 516-531, 03 de out. de 2017.
- BRASIL. Ministério da Saúde. Portaria GM/MS nº 518, de 25 de março de 2004. Estabelece os procedimentos e responsabilidades relativos ao controle e vigilância da qualidade da água para consumo humano e seu padrão de potabilidade, e dá outras providências. **Diário Oficial [da] União**: seção 1, Brasília, DF, n. 59, p. 266-270, 26 de mar. 2004.
- DE ANDRADE LIMA, J. R. **Missões de Paz, Ebola e outras zoonoses emergentes**: aspectos relevantes para a Proteção da Saúde Internacional. São Carlos: NEEDS, 2019.
- DION-FORTIER, A.; RODRIGUEZ, M.J., SÉRODES, J.; PROULXC, F. Impact of water stagnation in residential cold and hot water plumbing on concentrations of trihalomethanes and haloacetic acids. **Water Research**, v. 43, n. 12, p. 3057-3066, 2009. <https://doi.org/10.1016/j.watres.2009.04.019>
- DOUTERELO, I.; CALERO-PRECIADO, C.; SORIA-CARRASCOB, V.; BOXALLA, J. B. Whole metagenome sequencing of chlorinated drinking water distribution systems. **Environmental Science: Water Research & Technology**, v. 4, p. 2080-2091, 2018. <https://doi.org/10.1039/C8EW00395E>
- GU, Q.; ZHANG, Y.; MA, L.; LI, J.; WANG, K.; ZHENG, K.; ZHANG, X.; SHENG, L. Assessment of Reservoir Water Quality Using Multivariate Statistical Techniques: A Case Study of Qiandao Lake, China. **Sustainability**, v. 8, n. 3, p. 243, 2016. <https://doi.org/10.3390/su8030243>
- HARRIGAN, W. F. **Laboratory methods in food microbiology**. 3. ed. San Diego: Academic Press, 1998.
- JOSEPH, B.; OTTA, S. K.; KARUNASAGAR, I. Biofilm formation by *Salmonella* spp. on food contact surfaces and their sensitivity to sanitizers. **International Journal of Food Microbiology**, v. 64, n. 3, p. 367-372, 2001. [https://doi.org/10.1016/S0168-1605\(00\)00466-9](https://doi.org/10.1016/S0168-1605(00)00466-9)

- KOBAN, L. A.; GIBSON, J. M. Small-unit water purifiers for remote military outposts: A new application of multicriteria decision analysis. **Journal of Multi-Criteria Decision Analysis**, v. 24, n. 3/4, 2017. <https://doi.org/10.1002/mcda.1606>
- LIU, S.; GUNAWAN, C.; BARRAUD, N.; RICE, S.A.; HARRY, E.J.; AMAL, R. Understanding, Monitoring, and Controlling Biofilm Growth in Drinking Water Distribution Systems. **Environmental Science Technology**, v. 50, n. 17, p. 8954-8976, 2016. <https://doi.org/10.1021/acs.est.6b00835>
- SHIA, X.; ZHU, X. Biofilm formation and food safety in food industries. **Food Science & Technology**, v. 20, p. 407-413, 2009. <https://doi.org/10.1016/j.tifs.2009.01.054>
- UNITED STATES. Department of the Army, Marine Corps. FM 21-10 - MCRP 3-40A.4. **Field Manual. Field hygiene and sanitation**. 1d. Washington, DC, 21 jun. 2016.
- UNITED STATES. Army Corps of Engineers. **Water Quality Management Program: Historical Perspective**. Available at: <http://www.lrd.usace.army.mil/wq/overview>. Access: 10 May 2008.
- USTAOĞLU, F.; ISLAM, S. Potential toxic elements in sediment of some rivers at Giresun, Northeast Turkey: A preliminary assessment for ecotoxicological status and health risk. **Ecological Indicators**, v. 113, p. 106237, 2020. <https://doi.org/10.1016/j.ecolind.2020.106237>
- USTAOĞLU, F.; TEPE, Y. Water quality and sediment contamination assessment of Pazarsuyu Stream, Turkey using multivariate statistical methods and pollution indicators. **International Soil and Water Conservation Research**, v. 7, p. 47-56, 2019. <https://doi.org/10.1016/j.iswcr.2018.09.001>
- WHO. **Guidelines for Drinking-Water Quality**. vol. 1, Recommendations. 3. ed. Geneva, 2008.