

Physicochemical Evaluation of the Water Consumed by the Population of Santiago De Cao and Malca - Peru

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SUMMARY

The objective of the research was to make a physical-chemical evaluation of the water of Santiago de Cao, Malca and the puquial Los Tres Palos. The research is experimental, descriptive and cross-sectional. The first water sample comes from two interconnected wells, Santiago de Cao and Malca; the analysis indicates that it is water of poor quality, the hardness, the presence of phosphates and sulfates are very high, above the Maximum Permissible Limits issued by the Ministry of the Environment; in addition, it has a bad taste, it is not useful for drinking, cooking food and beans. The stored water forms a carbonate white layer on the surface, damaging the pipes and walls. The second sample of water comes from the puquial Los Tres Palos, being of regular quality, the values of hardness and phosphates are high, the value of sulfate is within the norm. In addition, a survey was carried out on the perception of the inhabitants regarding the water they consume, indicating that it is of poor quality and the service provided is terrible; so they use purchased water, from the puquial. It is concluded that, in order to take care of the health of the population and improve the quality of the water they consume, they must be made drinkable.

Keywords: water quality, Maximum Permissible Limits, drinking water.

INTRODUCTION

Water is an indispensable natural resource for life on planet Earth, every living organism requires water consumption to maintain and develop life, however, numerous actions of human beings at the global, national and local levels put the life of the planet and the quality of this natural resource at risk.

Water, as a resource of vital importance for the survival of species on Earth and of human beings in particular, must be free of contamination, and must also have "a satisfactory supply (sufficient, safe and accessible). Access to drinking water is a basic human right and must comply with certain characteristics that make it safe for consumption and should not have an impact on health" (Mamani *et al.*, 2022, p. 444).

However, the report on the progress of Sustainable Development Goal (SDG) 6, of the United Nations (UN, 2021) referring to water and sanitation for all, in which it was stated that, In 2021, more than 2 billion people lived in water-scarce countries, a situation that is likely to worsen in some regions as a result of climate change and population growth. In 2022, there were at least 1700 million people in the world who drank drinking water from sources contaminated with feces. (paras. 1-2)

In this sense, Villena (2018) points out that "Water quality, health, and economic growth are mutually reinforcing and are fundamental to achieving human well-being and sustainable development" (p.304). However, as Peña explained in 2017, the interest was concentrating on "economic growth and the incessant search for profits, which in his opinion surpasses environmental and social welfare concerns" (p.126), an aspect that is reaffirmed from the events that occur daily and are reflected from statistical reports from international and national organizations.

Based on the above approaches, the authors agree that water resources are a common good of humanity, which requires immediate occupation and it is everyone's duty to preserve it and protect its quality. In the case of Peru, it is recognized in the Political Constitution that, ... the right of every person to have progressive and universal access to drinking water. The State guarantees this right by prioritizing human consumption over other uses. The State promotes the sustainable management of water, which is recognized as an essential natural resource and as such, constitutes a public good and patrimony of the Nation. Its dominion is inalienable and imprescriptible (Peru, 2017, p.4)

However, even though it is a right that appears in the Constitution and the Peruvian State promotes numerous actions to achieve this purpose of the Law, currently, the distribution of quality water in the country continues to be a problem, among other things, due to a lack of execution in development strategies and policies, adequate sanitary management and water quality monitoring; As a consequence, the problem of the appearance of diseases in the population persists, increasing the costs of health services.

Evidence of this situation are the towns of Santiago de Cao and Malca, which are adjacent to each other, both are located in the department of La Libertad. They are located in the north of Peru and have a population of approximately 20,000 inhabitants.

Access to water for these populations is through two tubular wells, the first comes from Santiago de Cao and the second from Malca, both interconnected to the water supply network. The pumping is two hours in the morning, from 6:00 to 8:00 a.m. and two hours in the afternoon, from 3:00 to 5:00 p.m. The population considers that the water supplied to them is not of good quality. So the alternative is to consume water from the puquial of Los Tres Palos, the quality of water is regular and the population buys it. Taking into account the importance of water quality, the provisions of Peruvian law and regulations, as well as the criteria of the inhabitants, an investigation was carried out whose objective was to evaluate the quality of water consumed by the inhabitants of the area of Santiago de Cao and Malca in order to verify if what was expressed by the population regarding the quality of the water, is correct.

MATERIALS AND METHODS

The research carried out was quantitative, the design was descriptive experimental and the study was cross-sectional.

The selection of the first sample point is referred to Santiago de Cao where the main source was located, (SC) Pozo, and four houses (SC), 1, 2, 3 and 4, all distanced from each other; the second point is referred to Malca where the main source was located, (M) Pozo, and two houses (M), 1 and 2 also distanced from each other; the third point the puquial Los Tres Palos. The sampling points are presented in table 1, in UTM coordinates (the most important characteristics are that distances are easy to measure, the shape of geographical features is preserved for small areas and bearings and directions are easy to mark), link: <https://www.certicalia.com/blog/que-son-las-coordenadas-utm>

Table.1.

Location of the water samples taken, based on their GPS points, Malca, Santiago de Cao and the Puquial Los Tres Palos

Sampling Points	UTM coordinates	
	Latitude	Longitude
Malca (M), Pozo	9120112	693633
House 1, (M)	9120021	693480
2nd House, (M)	9119836	693540
Santiago de Cao (SC), Pozo	9120141	694154
Casa 1, La Estancia, (SC)	9119989	693663
2nd House, (SC)	9119835	693785
3rd House, (SC)	9119650	693907
4th House, (SC)	9119496	694151
Puquial Tres Palos (TP), Pozo	9116692	696099

Figure 1.

Location of water sampling points for Malca, Santiago de Cao and the Los Tres Palos puquial, La Libertad region, Peru.



Note: <https://earth.google.com/web/@-7.95745091,-79.23951133,19.77401343a,3311.89946118d,35y,0.08488121h,4.18017266t,0r/data=OgMKATA>

For the determination of pH, electrical conductivity and temperature, the HANNA Instruments brand equipment was used with the electrometric method, the measurement of the hardness of the water, was carried out through the determination of carbonates using the HI 9829 Multiparameter Meter, HANNA Instruments brand. The technical standard used was NTP 214.029 (2000) which establishes the parameters of water for human consumption.

The T80+ UV/VIS Spectrometer PG Instruments Ltd. was used for the identification and evaluation of the presence of nitrates. The technical standard was NTP 214.016:2000, Water for human consumption. In the case of the determination of sulfates, the Turbidimetric Method was used, with the technical standard NTP 214.023 (2000).

For the phosphate evaluation, the HI 83225 photometer, medium range, HANNA Instruments brand with the spectrophotometric method of Ascorbic Acid was used. The technical standard was NTP 214.027 (2000).

For the evaluation of metals, Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), Dual system, was used. The EPA Method 200.7 Rev. 4.4, (1994), Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Emission Spectrometry, which is a technique for the simultaneous or sequential determination of multiple elements of metals in solution.

The results of the water analysis for Santiago de Cao, Malca and Los Tres Palos were compared with the Technical Standard DS No. 031-2010-SA, water for human use and consumption, which indicates the Maximum Permissible Limits of the quality of the water that it must have.

Subsequently, a survey was carried out to measure the perception that the inhabitants of the area have regarding the quality of water provided. There were 50 respondents between 20 and 65 years old, most of them male and older, 45% (the elderly inhabitants are mostly those who are in the village, young people are out working or studying) while women over 30 years of age did not want to participate in the survey).

RESULTS

Once the physical-chemical analysis of the water has been carried out, only the data that exceed the Maximum Permissible Limits of the technical standard for the localities of Santiago de Cao, Malca and the puquial of Los Tres Palos are shown, as can be seen in table.2, table.3 and table.4

The survey applied to the population of Santiago de Cao and Malca, regarding the quality of water consumed by the population, which is indicated in the table, is also presented.⁵

Table 2.
Physical-chemical evaluation of the water sources of Santiago de Cao and Malca

Parameter	Water Source										
	(SC)						(M)				
Location	Well	1st House	2nd House	3rd House	4th House	Average	Well	1st House	2nd House	Average	Final average
pH	6.72	6.92	6.85	6.86	6.89	6.85	7.93	8.01	8.03	7.99	7.42
E.C. (μS)	1658	2835	1746	2627	2758	2324.80	920	1 031	1024	991.67	1658.23
STD (ppm)	1017	1457	1042	1313	1383	1242.40	460	493	486	479.67	861.03
Phosphates (ppm)	24	41	24	37	39	33.00	25	31	37	31.00	32.00
Sulfates (ppm)	1278	1480	1283	1440	1458	1387.80	1 230	1 356	1413	1333.00	1360.40

(SC) = Santiago de Cao

(M) = Malca

Source: own

Table 3.
Physical-chemical evaluation of the puquial Los Tres Palos

Parameter	P(3P)		
	1st trial	2nd trial	Average
pH	7.93	8.01	7.97
E.C. (μS)	920	1 031	920
STD (ppm)	460	493	476.5
Phosphates (ppm)	4.98	5.02	5
Sulfates (ppm)	130	136	133

P(3P): puquial Los tres Palos

Source: own

Table 4.
Evaluation of metals in water sources

Parameter (ppm)	Well Water, P(3P)	Well water, P(SC/M)	Detection Limit/Quantification
Silver (Ag)	<0.019	<0.019	0.019
Aluminum (Al)	0.036	0.050	0.023
Arsenic (As)	0.020	<0.005	0.005
Boron (B)	0.348	0.605	0.026
Barium (Ba)	0.007	0.016	0.004
Beryllium (Be)	<0.003	<0.003	0.003
Bismuth (Bi)	<0.016	<0.016	0.016
Calcium (Ca)	7.082	196.1	0.124
Cadmium (Cd)	<0.002	<0.002	0.002
Cerium (Ce)	<0.004	<0.004	0.004
Cobalt (Co)	<0.002	<0.002	0.002
Chromium (Cr)	<0.003	<0.003	0.003
Copper (Cu)	<0.018	<0.018	0.018
Iron (Fe)	<0.023	0.041	0.023
Potassium (K)	4.653	3.319	0.051
Lithium (Li)	0.006	0.020	0.005
Magnesium (Mg)	1.893	87.720	0.019
Manganese (Mn)	<0.003	0.035	0.003
Molybdenum (Mo)	0.010	0.004	0.002
Sodium (Na)	175.4	107.8	0.026
Nickel (Ni)	<0.006	<0.006	0.006
Phosphorus (P)	0.051	<0.024	0.024
Lead (Pb)	<0.004	<0.004	0.004
Sulphur (S)	34.94	215.9	0.091

Antimony (Sb)	<0.005	<0.005	0.005
Selenium (Se)	<0.007	<0.007	0.007
Silicon (Si)	8.012	9.824	0.104
Tin (Sn)	<0.007	<0.007	0.007
Strontium (Sr)	0.078	1.956	0.003
Titanium (Ti)	<0.004	<0.004	0.004
Thallium (Tl)	<0.003	<0.003	0.003
Uranium (U)	<0.004	<0.004	0.004
Vanadium (V)	0.072	0.024	0.004
Zinc (Zn)	<0.018	<0.018	0.018
Silica (SiO ₂)	17.14	21.01	0.2225

Source: own

Table 5.

Survey on the perception of the water consumed by the inhabitants of the area of Santiago de Cao and Malca

1. Who is the one who supplies water in Santiago de Cao and Malca?	
The Cartavio company	27%
The Municipality of Santiago de Cao	58%
He doesn't know	15%
2. Do you have water service all day in your home?	
Yes	0%
No	100%
3. Are you worried about the lack of water in your home, why?	
To cook food	0%
For personal hygiene	50%
For washing clothes, kitchen things	35%
To water the plants	5%
For house cleaning	10%
4. Do you think the water you consume is of good quality?	
Yes	0%
No	100%
5. Do you know of any initiative by the authority to improve the quality of the water you consume?	
Yes	0%
No	100%
6. Does the water you consume come with soil, straw or other solid waste?	
Yes	0%
No	100%
7. Is the water you consume transparent or opaque?	
Transparent	100%
Opaque	0%
8. Would you agree that people who waste water should pay a fine?	
Yes	0%
No	100%
9. Do you think that the water service you consume can be replaced, in case it is not of good quality?	
Yes	95%
No	5%
10. Have you received any talk from the Municipality about the water service, its quality, among other topics?	
Yes	0%
No	100%
11. You agree with the motto: "Water is life and clean water means health" (Audrey Hepburn)	
Yes	100%
No	0%

Source: own

DISCUSSION

The hardness of the water, as calcium and magnesium carbonate, for Santiago de Cao and Malca, is very hard, its value is 861.03 ppm; while, for the water of the puquial of Los Tres Palos, it is hard, with a value of 476.5 ppm, both referenced to Supreme Decree No. 031-2010-MINAM which indicates a value of less than 400 ppm.

We can also compare the value of the hardness of the water based on some research that has been done to indicate whether or not it is suitable for consumption, such as Gonzales et al., in the research on the physicochemical and microbiological evaluation of water for human consumption, who indicate in one of their conclusions that

For the concentration of total dissolved solids TDS, during the study, it was seen that the maximum value identified was 250 mg/L, in the reservoirs studied; therefore, we point out that the water of these communities is suitable for human consumption since they are within the highest desirable level range (p.23-31)

For Brousett et al. (2018), in the research on the physicochemical and microbiological evaluation of water for human consumption, they indicate that the measured hardness is within the limits of the standard, its value of 130 ppm, makes it suitable for consumption.

Castillo, Tuesta & Salazar (2022), in the evaluation of groundwater quality, points out that for catchment well No. 1, the hardness marked 893 ppm, indicating this value as very high and not suitable for human consumption.

Huamán et al. (2021), in the evaluation of the water quality of the Marvilla lagoon, indicates that the hardness value is very high, a value of 3 413.9 ppm, which concludes that the water quality is damaged.

The second value observed is that of sulfate, for the water of Santiago de Cao and Malca, it is very high, of 1 360.40 ppm; while the water of the Tres Palos, of 133 ppm, is within the range established according to Supreme Decree No. 031-2010-MINAM that indicates a value of 25–250 ppm.

These results can be compared with those issued by Chibinda, Arada, & Pérez (2017)

The average values of the concentration of sulfate ions in well 1 was 135.6 mg/L and in the waters of well 2 values higher than 243.6 mg/L, however, these waters comply with NC 827-2010 which is Drinking Water and NC 1021:2014, which is Water for supply (p.303-321)

Similarly, Alcívar et al (2017) in their research physical-chemical and microbiological evaluation of the quality of well water, point out that In the measured sulfate value, all the wells sampled in the 3 monitorings presented values below those established by the TULSMA 400 mg/l, being a general average of 259.92 mg/l (p.183-206)

Sulphate is one of the least toxic anions for human health; however, when concentrations exceed 400 ppm, damage such as catharsis, dehydration and gastrointestinal irritation is noticed. In many cases, people who ingest high levels of sulfates may experience diarrhea and dehydration (DIGESA, Peru)

In water systems for domestic use, sulfates do not produce an increase in corrosion of metal fittings, but when concentrations are higher than 200 ppm, the amount of dissolved lead from the pipes increases (Mejía, 2005).

The third value observed is that of phosphate, which, for the water of Santiago de Cao and Malca, is very high, of 32 ppm; while the water of the Tres Palos is high, of 5 ppm compared to Supreme Decree No. 031-2010-MINAM that indicates a value of 0-0.5 ppm.

Veloz & Carbonel (2018) when evaluating the presence of phosphates in water, indicate the following the maximum value is presented at the mouth of the Chibunga River to the Chambo River, which for the year 2017 was 0.49 mg/L with BAD Quality. In the dry stage, the concentration of phosphates decreases its quality at all sampling points, the maximum concentration is found in the San Luis Parish of 1.21 mg/L, which for the year 2015 was of TERRIBLE quality (p.13-26)

Among the damages that phosphate generates in people's health is hyperphosphatemia, when the serum phosphate concentration is greater than 4.5 mg/dL, as well as chronic nephropathy, hypoparathyroidism, and metabolic or respiratory acidosis (Lewis, 2021).

The high levels of carbonates such as hardness, phosphates and sulfates, mentioned above, are clearly observed by the residents on the surface of the water that has been standing for more than two days, through the presence of a layer of white crystals, which causes clogging in the water pipes and toilets.

The fourth referenced value in table.4 is the one observed for the metals calcium and magnesium, which for the water of Santiago de Cao and Malca are very high, of 196.1 and 87.720 ppm compared to the water of the puquial of Los Tres Palos of 7.082 and 1.893 ppm and the range established according to Supreme Decree No. 003-2010-MINAM that indicates a

maximum value of 100 and 39.0 ppm. respectively. This also confirms why the hardness of the water in Santiago de Cao and Malca is very hard and the water of the puquial of Los Tres Palos lasts.

The fifth value is for sodium, for the water of Santiago de Cao and Malca it is 107.8 ppm while the water of the puquial of Los Tres Palos of 175.4 ppm, when comparing it stoichiometrically as salinity (sodium chloride), gives us a value of 274.2 and 446.1 ppm which is very high, compared to Supreme Decree No. 003-2010-MINAM that for salinity indicates a value of 25-300 ppm. this confirms that the water of the puquial Los Tres Palos is salty because it is very close to the sea, the distance is 150 m.

Salinity is a physical parameter that measures the amount of salts dissolved in water, especially chlorides. Salinity and conductivity are intimately related to each other; the greater the number of dissolved ions, the greater the value of both properties. Excess salinity can cause damage to a person's health, such as an increase in blood pressure and the generation of cardiovascular diseases (Monckeberg, 2012).

The sixth value is for sulfur, which for the water of Santiago de Cao and Malca is very high, of 215.9 ppm while the water of the puquial of Los Tres Palos of 34.94 ppm, if we compare it stoichiometrically as sulfate, gives us a value of 647.7 ppm for Santiago de Cao and Malca which is very high, and 104.8 ppm for the puquial of the Tres Palos, a low value, with respect to Supreme Decree No. 031-2010-MINAM that indicates a value of 25-250 ppm, which shows that the waters of Santiago de Cao and Malca have a bad taste and high hardness so they cannot be ingested or used for cooking. These waters also confirm the high value of saltpeter present, because the location of its wells is very close to El Charco beach, a distance of 1 km.

For the survey on the perception of the water consumed by the inhabitants of the area of Santiago de Cao and Malca, indicated in table 5., we can affirm that the majority of the population recognizes that the administration of the drinking water service is in charge of the Municipality of Santiago de Cao, however, the wells belong to the Community of Santiago de Cao. Both in agreement have established that the Municipality must do the maintenance and cleaning service of the wells, including the payment of a worker to provide the service.

They point out that the water supply schedule is four hours a day; 2 hours in the morning (from 6:00 a.m. to 8:00 a.m.) and 2 in the afternoon (from 3:00 a.m. to 5:00 p.m.) demonstrating their discomfort to the population, which they believe should be 24 hours a day. In addition, they indicate that the water is used in many services, but not for cooking food and beans because it is of poor quality, has a bad taste and when the water is stored for several days a carbonate film is observed on the surface.

They emphasize that the Municipality of Santiago de Cao, to date, has no communication with the population regarding improving the quality of the water, so it is difficult to sanction the user. Having poor quality water, part of the population buys water from the Los Tres Palos puquial, in 25-liter drums and a price of 10 soles. With this water, you can drink and cook food. Others consider that it cannot be acquired because they do not have the resources to pay for it, on a daily basis.

Regarding the slogan presented in the survey, the population considers that it is correct and should be applied by the competent authority, it is their commitment to the population to make every effort to improve the quality of life of people and supply quality water.

We can point out that the conclusions obtained are very similar to those that have been made in the User Perception Survey, EMAPA-Pisco, INFORME-2015

When analyzing customer service, only 15% of those surveyed say they are satisfied or very satisfied, regarding the relationship with the media, 64% of respondents do not remember having received information issued by the company and about the main demands of users in relation to the service, the provision of the service stands out (44%), followed by maintenance (33%), information (18%) and maintenance (3%) of quality

Likewise, Cruz & Centeno (2020) in the study on the evaluation of the quality of the drinking water supply service based on the perception of users, concludes

What the level of satisfaction of the user, 30% consider it bad, problems with the number of hours a day they receive water at home, water with a bad smell, high turbidity in the water received, due to the discontinuity of the service when mud or solid particles are dragged into the network every time it is cut off and finally users tend to implement storage and treatment systems in their homes, generating a higher cost

For Faviel, Infante & Molina (2018), they indicate in their discussions

According to the opinion of the interviewees, the perception of water quality is determined by the uses given to the various sources of the liquid; A source of good quality water intended for domestic consumption and drinking should be used

bottled water. If the water is of regular quality, it is only used for personal hygiene and if it is of poor quality, it is only used to water the patio or plants

CONCLUSIONS AND RECOMMENDATIONS

The high values of salinity and hardness present in the waters of Santiago de Cao, Malca and the puquial of Los Tres Palos, generate damage to people's health, as well as obstruction in the pipes and clogging in the toilets.

The excessive presence of sulfates and phosphates in the water of Santiago de Cao, Malca and the puquial of Los Tres Palos produces diseases such as methemoglobinemia, gastric problems, kidney damage, neurological disorders and even cancer, all of them in the medium term.

Likewise, the population largely recognizes the type of water that is supplied, which is of poor quality; so they resort to other types of supply, the most important being to use water from the Tres Palos, but at the same time, it generates an additional amount of money in their economy that they have to spend.

From all this, it can finally be concluded that the research carried out is intended to be information to guide the Municipality of Santiago de Cao in improving the service and quality of water supplied to the inhabitants of the area.

BIBLIOGRAPHIC REFERENCES

1. Alcibar et al (2017). Physical-chemical and microbiological evaluation of the quality of well water. Vol. 3, No.4, p.183-206
2. Beutelspacher, T. (2019). Sulfates in groundwater from the lower zone in Chetumal, Quintana Roo. *Rev. Ana Cient*, 2(VII). Special Edition, p.51-60
3. Brousett et al. (2018). Physical-Chemical and Microbiological Evaluation of Water for Human Consumption Puno – Peru. *Fides Et Ratio*, Vol.15, p.47-68
4. Cartagena, L., & Vargas, D. (2020). Thesis: Study of the risk of phosphates, nitrates and nitrites in the water of the Magdalena River for the supply of Girardot-Ricaurte (Cundinamarca).
5. Castillo, D., Tuesta, L. & Salazar, S. (2022). Evaluation of groundwater quality during the COVID-19 pandemic at the National University of Trujillo, Peru. *Journal of Interdisciplinary Studies in Social Sciences*, 24 (2), Venezuela, p.219-234
6. Chibinda, C., Arada, M., & Pérez, N. (2017). Characterization by physical-chemical methods and evaluation of the quantitative impact of the waters of the Pozo la Calera. *Rev. Cub. Quim*. Vol.29, N°.2 Santiago de Cuba, p.303-321
7. Combatt, E., Narváez, H., & Bustamante, I. (2015). Estimation of salinity in groundwater in the area of influence of the mouth of the Sinú-Córdoba River, Colombia. *Idesia*, Vol.33, N°.3, Arica
8. Cruz, N., & Centeno, E. (2020). Evaluation of the quality of the drinking water supply service based on the perception of users: the case in Cartago, Costa Rica. *Environmental Sciences*. Vol.54, No.1
9. Supreme Decree No. 003-2010-MINAM. Maximum Permissible Limits for Effluents from Domestic or Municipal Wastewater Treatment Plants Approved
10. Supreme Decree No. 004-2017-MINAM. Environmental Quality Standards (ECA) for Water Approved and Complementary Provisions Established
11. Supreme Decree No. 031-2010-SA. Regulation on the Quality of Water for Human Consumption. General Directorate of Environmental Health Ministry of Health
12. DIGESA. Organoleptic parameters. Peru.
13. Lavie et al. (2010). Phosphate contamination in the oasis under irrigation of the Mendoza River. *Journal of the Faculty of Agrarian Sciences*. Vol. 42, No. 1, pp. 169-184
14. Faviel, E., Infante, D., & Molina, D. (2018). Water perception and quality in rural communities of the La Encrucijada Natural Protected Area, Chiapas, Mexico. *Rev. Int. Contam. Ambie*. 35 (2) 317-334, 2019
15. García, M. (2015). Right to water and quality of life. *Ibero-American Journal for Educational Research and Development*. Vol. 6, No. July 11 – December. 2015. RIDE
16. Gonzáles, W. (2023). Physical, chemical and microbiological evaluation of water for human consumption in six rural communities in the high Andes of Huancavelica, Peru. *Journal of High Andean Research* 25(1), p.23-31
17. Hernández, L., Chamizo, H., & Mora, D. (2011). Water quality for human consumption and health: two case studies in Costa Rica. *Rev. Costarr. Public Health* 2011; 20: 21-26, V°.20, N°.1
18. Huamán et al. (2021). Evaluation of the water quality of the Marvilla lagoon in the Pantanos de Villa (Lima, Peru). *South Sustainability*, 1(2), e019. Vol.1, No.2

19. L. Guarín (2011). Standardization of phosphate and chloride techniques in raw and treated water for the laboratory of the municipal association of community aqueducts (AMAC) in the municipality of Dosquebradas. Bachelor's thesis. Technological University of Pereira, Colombia
20. Lewis, J. L. (2021). MSD Manual. Hyperkalemia. MD, Brookwood Baptist Health and Saint Vincent's Ascension Health, Birmingham
21. Márquez, O. & Ortega, M. (2017). Social perception of the drinking water service in the municipality of Xalapa, Veracruz. *Revista mexicana de opinión pública*, N°.23, p. 41-59
22. Mejía, M. R. (2005). Thesis, Analysis of the quality of water for human consumption and local perception of the appropriate technologies for its disinfection at home scale, in the El Limón micro-basin, San Jerónimo Honduras. Costa Rica.
23. Monckeberg, F. (2012). Salt is essential for life, but how much? *Rev. chil. nutr.* Vol.39, N°.4 Santiago
24. Peña, A. (2017). A social perspective of the water problem. *Invest. Geog.* N°.62, Mexico City
25. Constitutional reform on the right of access to water. Law No. 30588. Constitutional Reform Law, Article 7-A. Peru
26. Rodríguez, R. (2007). Water quality from spring sources in the basic health area of Sigüenza. *Rev. Esp. Salud Pública*, Vol.77, N°.3, Madrid
27. Samboni, N., Carvajal, Y., and Escobar, J. (2007). Review of physicochemical parameters such as indicators of water quality and pollution. *Engineering and Research Journal*. Vol. 27, No. 3, p. 172-181
28. Severiche, Agu C. & González, H. (2012). Analytical evaluation for the determination of sulfates in water by modified turbidimetric method. Vol.3, No.2
29. Torres, P., Hernán, C., & Patiño, P. (2009). Water quality indices in surface sources used in the production of water for human consumption. A critical review. *Revista Ingenierías Universidad de Medellín*, p.82
30. Veloz, N., & Carbonel, C. (2018). Evaluation of the water quality of the Chibunga River micro-basin-Ecuador in seasonal variations, period 2013-2017. *Rev. of the FIGMMG-UNMSM Research Institute*. Vol.21, No.42, p.13-26
31. Villena, J. (2018). Water quality and sustainable development. *Peruvian Journal of Experimental Medicine and Public Health*. *Rev. peru. med. exp. salud publica* Vol.35, N°.2. File