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Quality Monitoring of Drinking Water in Chucuito Province: One Health Perspective

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Abstract: The One Health approach considers the interdependence of human, animal, and environmental health because 70% of diseases affecting humans are mainly in animals. Water serves as a vehicle for the transmission of these diseases. Consequently, monitoring the quality of water for human consumption is crucial, constituting an activity of the environmental health units of the Peruvian Ministry of Health. In 2019, water quality monitoring was conducted in the province of Chucuito, Puno Region, to determine the quality of drinking water for human consumption under the One Health approach. The physicochemical analysis indicated that the parameters were within normal limits, except for residual chlorine, which was completely absent. Microbiological analysis revealed total coliforms and E. coli. These findings impact the responsible production of water for human consumption. According to water quality regulations in Peru, this water has fecal contamination, posing a high microbiological risk and rendering it unsuitable for human consumption. Urgent disinfection is required. These results highlight the breakdown of the human–environment–animal interface of the One Health approach, putting public health at risk.

Keywords: One Health, public health, risk, water quality, disinfection.

丘奎托省飲用水品質監測：一種健康視角

摘要：「同一個健康」方法考慮了人類、動物和環境健康的相互依存性，因為影響人類的70%疾病主要發生在動物身上。水是這些疾病傳播的媒介。因此，監測人類飲用的水的品質至關重要，這是秘魯衛生部環境衛生部門的一項活動。2019年，在普諾地區楚奎托省進行了水質監測，以確定「同一個健康」方法下人類飲用的飲用水的品質。理化分析表明，除餘氯完全不存在外，各項參數均在正常範圍內。微生物分析顯示總大腸桿菌群和大腸桿菌。這些發現影響了人類消費用水的負責任生產。根據秘魯的水質法規，這些水受到糞便污染，具有很高的微生物風險，不適合人類飲用。需要緊急消毒。這些結果凸顯了「同一個健康」方法的人類環境動物界面的崩潰，使公共衛生面臨風險。

关键词：一、健康、公共衛生、風險、水質、消毒。

1. Introduction

The One Health approach recognizes the interdependence of humans, animals, and environmental health because 70% of diseases affecting humans are also common in animals, and water serves as a vehicle for transmitting these diseases [1]. Water, an indispensable element for human survival, is becoming increasingly scarce and is a non-renewable resource. Currently, one of the most significant challenges lies in ensuring its quality and effective management for human consumption. It is alarming to note that approximately two million people, predominantly children under the age of five, succumb annually to waterborne diseases resulting from the consumption of contaminated water [2, 3] that is primarily due to a breakdown in the interface between human and environmental health. Therefore, for greater emphasis on pollution control, it is necessary to address this issue through the One Health approach, which examines the interactions among people, domestic animals, wildlife, plants, and the environment [4, 5].

Water-associated diseases constitute one of the leading causes of morbidity and mortality in developing countries [6–8]. Hence, ensuring an ample supply of safe drinking water for human consumption is crucial in reducing disease transmission [9], including zoonotic waterborne diseases [10]. Individuals who rely on water for human consumption are at risk of consuming contaminated food and water under conditions of inadequate supply. They may also come into contact with contaminated water during activities such as bathing [11].

Over the years, the prevalence of anemia in the Puno region has been alarmingly high. Out of every ten children, seven suffer from anemia. In addition, acute diarrheal diseases contribute to infant mortality [12–15].

These figures, endorsed by central and local governments, impede the correct development of the child population living in extreme poverty. The entities responsible for providing drinking water have fallen short, underscoring the necessity for implementing additional re-chlorination steps throughout the distribution system to ensure the maintenance of residual chlorine levels that guarantee the microbiological quality of the water [16].

One of the contributing factors to these circumstances is the quality of water designated for human consumption. According to the WHO, half of anemia cases are associated with water consumption lacking any form of disinfection. It is crucial to consider that childhood anemia relates to chronic malnutrition, water source, family socioeconomic status, and geographic location [17, 18]. Furthermore, inadequate access to drinking water is a primary cause of diarrhea [19], which leads to malnutrition [20].

It is crucial to consider that the purification processes for drinking water intended for human consumption involve multiple stages of assessment. These encompass various parameters, including physical, chemical, microbiological, and heavy metal factors, stipulated by sanitary regulations, as in Peru [21, 22]. Among these, particular parameters are prioritized and subject to mandatory control in Peru, including pH, temperature, conductivity, residual chlorine, turbidity, and microbiological analysis.

An evaluation conducted in Puno revealed that the residual chlorine levels in the water distribution system exceeded 0.5 mg/L. Historically, variations in diarrheal diseases have been linked to temperature fluctuations. The sustained presence of residual chlorine indicates water is in good bacteriological condition [23]. Conversely, detecting traces of certain inorganic chemical compounds raises concerns about the water's acceptability for human consumption, particularly in the high Andean rural communities of Peru [24]. In peri-urban communities, fecal contamination of drinking water is prevalent in Peru [16, 25–29]. This underscores the pressing need for an ample, safe, and consistently available drinking water supply to safeguard human health, well-being, and development [30]. In addition, there is a necessity for integrating supplementary re-chlorination measures throughout the water distribution system for human consumption [16]. Given that pathogens persist as a significant challenge for human health, particularly in developing regions [31], this presents an opportunity to implement interventions aligned with the One Health approach [1].

Considering the above, it is essential to identify the parameters for routine monitoring that will enable the assessment of water quality consumed by the population of Chucuito. The objective is to present the findings of water quality surveillance for human consumption and its correlation with the One Health framework.

2. Materials and Methods

2.1. Delimitation of the Study

Chucuito is one of the provinces in the Puno Region, located in southern Peru, and serves as the headquarters of the Chucuito Health Network (Fig. 2). The Environmental Health Unit is responsible for monitoring all potable water systems (PWSs) within Chucuito. However, due to budgetary constraints, only one PWS is monitored for each health establishment under the Chucuito Health Network (Table 1).

Various entities that provide drinking water services administer the monitored PWSs. In all cases, they have a conventional drinking water system (simple gravity).

Sampling was conducted throughout all months of 2019 for both physical–chemical and microbiological parameters. Samples were collected from the PWS distribution system (network) following the criteria established by the Ministry of Health [22].

2.2. Evaluated Parameter

The parameters monitored, according to Peruvian regulations [21], included physical-chemical measures (turbidity, residual chlorine, temperature, conductivity, and pH) and microbiological measures (total coliforms and *E. coli*) (Fig. 1).

The HI9828 Multiparameter (HANNA) equipment was used to determine pH, conductivity, and temperature. A TN-100 portable turbidimeter (EUTECH) was used to measure turbidity, and for residual chlorine, a POCKET II CLORIMETER (HACH, USA) was employed usingdiethyl-p-phenyldiamine) tablets as a reagent for the measurement.

For the microbiological analysis, portable MEL Total Coliform and *E. coli* Laboratory equipment (HACH, USA) was used. All containers were previously sterilized to collect treated water. However, in areas where the presence of chlorine was detected, they were prepared with 10 mg of sodium thiosulfate per 100 mL of sample to neutralize the chlorine. Volumes of 100 mL of water sample were used. The m-ColiBlue 24 broth (HACH Company, M00PMCB24) was used to detect and quantify total coliforms and *E. coli* after 24 h of incubation at 35ºC.

3. Results

The physical–chemical parameters (pH, temperature, turbidity and conductivity) were evaluated, and they fall within the maximum permissible limits outlined in the regulation of water quality for human consumption in Peru [21].

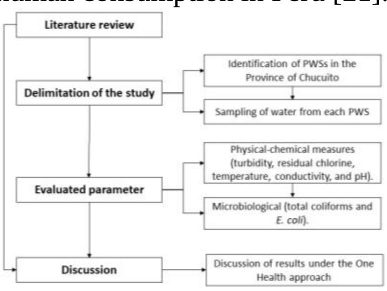

Fig. 1 Flowchart of the research methodology (Developed by the authors)

However, there is an exception of residual chlorine, with values ranging between 0 and 0.4 mg/L. The minimum allowed value, according to [21], is 0.5 mg/L, as illustrated in Fig. 3.

On the other hand, the microbiological analysis revealed the presence of total coliforms in most PWSs, along with *E. coli*, with ranges from 0 to >200 and 0 to 34 CFU/100 ml, respectively (Figs. 4 and 5).

4. Discussion

The absence of chlorine is evident in most cases, and where it is found, it does not meet the concentration criteria established by health authorities for considering water potable [21, 29]. Therefore, there is a risk of the presence of microorganisms that may adversely affect the health of the population. This risk was confirmed by microbiological analyses, which showed total coliforms and *E. coli* in most cases. According to Peruvian health regulations, water for human consumption with such findings indicates fecal contamination, posing a high microbiological risk, consistent with the standards set by WHO and UNICEF [32].

This aligns with previous studies, as reported by [33] in Ethiopia, and corroborated by [25–28], [34–38]. These studies have also reported total coliforms exceeding established limits, underscoring the need for appropriate water treatment for human consumption, particularly to address the anthropogenic filtration of animal waste.

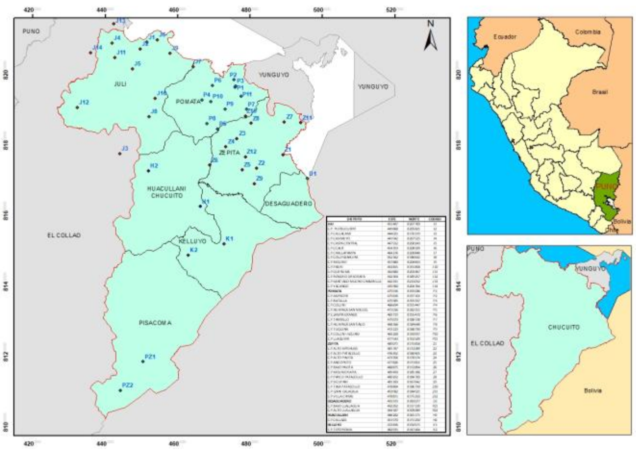

Fig. 2 Geographical location (Developed by the authors)

Table 1 Surveillance of potable water systems in the province of Chucuito, Puno Region (Developed by the authors)

Sampling point	District, town	Georeferenced (Utm)		Altitude (m.a.s.l.)	Sampling Point	District, town	Georeferenced (Utm)		Altitude (m.a.s.l.)
		East	North				East	North	
	1. Juli					3. Zepita			
J1	Juli	0451487	8207783	3848	Z1	Zepita	0489071	8175818	3856

Continuation of Table 1

J2	Pueblo Libre	0449668	8205821	3938	Z2	Alto Ayrihuas	0481787	8172009	3881
J3	Callacami	0444226	8176109	4080	Z3	Alto Patacollo	0476392	8180401	3863
J4	Casimuyo	0441942	8207525	3923	Z4	Alto Pavita	0473356	8178174	4129
J5	Caspa Central	0447552	8200243	3971	Z5	Ancoputo	0477826	8171651	3913
J6	Ccajje	0454393	8208509	3945	Z6	Bajo Pavita	0468875	8172894	3914
J7	Challapampa	0464276	8200848	3891	Z7	Molino Kapia	0489490	8185166	3995
J8	Collpajahuira	0452162	8186632	4070	Z8	Parco Patacollo	0482143	8185912	3975
J9	Molino	0457880	8204653	3834	Z9	Sicuyani	0481183	8167642	3877
J10	Pasiri	0453815	8191858	4163	Z10	Tasapa Patacollo	0479496	8187844	3955
J11	Queruma	0442680	8203467	4099	Z11	Izani Calacala	0493982	8184921	3836
J12	Rosario De Sorapa	0432304	8189257	3992	Z12	Villa Chimu	0478811	8175250	3856
J13	Santiago Mucho Chambilla	0442708	8213108	3825		4. Desaguadero			
J14	Yacango	0435973	8204760	4078	D1	Desaguadero	0495919	8169077	3872
	2. Pomata					5. Pizacoma			
P1	Pomata	0475916	8195036	3858	PZ1	Pizacoma	0451500	8107927	3834
P2	Ampatiri	0475616	8197101	3839	PZ2	Bajo Llallagua	0489621	8170398	3904
P3	Batalla	0475985	8195337	3854	PZ3	Alto Llallagua	0475304	8171711	3890
P4	Collini	0466694	8191447	3909		6. Huacullani			4129
P5	Huapaca San Miguel	0471016	8183151	3863	H1	Huacullani	0466282	8161171	3976
P6	Lampa Grande	0469719	8195470	3866	H2	Callaza	0451970	8171250	4024
P7	Tambillo	0479070	8188738	3935		7. Kelluyo			3995
P8	Huapaca Santiago	0468166	8184648	4041	K1	Kelluyo	0472816	8150571	3960
P9	Tuquina	0473129	8188790	3831	K2	Totoroma	0462931	8147404	4035
P10	Collini-Iscuani	0469200	8190997	3828					
P11	Llaquepa	0477543	8192509	3949					

Notes: C.P. - populated center; m.a.s.l. - meters above sea level

Table 2 Legal limits allowed in water used for human consumption according to Peruvian regulations (DS N° 031-2010-SA) [21]

Parameter	**Legal limit (DS N° 031-2010-SA [21])**
Physical-chemical turbidity	5 NTU
Residual chlorine	250 mg Cl^-/L
Temperature	n. a.
Conductivity (25°C)	1500 µhmo/cm
pH	6.5–8.5
Microbiological total coliforms	0 CFU/100 mL at 35°C
fecal coliforms and *E. coli*	0 CFU/100 mL at 44.5°C

The microbiological conditions observed in water for human consumption do not contribute to the challenging task of reducing the high rates of childhood anemia in our region, which is particularly significant considering the association between childhood and maternal health [39]. The fecal contamination detected in the studied drinking water system renders it unsafe for human health and raises concerns about potential waterborne epidemics [40] and the possibility of outbreaks of foodborne diseases [41]. This situation disrupts the man–animal–environment interfaces, as considered in the One Health approach [1].

Considering these findings, we recommend that the entities providing drinking water services ensure the availability of residual chlorine to the final consumers [21, 42, 43], as reported elsewhere [23]. Notably, chlorine is an effective disinfectant against bacteria, whether resistant or not to antibiotics [44–49].

Consequently, immediate action is imperative to ensure the provision of safe drinking water and prevent the potential occurrence of waterborne diseases, including zoonotic waterborne diseases that require a robust reinforcement of strategic surveillance and awareness approaches to prevent drinking water from becoming contaminated [38]. This situation presents an excellent opportunity to implement the One Health approach [1], considering that most communicable diseases are associated with an unsafe and inadequate water supply [35, 37].

However, it has been estimated that the lack of access to good-quality water and poor hygiene practices may contribute to half of all cases of malnutrition [50–53]. Addressing these issues not only ensures public health and prevents diseases but also plays a crucial role in tackling malnutrition.

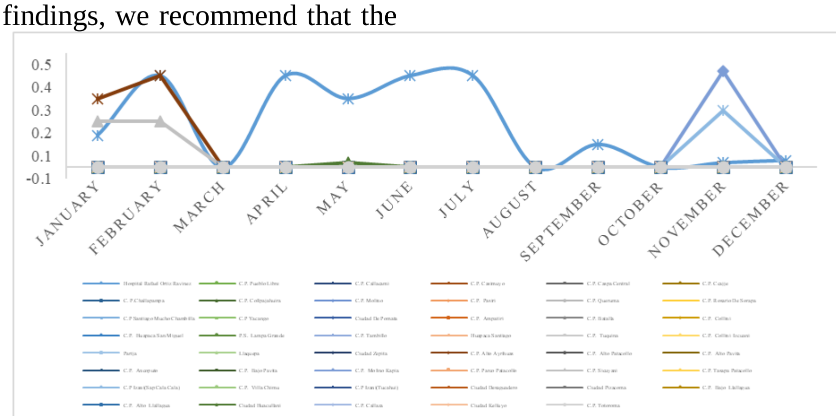

Fig. 3 Residual chlorine in PWSs in the Chucuito province (Developed by the authors)

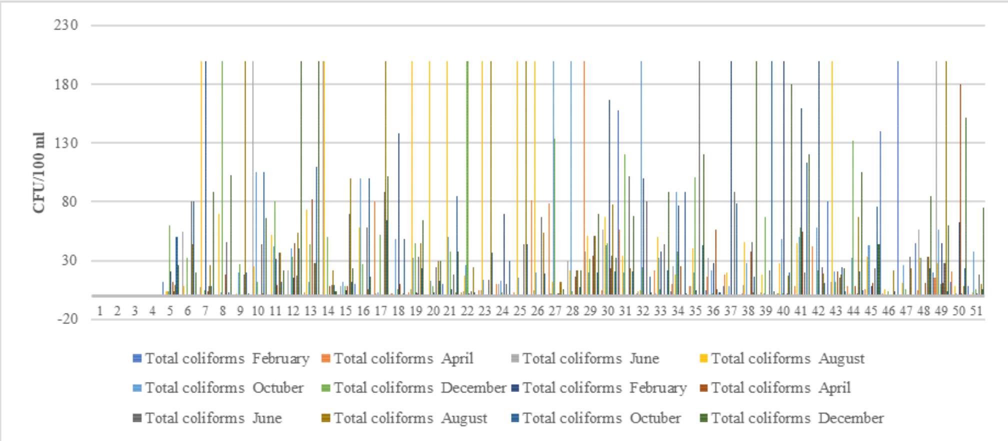

Fig. 4 Total coliforms in PWSs of Chucuito's province (Developed by the authors)

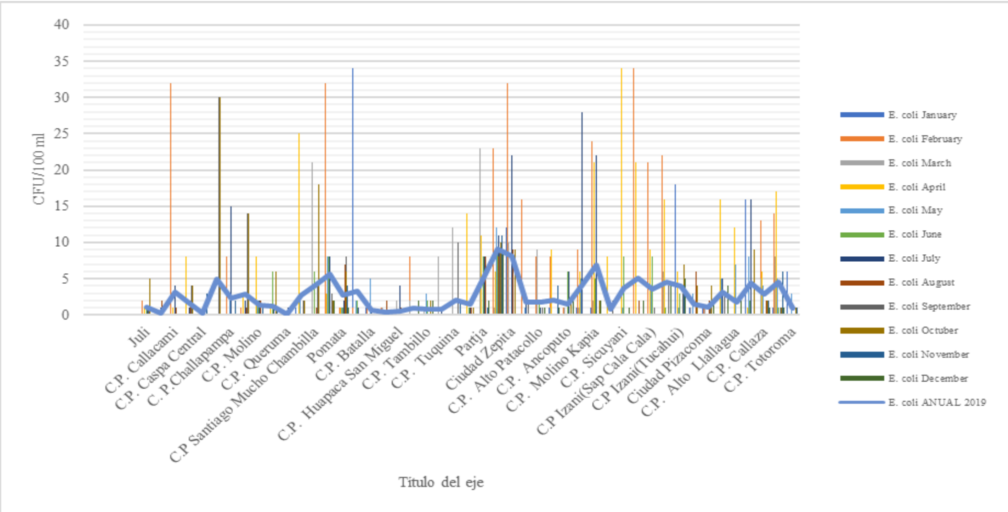

Fig. 5 *E. coli* in PWSs of Chucuito's province (Developed by the authors)

5. Conclusion

Water intended for human consumption does not meet potability standards and displays levels of fecal contamination, similar to most water supply systems in rural settings. These findings significantly alter the interaction among humans, animals, and the environment, as contemplated within the One Health approach. Consequently, it is imperative to analyze water intended for human consumption within this approach, to safeguard public health.

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