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Philosophical Essay on the Traditional Knowledge and Use of Rock Pools in the Brazilian Drylands: Memory and Identity in Temporary Ecosystems

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ABSTRACT

In northeastern Brazil, the drought history has been well documented, reflecting a resilient population with a robust regional identity. Last year, in response to the need to perpetuate water access and reduce scarcity, the Brazilian government implemented a program called the Program One Million Cisterns (P1MC). Considering that the need for water resource perpetuation can impact traditional knowledge transmission between generations, this study aimed to analyze the knowledge regarding rock pools in a small village located in a semiarid region in Brazil. The interviews addressed questions about the traditional knowledge, use, and management of rock pools. The abiotic and biological water variables were collected to establish the population's knowledge status. Our results identified that the use and management of rock pools were reduced after implementing P1MC. Despite the historical relevance of these ecosystems, their use was abandoned by most of the inhabitants, except for domestic use. Therefore, the transmission of traditional knowledge regarding rock pools have decreased between generations, compromising hydric security and representing a serious socio-economic risk for a region characterized by extreme droughts.

Keywords: Cyanobacteria Blooms, Drylands zones, Ethno-limnology, Rock pools, Water security

Ensaio filosófico sobre o conhecimento tradicional e o uso de tanques de pedra no Semiárido Brasileiro: Memória e identidade em ecossistemas temporários

RESUMO

No nordeste do Brasil, a história da seca foi bem documentada, refletindo uma população resiliente com uma identidade regional robusta. Nos últimos anos, em resposta à necessidade de perpetuar o acesso à água e reduzir a escassez, o governo brasileiro implementou um programa denominado Programa Um Milhão de Cisternas (P1MC). Considerando que a necessidade de perpetuação dos recursos hídricos pode impactar na transmissão do conhecimento tradicional entre gerações, este estudo teve como objetivo analisar o conhecimento sobre os tanques de pedra em uma pequena aldeia localizada em uma região semiárida do Brasil. As entrevistas abordaram questões sobre o conhecimento tradicional, uso e gestão dos tanques de pedra. As variáveis abióticas e biológicas da água foram coletadas para estabelecer o estado de conhecimento da população. Nossos resultados identificaram que o uso e gerenciamento de piscinas naturais foram reduzidos após a implementação do P1MC. Apesar da relevância histórica desses ecossistemas, seu uso foi abandonado pela maioria dos habitantes, exceto para uso doméstico. Portanto, a transmissão do conhecimento tradicional sobre os tanques tem diminuído entre as gerações, comprometendo a segurança hídrica e representando um sério risco socioeconômico para uma região caracterizada por secas extremas.

Palavras-chave: Florações de cianobactérias, Semiárido, Etnolimnologia, Tanques de pedra, Segurança hídrica

Introduction

From classical philosophers to current researchers, many have sought to understand memory transfer mechanisms between generations. Agostinho indicated memory as a key component

of knowledge and emotions, whereas Aristotle developed the role of community memory in the exercise of thinking (Miranda, 2001; Morel, 2009). Memory establishes a generational bridge within a collective and individual past (Agnew, 2005). The

close relationship between memory and identity presumes the recognition of the true significance of temporal sequences of specific events of people's lives. This relationship also entails the retention of these recognitions (Candau, 2009). Thus, memory acts as a driver of personal individuality (Schechtman, 1990) and is relevant to legitimate identity building. Whether material or intangible, cultural heritage is composed of elements such as individual and collective memory together with historical experiences. These experiences, among other aspects (Lima and Sampaio, 2011), build individual and collective identities (Heersmink, 2021).

Historically, residents in dryland zones have been resilient and prepared for natural disasters and the consequences of climate change (Adger et al., 2003). Moreover, these populations may develop an organized structure to confront climate change consequences that guarantee basic livelihoods through human, social, physical, financial, and natural resources (DFID, 1999; Dupar et al., 2021). Evaluating the dynamics of these areas may help identify possible solutions to the effects of climate change (Mancal et al., 2016; Stavi et al. 2021). The financial structure of family farmers in the semiarid region has now been weakened by rainfall reduction and prolonged drought periods, which have been recorded at least once every decade (Marengo and Bernasconi, 2015; Costa et al., 2021). Climate change scenarios indicate alarming projections for arid and semiarid regions. An increase in temperature and reduction in water availability, has resulted in an expansion of these areas on a global scale (IPCC, 2007) reducing access to water in regions such as South Africa, the Aral Sea region, and Australia (Ragab and Prudhomme, 2002; Bourdais et al., 2021). Aboriginal peoples, for example, describe "living water" as a permanent source (Andersen, 2019), whereas seasonal waters are associated with dry periods and are sometimes stochastic and irregular in dryland regions. These elements of the Aboriginal heritage highlight a close relationship between the native people and water, serving as an important symbol that influences their current artistic esthetics (Toussaint et al., 2005) and conservation patterns (Moggridge et al. 2019; Jackson and Moggridge 2019).

For centuries, rural populations worldwide have used simple strategies with easily accessible construction and low costs (Lima and Sampaio, 2011). Among these strategies, the rainwater

catchment is an essential resource used by several communities during long periods of drought (Menezes and Souza, 2011; Huang et al. 2021). Thus, while the state politically allocates resources, the population develops techniques to deal with water shortage situations through traditional knowledge (Lima and Sampaio, 2011). Among the leading traditional storage technologies, rock pools inserted into rocky natural or artificial fissures represent a natural source of rainfall storage (Pereira et al., 2018), including all temporary depressions found in rocky substrates that accumulate freshwater (Brendonck et al., 2010). In worldwide scale, rock pools are considered important hotspots of biodiversity (Porembski et al., 2016; Kulkarni et al. 2022).

The water distribution on these regions are irregular in spatial and temporal scale making these people extremely vulnerable (Kuchimanchi et al. 2021). Traditional communities have used rock pools for different purposes, such as human and animal consumption, domestic and agricultural use, and maintaining small rural areas (Almeida and Cabral, 2013; Ribeiro and Oliveira, 2019). Rock pools are a common structure in inselbergs worldwide and act as rainwater collection depositories (Andrade et al., 2017) used for human supply, ensuring water safety for rural populations.

Considering the potential threat scenarios caused by global warming and climate change, the present study (1) analyzed how traditional knowledge regarding rock pools has been transferred inter-generationally in a traditional rural community in the Brazilian semiarid region; and (2) examine inhabitants' knowledge concerning water quality and management techniques by comparison with data obtained by sampling local and natural rock pools. We hypothesize that the transmission of traditional techniques between generations, specifically rock pools management, has decreased after the implementation of new technologies associated with the water supply.

Methodology

Study Area

The rural community "Rio Direito" is located in Paraíba state (Brazil), in the mesoregion of Borborema and the microregion of Eastern Cariri. Situated in the Paraíba River hydrographic basin, the major water bodies are intermittent, with

a dendritic drainage pattern throughout the Taperoá, Paraíba, and Boa Vista rivers (Mascarenhas et al., 2005).

The high seasonal variation in precipitation and the predominance of shallow soils inserted into crystalline rocks cause low water exchange between the reservoir and adjacent soil (Cirilo, 2008). The climate is hot semiarid (BSh) (Alvares et al., 2013), with a mean annual temperature of > 20°C and the lowest mean annual rainfall in Brazil,

which was ≤ 77.3 mm during the sampling period (Alves et al., 2008). Located near “Lajedo de Pai Mateus,” a rock formation typical of the Brazilian Caatinga, the rock pools are natural and ephemeral, with a short hydroperiod of approximately two to three months. Most of the rock pools are shallow and small, except for the artificial emergency rock pools (Figure 1), built to the attendance of the local population.



Figure 1. Natural rock pools and main limnological highlights (Cabaceiras, Paraíba, Brazil). (A) and (B): Caatinga natural vegetation around the rock pools; (C): Rock pools with the *Lemna* sp. presence (aquatic macrophyte); (D) and (E): Rock pools near to the village, with the *Microcystis* sp. blooms (harmful algae); (F): Presence of submerged aquatic macrophyte, *Chara martiana* A.Braun

Rio Direito is a small and traditional village with a predominantly population of retirees, farmers, and ranchers who cultivate corn, beans, and palm, and rear goats and cattle. Another common economic activity in this region is the production and sale of coal. Overall, the population have a close relationship with management techniques and the historical use of rock pools.

Ethnoecology: Study design

The interview was structured to obtain more accurate information, as interviewees could speak freely about the proposed topics. These topics were distributed as follows: (1) issues

associated with traditional knowledge regarding rock pool use, (2) traditional knowledge transfer between generations, and (3) issues associated with understanding water quality concepts. Traditional knowledge and memory were used as synonyms, with memory as a collective property of the inhabitants linked to building a person's collective identity.

During sampling, guided tours (Spradley and McCurdy, 1972) were performed on all the natural rock pools. Two key respondents were selected among the village inhabitants—those with more experience and more knowledge of these

ecosystems. To identify key respondents, we used the snowball technique (Bailey, 2008).

Material and methods

Field survey and ethical research guidelines

The dynamics of the use and management of rock pools were determined by interviewing all the Rio Direito River residents between January and February 2015. All residents were asked to sign the informed consent demanded by the National Council of Health, through the Ethics and Research Committee (REC) (Resolution 196/96 of the CNS/MS). This research was approved by the Committee of Ethics in Research with Human Beings (CEP) of the Wanderley Lauro Hospital of the Federal University of Paraíba (HULW), registered in protocol ECR/HULW n° 297/11.

In total, 15 respondents between the ages of 34 and 81 (six men and nine women) participated in the interviews. The survey was structured with broader issues and some more specifics regarding species and water quality. Knowledge regarding the use and management was obtained through the broader questions, addressing the rock pools' morphometric structure (i.e., area, depth, and color) and use (i.e., domestic or irrigation). Regarding management and use, we included the perception of the current inhabitants about ancient knowledge and changes in the transfer of knowledge techniques. The terminology and classification associated with the rock pools were identified through open questions, favoring local nomenclature mapping.

The information obtained was analyzed using associated cognition tables (Marques, 1995), which compared the knowledge of the inhabitants with scientific information obtained through the literature review. Comparative analyses were performed between the biological and abiotic databases and information gathered through interviews.

Water data sampling

Water samples for biological and abiotic analyses were collected from the subsurface of 20 rock pools on inselbergs in the Cabaceiras region during the wet season. The transparency (m), temperature (°C), pH, dissolved oxygen (mg L⁻¹), turbidity, and total dissolved solids were measured *in situ* using a Hanna Instruments HI 98130 portable multiparameter probe. The vertical light attenuation coefficient (k) was calculated using the

relation $k = 1.7 \times Z_{DS}^{-1}$ (Poole and Atkins, 1929). The euphotic zone (Z_{eu}) was calculated by multiplying the value obtained by the Secchi disk (10% incidence of light) by 2.7 (Cole, 1994).

Phytoplankton quantification was performed according to Utermöhl (1958) and sedimentation time, following Lund et al. (1958). The biovolume (mg L⁻¹) of each species was calculated based on the methods of Sun and Liu (2003) and Hillebrand et al. (1999). Phytoplankton analyses were performed to identify possible harmful blooms and associate them with health risks.

Results

Traditional knowledge and rock pool use

For decades, the Rio Direito community has witnessed many changes since rock pools have been found. One of the most important historical events occurred when two emergency rock pools were constructed, which older adults reported as a project created and maintained by the government.

In addition to constructing these ecosystems, other ecosystems that received specific names have been reported by some respondents. Among the main local nomenclature, stone tanks (54%), cauldrons (26%), and cacimbas (20%) were the most cited.

The deepest Lagoa da Cobra;
As well as Lagoa da Batata,
Lagoa da Mucunã, Baixa detrás da lagoa,
Piscina, Lagoa Velha,
Tanque de Severino Tito, Tanque Inácio
Roberto,
Cortume de Maria Simão, Baixa do Anel,
Tanque Baixa de Rita,
Baixa de Tia Francisca, Tanque de Santo
Moura, Baixa de Alexandrina,
Loca de Lotero, Baixa escondida, Tanque
do Pereiro, Tanque da Caubêira,
Tanque dos Nêgro. (Anonymous, 81 years
old)

Among the management techniques used to reduce water evaporation, residents reported the use of wood (stake) and stones (90%). This main objective of this management was to prevent animals, leaves, and twigs from entering the rock pools, favoring high water quality (Figure 2) and increasing water transparency between pools.



Figure 2. Management strategy used by community residents to prevent the evaporation and contamination of natural pools (Cabaceiras, Paraíba, Brazil).

Most participants understood water quality concepts and correct application (Table 1), specifically watercolor. One common association was low water quality and green-colored rock pools. In general, green was associated with cyanobacterial blooms and macrophytes (i.e., *Lemna* sp.) (Fig. 1c). Overall, residents did not recognize floral diversity and taxonomy, calling all species (or biological groups) sludge or paste. In this way, inhabitants described the different steady states occurring in rock pools (80% of the interviewed), one associated with clear waters and submerged macrophytes, and another with turbid waters and cyanobacterial blooms (Fig. 1d and 1e).

According to all respondents, the use and management of rock pools were reduced after the implementation of government programs, including the project named Program One Million Cisterns (P1MC). The quality of life in the Rio Direito community has improved; however, rock

pool use and management have decreased drastically. In the past, water was used for domestic activities, agriculture, and human consumption (Table 2).

In the present study, cisterns were more commonly used than rock pools. Thus, some correspondents reported cisterns as the best water storage method, with better water quality and hydric security over the year:

Today, local and neighboring rock pools are restricted to domestic activities such as laundry and human consumption. The farmers had their own perspectives on water quality, including sweet taste and transparency, that is, more transparent and sweeter water is better. The relationship between cleaning of rock pools and water quality is unanimous.

Table 1. Knowledge and Use of Rock pools (Comparative Cognition).

CONSTRUCTION / ORIGIN OF ROCK POOLS	USE OF ROCK POOLS IN PAST	USE OF ROCK POOLS IN PRESENT	MANAGEMENT	REFERENCES
“Between a rock and another. then you dig and there is the tank.” (Anonymous, 37y/o)	Drink	Animal use	Almost extinct. Cleaning is done by some community members.	Rock pools are formed where there are natural holes in the crystalline that rises to the surface (so-called "lajedos") (Menezes and Souza, 2011).
“Dig until reach the stone. when necessary use fire to break the stones.” (Anonymous, 73y/o)	Cook	Washing	With the arrival of the cisterns, this concern no longer exists.	Rock pools occur naturally in the cracks of rocky outcrops of crystalline bases and enable rainwater storage (Pereira et al., 2018).
“When there is a stone together with other and is made with shooting (dynamite).” (Anonymous, 80y/o)	Agricultural	Agricultural	The care with cleaning rock pools are in: exhaust the little dirty water left. sweep and wash. so when it rains gather clean water. Also cover with stones and pieces of wood to avoid water evaporation.	Also called "Cauldron" by Gnadlinger et al., 2007, rock pools are natural cracks in the rock, deepened by the rural population itself. which removes dirt and gravel from the deepest part. clearing it. This is an excellent reservoir to store rainwater for human, animal, and agricultural use" (Lima et al., 2011).
“Is a work of nature that digs the sand of the stones and make up the rock pools.” (Anonymous, 44y/o)	-	Little used for domestic consumption.	-	Example of technology that enables the increase in water supply not only for human purposes but for irrigation and animal consumption, favouring sustainable rural development (Almeida and Cabral, 2013).

–Table 2. Community perception / cognition comparative.

Traditional Knowledge	Information according to limnological analysis
“The more transparent the better the water” (Anonymous, 48y/o).	Overall, low values of water transparency were observed, ranging from a minimum of 0.21 to a maximum of 1.5 m, where the lower value identified for the rock pool XIV and the highest in the rock pool XIII. These characteristics showed that most rock pools are turbid.
“By taste, if it is sweet it is good” (Anonymous, 74y/o).	Most environments analyzed showed low transparency values, with cyanobacteria blooms, indicating that the water may be improper for consumption in most cases.
“The best water is the one that has a green paste, the water gets colder and cleaner” (Anonymous, 48y/o).	The presence of the <i>Chara martiniana</i> J. Wallman (Characeae) in at least two rock pools, indicated a good water quality.
“By color, the more greenish is not good” Anonymous, 73y/o).	In the twenty environments analyzed, harmful cyanobacteria blooms were found in 2 rock pools. Conversely, the presence of harmful cyanobacteria was found in all rock pools, indicating the optimum of the occurrence conditions.

“How can a rock pool be found?”

The residents used certain parameters to find rock pools, including the presence of soil between rocks, rock quality (intermediate to hard rocks), and if rocks were continuous, shattered, or presented fissures. Over time, residents have assessed and enhanced their perceptions. These rock pools received human adaptations in specific cases, such as walls built with cement or concrete. Most respondents reported that they did not know the origin of the water bodies, whereas others claimed it was “nature's blessing.”

Water quality

All the rock pools, were classified as shallow (≤ 5 m), with warm and mixed waters (≤ 36.7 °C) and low light availability ($Z_{eu}:Z_{mix} \leq 1$). The pH values ranged from acidic (5.8) to slightly alkaline (≤ 10.2).

We identified 55 species and morphospecies; the highest biomass from the phytoplankton community was associated with *Microcystis* sp. in rock pools I (maximum 22.8 mg L⁻¹), II (maximum 269.5 mgL⁻¹) and VII (maximum 2366.2 mg L⁻¹). In the absence of *Microcystis* sp., *Chlorococcales* were dominant

(XIII and XV). In addition to *Microcystis* sp., other harmful cyanobacteria were identified with high biomass, *Raphidiopsis raciborskii* (Woloszynska) Aguilera, Berrendero Gómez, Kastovsky, Echenique and Salerno. Submerged macrophytes (*Chara martiana* J. Wallman) were only found in VIII and IX, which coincided with the highest values of $Z_{eu}:Z_{mix} (\leq 1)$ (Figure 2, Figure 3).

Discussion

Techniques or strategies used to manage local rock pools are part of the collective memory, including traditional knowledge regarding the conservation and maintenance of rock pools and knowledge acquired throughout the generations. However, the Rio Direito knowledge transmitted was restricted to structural identification and methods for maintaining and improving cleaning procedures during drought periods. Despite the low use of these ecosystems in Rio Direito, the collective memory transmitted by the ancestors of current inhabitants in drylands zones could be strategic insurance for tackling climate change (Figure 3).

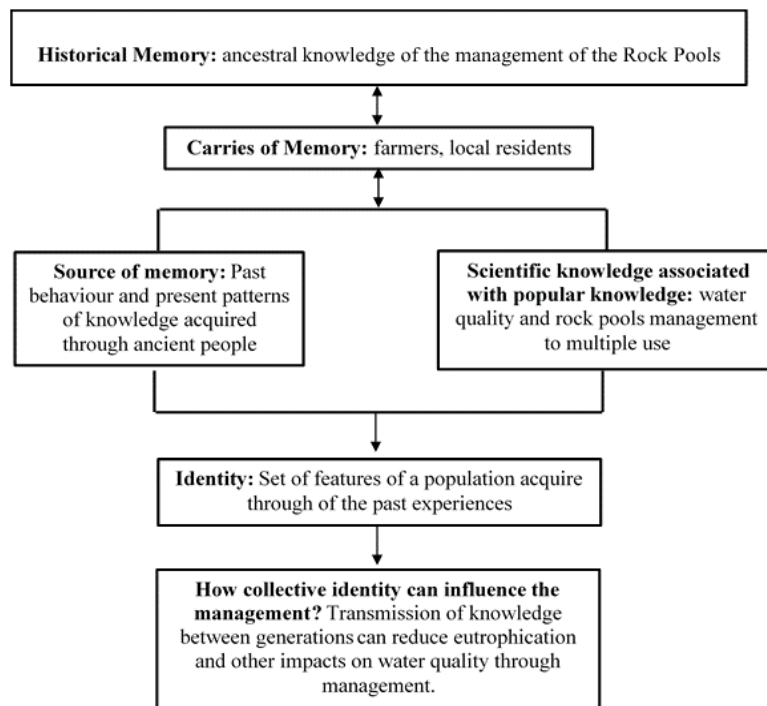


Figure 3. Schematic concept of the memory transmission mechanism through of a Model Community (Paraíba, Brazil).

Historical records did not reveal when the rock pools were first used or emerged. However, the use and management arose when the community experienced years of prolonged drought. According to one of the most experienced respondents in the community, some rock pools have existed in the lifetime of past generations, while others emerged due to needs caused by water shortages. In prolonged drought scenarios, it is possible to identify the positive impact of these natural reservoirs on the local economy because of easy maintenance and low management costs.

Human development has always been associated with water availability and supply, as it influences human economic activities, such as livestock and farming. Collective identity comprises intangible cultural heritage, gathering common community experiences over time, and changing space-time (Bertagnolli, 2015). Hence, management techniques of traditional water sources may be considered part of the intangible heritage associated with social development and historical use, needing to be preserved in the face of new technologies of water storage. Additionally, the terminology of local and regional rock pools has been of great relevance to describing people's

culture and customs over time, making part of their identity. Most of the Rio Direito inhabitants, mainly older adults, recognize the stone tanks as natural temporary water bodies present in Caatinga inselbergs. This natural ecosystem is called Gnammas by the Australian Aboriginal peoples (Bayly, 1999; Timms, 2006; Pignatti & Pignatti-Wikus, 2021). However, most international literature uses 'rock pools' to describe these ephemeral, shallow, and small ecosystems with a simple structure shaped by rainfall (Pellowe-Wagstaff and Simonis, 2014). Variations in global terminology reflect the considerable semantic variability and influence of the local culture and the people's adaptative flexibility to survive in drylands with a negative water balance (Bayly, 1999).

The presence of lakes, rivers, reservoirs, or any other water sources, such as rock pools, has been decisive for the emergence of villages, occupation of territories, and agricultural development (Silvestre, 2002), not only in northeastern Brazil but worldwide (Vuorinen, 2007; Angelakis and Zheng, 2015). Water supply is critical for the economic development of dryland regions. There is a high demand for water for

agriculture and other economic activities in these regions, and rock pools are one method to mitigate this condition (Ribeiro and Oliveira, 2019). The search for survival and resilience due to extreme and prolonged droughts has led populations to search for alternative technologies to support domestic and agricultural activities. Thus, the perspective of these populations improved to recognize the main structural aspects present in rock pools and the importance of managing them to avoid contamination. However, the loss of ancient knowledge reported in our study could have negatively impacted the local water supply, enhancing the water crisis.

Construction and implementation of cisterns through P1MC in 2007 has led to social and economic progress in these local communities. Cisterns, now popular in the Rio Direito community, were constructed to improve access to water and maintain this resource as a potable water supply (Ribeiro and Oliveira, 2019). However, despite cisterns representing 50% of the families interviewed in neighboring regions, 73% used water from rock pools (Almeida and Cabral, 2013). This result indicates a distinct pattern in the river Direito, where the highest proportion of use is attributed to cisterns. Perennial sources are an excellent alternative for this population; however, they are detrimental to maintaining and managing rock pools and transferring knowledge about them between generations.

Among the main changes in the water quality of rock pools and other shallow water bodies, fluctuations in water level and processes associated with artificial eutrophication and human occupation can cause shifts from clear to turbid states (Scheffer, 1998; Burks et al., 2006; Da Silva et al. 2020). Some interviewees indicated that water level fluctuation could be a useful strategy to decrease the recurrence of harmful cyanobacterial blooms. Still, successful management depends on the morphological characteristics of the ecosystems (Bakker and Hilt, 2015). Some rock pools were exposed to allochthonous contributions, such as animal waste, twigs and leaves, and human overexploitation. These factors could have contributed to the decrease in water quality of rock pools near the village, which presented common changes in shallow and temporary water bodies, such as a change from clear to turbid waters and dominance of harmful cyanobacteria (Burks et al., 2006). The harmful cyanobacteria blooms may

represent a risk for human health (Christensen and Khan, 2020) over the world.

In recent years, alternative regimes (Scheffer et al., 1993; Scheffer and Van Nes, 2007; Yan et al. 2021) have emerged as one of the more relevant theories to indicate the critical threshold level of nutrients in the shift to a turbid state. The indication of this theory's main elements by the inhabitants of the Rio Direito showed us the relevance of traditional knowledge incorporation between generations, revealing sophisticated technical expertise and potentially applicable to rock pool conservation. A transient or ghost state could arise after prolonged drought periods, characterized by water bodies in a longer transient state, where growing conditions for macrophytes or phytoplankton would be more favorable (Scheffer and Van Nes, 2007; Van Geest et al., 2007).

In climate change scenarios, drought has drastically influenced the water levels and, consequently, nutrient concentrations favoring the eutrophication process and cyanobacterial blooms (Bouvy et al., 1999; Wiegand et al., 2016; Costa et al., 2017; Silva et al., 2017). In Northeast Brazil, 52 deaths were reported to be a common syndrome, now called Caruaru syndrome, associated with harmful cyanobacteria (Carmichael, 2001). Analyses of the dialysis clinic's water source and liver tissue of clinical patients led to identifying two groups of cyanobacterial toxins that likely caused the deaths (Pouria et al., 1998; Carmichael, 2001; Komárek et al., 2011). Cyanobacterial blooms produce cyanotoxins, including saxitoxins, which induce congenital Zika syndrome (ZIKV) (Pedrosa et al., 2020; Cardoso et al. 2022). Recently, ZIKV has emerged as a serious problem in this region, with a high microcephaly index coinciding with extreme drought periods (Pedrosa, et al., 2020).

The increased popularity of cisterns, the transmission of traditional knowledge has decreased between families and generations, presenting a grave social problem in the face of prolonged droughts. Therefore, we must improve the dialog between traditional communities and public authorities to preserve the culture, identity, and popular memory of populations originating from dryland zones.

Ethical approval and Informed consent

Ethics declarations

The objectives of this study was explained to each resident and consent was given by signing

a Free and Informed Consent Term. The National Council of Health, through the Ethics and Research Committee (REC) (Resolution 196/96 of the CNS/MS) requests these documents. This study was approved by the Committee of Ethics in Research with Human Beings (CEP) of the Wanderley Lauro Hospital of the Federal University of Paraíba (HULW), registered in protocol ECR/HULW n° 297/11.

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