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Evaluation of the physical-chemical parameters of the Viñas River in Peru

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ABSTRACT

In the annex of Viñas, Pampas district, Tayacaja Province, Huancavelica department, Peru, they lack the benefit of a drinking water treatment plant and consume water directly from the river, which is also used for livestock and agricultural activities, and waste is dumped, Therefore, the objective of the study was to analyze the physical-chemical parameters of the Viñas River and compare it with drinking water. The evaluation was performed according to the Jefatural Resolution N° 010-2016-ANA and a Hanna brand multiparameter water analyzer was used to evaluate temperature, total dissolved solids (TDS), dissolved oxygen, conductivity, pH, salinity, biochemical oxygen demand (BOD) and chemical oxygen demand (COD). In addition, ANOVA and Tukey tests, Hierarchical Cluster Analysis and Pearson correlation tests were performed. It was determined that none of the samples analyzed exceeds the ECA for water (DS 004-2017-MINAM), nor LMP (DS 031-2010-SA), in addition, if there are significant differences between samples. On the other hand, the parameters that influence the water quality of the Viñas River are STD (975 mg/L), BOD (58 mg/L) and COD (250 mg/L). It is concluded that the habitants of Viñas consume water according to Peruvian standards, even though it comes directly from the river; therefore, there is a need to improve the water purification systems in the annex.

Keywords: water quality, water physicochemical parameters, Viñas River.

INTRODUCTION

Water is a basic element for the realization of life, and worldwide freshwater consumption is in the middle and increasing (Vargas and Vizcarra, 2023). Its quality depends on both anthropogenic and natural factors and is related to chemical, physical and biological characteristics (Aguilar and Obando-Díaz, 2020), and is compared with guidelines on national standards to ensure the safety of consumption and, if not, to recommend treatment techniques (Araujo et al., 2022). However, for decades, multiple diseases related to water quality have been reported in the world, due to deficiencies in the treatment or loss of safety in water distribution (Ramírez et al., 2021). Contaminated water is generated from the insertion of waste, direct or indirect by human and/or natural actions, which when exceeding its concentration generates some negative effect on human health, ecosystems and economic activities (Mancheno, 2024), for example, it is estimated that more than 485,000 people die from diarrhea caused by drinking contaminated water (Addisie, 2022) and more than 1.4 million people die from unsafe and inefficient water sanitation (WHO, 2022). That is why a constant follow-up, through monitoring, on water quality helps countries to assess, predict and control the contamination of water resources and better plan their sustainable use (Syeed et al., 2023), in addition to the evaluation methods are constantly evaluated with the intention of ensuring public health (Toniolo et al., 2024).

Among so many anthropogenic factors, the extension of agricultural areas, pastures and deforestation has caused the lack of protection of water resources, generating contamination and erosion in aquatic environments and a decrease in the amount of water (Ferrer-Sánchez et al., 2024) and a modification in the physical, chemical and biological characteristics of water sources and their environment (Ramírez, 2022). In addition, livestock and grazing also influence the salubrity and quantity of water in watersheds (Chugden, 2021), since livestock frequently enter streams in order to drink water, thus allowing sedimentation of watercourses and deposition of feces and urine, affecting the uptake of this resource (Ferrer-Sánchez et al., 2024). Because of these and many other reasons, the deterioration of water quality has become a concern, in addition to considering its scarcity in the future, which would imply risks to drinking water and the economic development of societies (Domenech et al., 2022). Therefore, it is important to understand how land use is related to the quality of water sources within watersheds, especially those that are not monitored and lack information (Toniolo et al., 2024).

In the Huancavelica region, water resources are affected by contamination from mining and agricultural activities (Gaspar, 2021); among many, the province of Tayacaja is a major agricultural production sector, and the compounds used can alter the physical-chemical parameters of nearby rivers, streams and lagoons, which are mostly destined for human consumption, affecting the health of citizens. For example, the Mantaro River contains heavy metals such as Zinc, Copper, Chromium, Arsenic, Lead and Cadmium that exceed the MPL, affecting the quality of the water body and surrounding areas directly or indirectly (Cerrón et al., 2018).

Pampas, a district in the Tayacaja province of the Huancavelica region, distributes drinking water to its population through the collection and treatment of water from the Viñas River, but there are still towns and/or annexes that do not have the benefit of a drinking water treatment plant and directly use the river water without considering its conditions and generating complications to their health. In addition, the main economic activities are livestock and agriculture, most of which are carried out in the headwaters of the river. Therefore, the objective of the research was to analyze the physical-chemical parameters of the drinking and direct source water of the Viñas River.

MATERIALS AND METHODS

Study area

The geographical location of the center of Pampas, Tayacaja, Huancavelica, is located at 74°52’02”W and 12°23’42”S at 3276 m.a.s.l. (Azarte, 2016). The city uses the Viñas River as a source of water for human consumption. The average annual temperature is 12 °C, with an annual precipitation of 780 mm and it is considered a dry forest (bsMT, 3000–3500 m.a.s.l.) according to the Holdridge classification (Cáceres, 2015), it also has a semi-dry and cold climate with moisture deficiencies in winter and autumn (Castro et al., 2021).

During the sampling, grazing and agricultural areas (Figure 1) were identified around the Viñas river because of the settlers of the Viñas Annex, and it should also be noted that these are some factors that influence the availability of water for the Pampas locality. The present investigation was carried out Ex situ in the facilities of the Universidad Nacional Autonomy de Tayacaja Daniel Hernández Murillo.

Materials

The following materials were used: a 5 L glass container with protective covers (plastic or mesh), a stylet, Tecnopor and a Hanna Multiparameter water analyzer. As well as filter paper, funnels, labels, and personal protective equipment (gloves, goggles, dust cover and masks).

Procedure

An integrated sampling of 4 points along the Viñas River (Figure 1) was performed, each with a capacity of 1 liter in the winter season, according to the National Protocol for monitoring the quality of surface water resources (Jefatural Resolution N° 010-2016-ANA), in force at the time of the execution of the research, and preserved in a cooler with ice to preserve the samples.

Then, from the integrated sample of 5 liters of water, a portion of 1 liter was extracted in a glass container of 1.5 liters capacity, for subsequent analysis in the biology laboratory of the Universidad Nacional Autonomy de Tayacaja Daniel Hernández Murillo. In the case of the sample for water for human consumption, sampling was carried out according to DS 031-2010-SA (MINAM, 2017), where the first house to receive drinking water from the drinking water treatment plant in

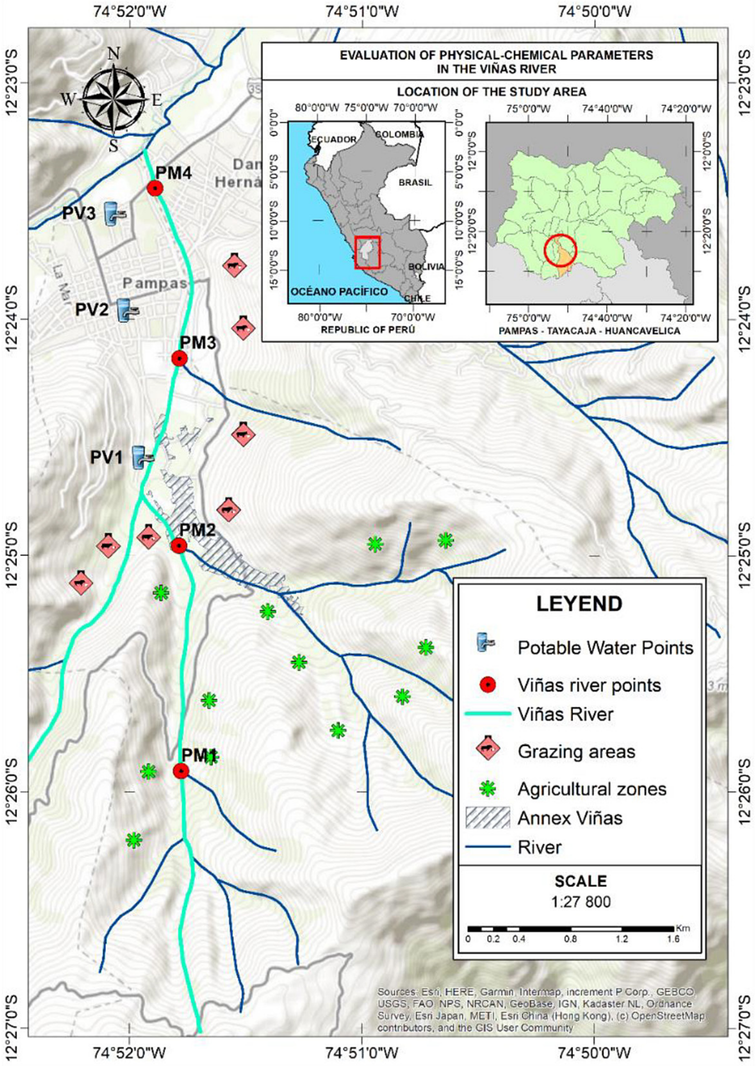

Figure 1. Identification and evaluation of sampling points in the Viñas river

the city of Pampas, one house representing the center of the city and the last house were considered (Figure 1). As well as the sample, an integrated sample of 1 liter was considered for evaluation.

Measurement of parameters

The research did not intend to manipulate the variables analyzed; thus, it is descriptive, non-experimental and transectional. The following physicochemical parameters were mainly considered: temperature, TDS, dissolved oxygen, conductivity, pH, salinity, BOD and COD.

Data analysis

The statistical package RStudio Version 2024.04.2 Build 764 was used to analyze the physical-chemical parameters of the samples collected from the Viñas River and drinking water according to the ANOVA test and Tukey's test, and the Pierson's correlation and a Hierarchical Cluster Analysis (HCA) of the parameters were also determined.

RESULTS AND DISCUSSIONS

In Table 1, the amount of STD is lower in the water for human consumption because it went through a sedimentation process; however, the sample to be evaluated contains residual organic matter. In the case of the drinking water sample, it complies with the ECA for water that can be made potable with conventional treatment (Ministerio Del Ambiente (MINAM), 2017), as does the untreated water; however, the latter is about to exceed both the ECA and LMP, so it may have health implications. However, the case of TDS can be due to minerals from

Table 1. Physical-chemical parameters of the Viñas river and drinking water

Parameter	Water for human consumption (potable)	Water from the Viñas river (unpotabilized)	ECA water Sub category A2 (DS 004-2017-MINAM)	MPL for water consumption (DS 031-2010-SA)
Temperature (°C)	14	14	Δ3	—
Total dissolved solids (mg/l)	420	997.5	1000	1000
Dissolved oxygen (mg/l)	2	3	≥ 5	—
Conductivity (μs/cm)	420	834	1600	1500
pH	7.5	8.1	5.5–9.0	6.5–8.5
Salinity (%)	0	1.2	—	—
Biochemical oxygen demand (mg/l)	25	58	20	—
Chemical oxygen demand (mg/l)	120	245	10	—

the surface, subsoil or interior of the mountains, which are carried by water and are dangerous due to bioaccumulation (Chávez Araujo et al., 2022); in addition, agriculture can generate eutrophication and decrease oxygen concentrations, with modification of banks and canals, increasing sediments in the water (Ferrer-Sánchez et al., 2024).

Likewise, conductivity (Table 1) also influences the presence of metals in water and is related to the concentration of ions and TDS. For example, in an evaluation of the Lluchca micro-watershed, Amazonas, 39.90 mg/l of TDS and 64.83 μs/cm of conductivity were recorded, and other records showed a direct relationship, the higher the TDS, the higher the conductivity of the water (Chugden, 2021). In addition, a concentration of less than 600 mg/l of TDS is considered good, but if it starts to be higher than 1000 mg/l is significantly unpleasant to the consumer (WHO, 2022), therefore, water for human consumption complies with this indicator, as well as in the study of (Bendezú and Hernández, 2022), while the water of Viñas does not.

In other studies, (Mata et al., 2024), after pH analysis in water systems, there are cases that exceed international technical standards, being a risk to human health. While the samples evaluated in this study do not exceed national standards, as in the study of (Bendezú and Hernández, 2022).

In turn, there is a certain amount of BOD and COD, which are considered indicators of the development of microorganisms, as they may be due to the concentration of nutrients caused by domestic waste and the presence of organic matter generated by urban settlements and their economic processes such as agriculture and livestock (Sivalingam et al., 2024). It is important to point out that, according to Peruvian regulations, there is an ECA for water that is destined to be treated (MINAM, 2017); BOD and COD are considered as indicators of water contamination; however, the town of Viñas still depends on the river for human consumption without prior treatment and, since it is not contemplated in the national MPL, there are risks for the population's health due to the existence of bacterial activity in rivers (Ken-Onukuba et al., 2021).

On the other hand, pH, BOD, COD and DO differ with (Makumbura et al., 2024), with the following results: pH (6.96 ± 0.45), DO (6.34 ± 1.39 mg/l), COD (13.08 ± 11.67 mg/l) and BOD (2.18 ± 1.80 mg/l). In addition, all the parameters in this research exceed standard ranges, while those of this study are within, at least according to Peruvian technical standards.

However, despite the fact that water from the Viñas River is used without prior treatment, which does not guarantee the quality requirements, it can be indicated in this study that they are within the range according to technical standards. On the other hand, a factor that becomes a topic of discussion is population growth, which negatively affects water quality, and solid waste is an aspect to be highlighted (Ramírez, 2022), since in some situations it is disposed of in water sources. At the same time, the type of vegetation cover and land use around rivers affects surface water quality, with livestock being a key factor (Domenech et al., 2022).

Temperature (Figure 2A) in both samples analyzed is significantly the same, as it is closely related to factors such as altitude, latitude and season (Sivalingam et al., 2024). On the contrary, TDS are statistically different in the samples (Figure 2B), due to a water treatment process intended for consumption in one of them; in addition, together with temperature, it has a strong statistical relationship in the presence of Na^{+}, Mg^{2+}, Ca^{2+}, SO_4^{-2}y HCO^{-3} (Velandia, 2018).

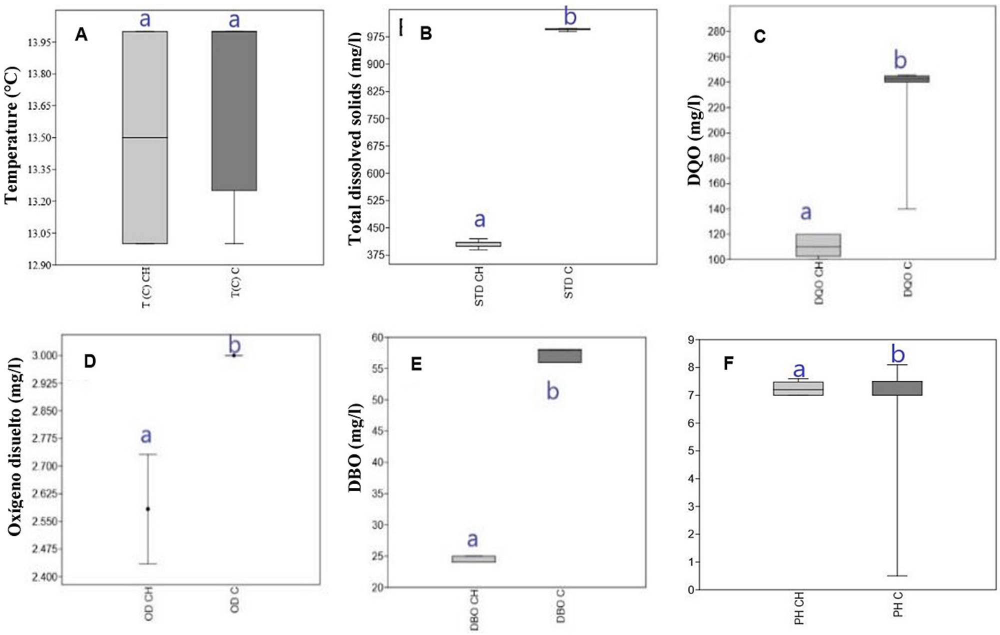

Figure 2. Comparison of temperature, TDS, dissolved oxygen, COD, BOD and pH of water samples, where "CH" is water for human consumption and "C" is water from the Viñas river. Tukey-Anova test is used, 95% confidence level

Figure 2C, 2D and 2E shows the significant differences in the water samples for DO, BOD and COD. In the three cases there are differences due to the existence of treatments that reduce their quantity to ensure the quality of water to be consumed and are within the Peruvian technical standard, however, it is necessary to indicate that they are punctual evaluations in winter, and a spatio-temporal monitoring is not considered where the concentrations can vary significantly, as indicated by (Li et al., 2024), where the DO can decrease at the beginning of the year and increase in summer, while the BOD can fluctuate in the first half of the year with respect to the second, but for COD can be higher in spring and winter and lower in autumn and summer. In addition, COD may increase because of the death of microbial cells that, as they decompose, release dissolved organic carbon, COD increases (Gqomfa et al., 2022), and low levels in river systems indicate good water quality (Edokpayi et al., 2017).

In the case of pH (Figure 2E), the purified water coincides with (Reddy et al., 2023), who obtained a pH value of 7, which is an indicator that the drinking water in the untreated sample is slightly alkaline, but it is necessary to indicate that it can vary throughout the year, being one of the parameters that can undergo the greatest change due to different natural and anthropogenic activities. In the study of (Giao and Ly, 2023), they found that there are no significant differences in the dry season and rainy season; however, alkalinized detergents and cleaning products can increase the pH of water (Aminuddin and Chotib, 2021). In the case of Viñas, they discard detergent containers near water sources, which causes a change in pH.

In addition, an HCA was performed to classify the primary water quality variables evaluated in this study into distinct groups based on similarities. In this way, it is intended to identify whether the variables studied share some type of characteristic as a source or origin. Figure 3 shows a total of three main groups. The first one is formed by conductivity and STD of water for human consumption with BOD and COD of both categories (for human consumption and from the same water source), being the main parameters governing water quality in the study area. This suggests its origin in the waste that prevails despite the existence of some treatment, mainly due to the activity of nearby urban settlements. However, for (Zafar and Kumari, 2024), the water quality index is related to STD, total hardness, total alkalinity and electrical conductivity. The second includes pH and temperature influenced by salinity and DO. These last two indicators are associated with rock weathering (Le et al., 2021), land development, solid waste and fertilization (Cañedo-Argüelles et al., 2013; Kaushal et al., 2018); on the other hand, it can also be associated with microbial activity as indicated by (Luís Fuentes et al., 2009), which

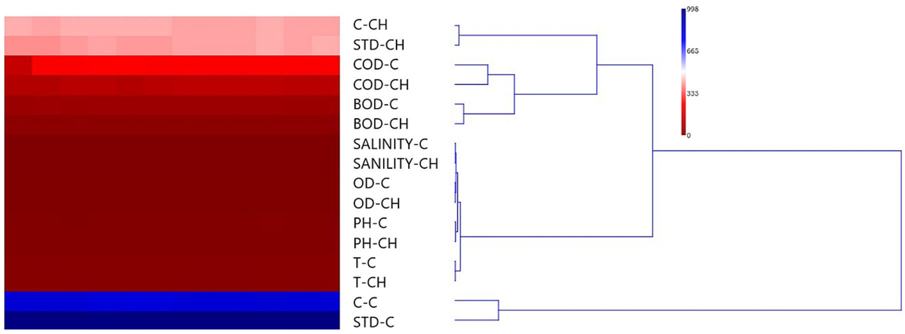

Figure 3. HCA of water quality parameters for human consumption and direct source water to the river. The meanings of each of the variables are as follows: conductivity (C), total TDS, COD, BOD, salinity (S) DO, hydrogen potential (pH) and temperature (T). The symbols added at the end of each variable, CH and C written at the end of the acronyms that represent the monitored variables correspond to a sample of water intended for human consumption (CH) and a sample of water directly from the river (C), respectively

found a high correlation in ponds. The last cluster shows that STD and conductivity are closely related, suggesting a geogenic origin caused by rocks.

Some parameters have high correlations (Figure 4). A very high positive correlation is observed between BOD-CH and C-CH with T-CH, but negative with COD-CH, however, between BODCH and CODCH is a very low negative correlation, which differs from the research of (Li et al., 2024), which found a positive relationship between the latter parameters, being similar to the results with BOD-C and COD-C, as well as the research of (Sidek et al., 2024); this last finding is due to the fact that the first parameters are treated water intended for human consumption, which underwent treatment, and the last two were evaluated directly from the water source. In addition, PH-C has a positive and negative correlation with BDO-C and COD-C, respectively, which differs from (Sidek et al., 2024), where both are positive,

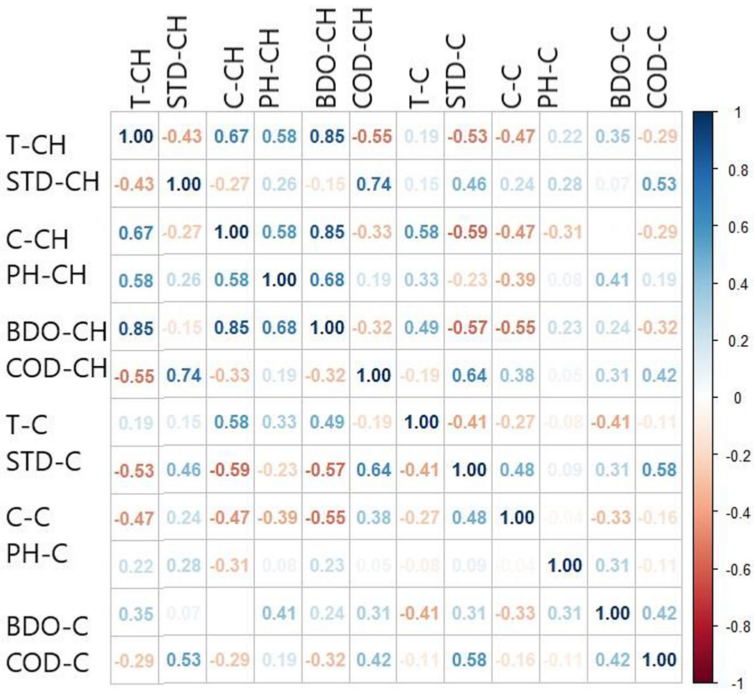

Figure 4. Pearson correlation of water quality parameters for human consumption and direct source water to the river. The meanings of each of the variables are as follows: C, TDS, COD, BOD, S, DO, pH and T. The symbols added at the end of each variable, CH and C written at the end of the acronyms that represent the monitored variables correspond to a sample of water intended for human consumption (CH) and a sample of water directly from the river (C), respectively

but for (Makumbura et al., 2024) they are negative close to zero. On the other hand, C-C has a negative correlation with PH-C and T-C, having similarity to the study of (Siti et al., 2022), in normal flow, without considering storms.

CONCLUSIONS

The parameters evaluated for both treated waters intended for human consumption and direct consumption of the water source (Viñas River), are within the environmental quality standards for water, according to DS 004-2017-MINAM. However, there are parameters that are at the limit of these standards, mainly untreated water, thus being a danger to the health of the population of Viñas that directly uses water from the river, because of ignorance for consuming untreated water. Therefore, it is necessary to improve the sanitation and water distribution systems in the locality, as well as to raise awareness and sensitize the community about the dangers of consuming water directly from the river.

On the other hand, the study reaffirms the need to make the water potable before consumption, as there are significant differences in the parameters evaluated. In addition, periodic monitoring of conductivity, STD, BOD and COD should be carried out before and after water treatment, since they have an influence on water quality in the Viñas River.

REFERENCES

1. Addisie, M.B. (2022). Evaluating drinking water quality using water quality parameters and esthetic attributes. *Air, Soil and Water Research, 15*. https://doi.org/10.1177/11786221221075005
2. Aguilar Aguilar, A. C., & Obando - Díaz, F. F. (2020). Aprendizaje automático para la predicción de calidad de agua potable. *Ingeniare, 28*. https://doi.org/10.18041/1909-2458/ingeniare.28.6215
3. Aminuddin, M., & Chotib. (2021). Analysis of the impact of urban development on river water quality case study of the Pesanggrahan River. ICSDEMS 2019 - Proceedings of *the International Conference on Sustainable Design, Engineering, Management and Sciences*. https://doi.org/10.1007/978-981-15-3765-3_12
4. Castro, A., Davila, C., Laura, W., Cubas, F., Avalos, G., Ocaña, C.L., Villena, D., Valdez, M., Urbiola, J., Trebejo, I., Menis, L. & Marín, D. (2021). *Climas del Perú - Mapa de Clasificación Climática Nacional.* In Servicio Nacional de Meteorología e Hidrología del Perú. https://www.senamhi.gob.pe/?p=mapa-climatico-del-peru
5. Zosimo, A., Gaspar, B.Ñ. (2021). *Estudio De Acumulación Del Plomo, Cadmio Y CromoEn Vegetales Autoctonas En Lodos Ribereños DelRío Opamayo Lircay-Angaraes-Huancavelica.* https://orcid.org/0000-0001-8209-989X
6. Azarte, J.A. (2016). Caracterización hidrológica del distrito de pampas y santiago de tucuma – departamento huancavelica *SENAMHI*, 301.
7. Bendezú, M.A.B., & Hernández, C.V.B. (2022). Evaluación de la idoneidad de la calidad del agua potable utilizando el índice de calidad en el distrito de subtanjalla, Perú. *South Florida Journal of Development, 3*(1). https://doi.org/10.46932/sfjdv3n1-027
8. Cáceres, R. (2015). Manejo de la producción lechera en dos sistemas de utilización de pasturas en la Sierra Central. 1, 188.
9. Cañedo-Argüelles, M., Kefford, B. J., Piscart, C., Prat, N., Schäfer, R.B., & Schulz, C.J. (2013). Salinisation of rivers: An urgent ecological issue. In *Environmental Pollution 173*. https://doi.org/10.1016/j.envpol.2012.10.011
10. Cerrón, R.M., Figueroa, O.L., Leyton, A.A., Gilberto, & Sánchez, G. (2018). Fitorremediación con Maíz (*Zea mays* L.) y compost de Stevia en suelos degradados por contaminación con metales pesados. *Scientia Agropecuaria, 9*(4).
11. Ramírez, CC. (2022). Evaluación del estado ambiental del lago en el Parque Metropolitano La Sabana, San José, Costa Rica, para la implementación de medidas de rehabilitación ecológica. *Biocenosis, 33*(2). https://doi.org/10.22458/rb.v33i2.4544
12. Araujo, E.R.C., Astocasa, L.L.H., Huiza, Y.Y, Rojas, R.A. (2022). Determinación de la calidad del agua de consumo humano mediante parámetros físicos, químicos y microbiológicos en la ciudad de Huancavelica. *Revista Científica Siglo XXI, 2*(2). https://doi.org/10.54943/rcsxxi.v2i2.191
13. Ramírez, L.C.C., Mosquera, Y.N.S., Peña, D.A.L., Casas, M.A.C. (2021). Evaluación de la calidad del agua de la vereda Río Suárez de Puente Nacional, Santander. *Nova, 19*(37). https://doi.org/10.22490/24629448.5497
14. Edokpayi, J. N., Odiyo, J. O., & Durowoju, O. S. (2017). Impact of wastewater on surface water quality in developing countries: A case study of South Africa. In Water Quality. https://doi.org/10.5772/66561
15. Domenech, R.Y.E., Infante Mata, D.M., Alfaro, J.R.G., Ramírez Marcial, N., Ortiz Arrona, C.I., Barba Macías, E. (2022). Evaluación de la calidad del agua y de la ribera en la cuenca del río margaritas,

Chiapas, México. *Revista Internacional de Contaminación Ambiental, 38*.

16. Ferrer-Sánchez, Y., Ramírez Castillo, A.J., Plasencia-Vázquez, A.H., & Abasolo-Pacheco, F. (2024). Impact of land use and landscape fragmentation on water quality of the Teaone river in Ecuador. *Revista Internacional de Contaminacion Ambiental, 40*(January), 15–36. https://doi.org/10.20937/RICA.54900
17. Gqomfa, B., Maphanga, T., & Shale, K. (2022). The impact of informal settlement on water quality of Diep River in Dunoon. *Sustainable Water Resources Management, 8*(1). https://doi.org/10.1007/s40899-022-00629-w
18. Kaushal, S.S., Likens, G.E., Pace, M.L., Utz, R.M., Haq, S., Gorman, J., Grese, M. (2018). Freshwater salinization syndrome on a continental scale. *Proceedings of the National Academy of Sciences of the United States of America, 115*(4). https://doi.org/10.1073/pnas.1711234115
19. Ken-Onukuba, D., Okeke, O.C., Amadi, C.C., Akaolisa, C.C.Z., Okonkwo, S.I., Offoh, J., Nwachukwu, H.G. (2021). Water quality assessment of ekulu and Asata Rivers in Enugu Area, Southeastern Nigeria, using physico-chemical and bacteriological parameters. *Journal of Environment and Earth Science*. https://doi.org/10.7176/jees/11-4-07
20. Le, T.D.H., Schreiner, V.C., Kattwinkel, M., Schäfer, R.B. (2021). Invertebrate turnover along gradients of anthropogenic salinisation in rivers of two German regions. *Science of the Total Environment, 753*. https://doi.org/10.1016/j.scitotenv.2020.141986
21. Li, K., Yang, Q., & Li, X. (2024). An analysis of the spatiotemporal variability of key water quality parameters in China. *Hydrology, 11*(9), 135. https://doi.org/10.3390/hydrology11090135
22. López Velandia, C.C. (2018). Análisis de las características fisicoquímicas del agua subterránea de la cuenca del río chicú, Colombia, usando indicadores hidroquímicos y estadística multivariante. *Ingeniería y Ciencia, 14*(28). https://doi.org/10.17230/ingciencia.14.28.2
23. Luís Fuentes, J.Z., Patiño, R., López, P.G., & López, J.C. (2009). Densidad de bacterias coliformes y su relación con algunas variables físicoquímicas en aguas de la laguna los Mártires, isla de Margarita, Venezuela. SABER. *Revista Multidisciplinaria Del Consejo de Investigación de La Universidad de Oriente, 21*(2).
24. Makumbura, R.K., Mampitiya, L., Rathnayake, N., Meddage, D.P.P., Henna, S., Dang, T.L., Hoshino, Y., & Rathnayake, U. (2024). Advancing water quality assessment and prediction using machine learning models, coupled with explainable artificial intelligence (XAI) techniques like shapley additive explanations (SHAP) for interpreting the black-box nature. *Results in Engineering, 23*(September), 102831. https://doi.org/10.1016/j.rineng.2024.102831
25. MINAM. (2017). *Aprueban Estandares de Calidad Ambiental (ECA) para Agua y establecen disposiciones complementarias.* El Peruano, 6–9. http://www.minam.gob.pe/wp-content/uploads/2017/06/DS-004-2017-MINAM.pdf
26. Ramos Mancheno, A.D. de J. (2024). Efectos del consumo de agua contaminada en la calidad de vida de las personas. *Polo Del Conocimiento, 9*(1), 614–632. https://doi.org/10.23857/pc.v9i1.6396
27. Reddy, A.N., Tholkapiyan, M., & Vijayan, S. (2023). Comparative analysis of water quality parameters of poondi reservoir with drinking water quality standards for sustainable development. *SSRG International Journal of Civil Engineering, 10*(5). https://doi.org/10.14445/23488352/IJCE-V10I5P103
28. Rojas Vargas, R.P., and Rojas Vizcarra, L.N. (2023). Caracterización y determinación de la calidad de agua superficial. *Revista de Investigaciones, 12*(1). https://doi.org/10.26788/ri.v12i1.4014
29. Ruiz Chugden, S.M. (2021). Calidad de agua de la microcuenca Lluchca, Amazonas, Perú. Revista Científica UNTRM: *Ciencias Naturales e Ingeniería, 3*(3). https://doi.org/10.25127/ucni.v3i3.631
30. Sidek, L.M., Mohiyaden, H.A., Marufuzzaman, M., Noh, N.S.M., Heddam, S., Ehteram, M., Kisi, O., & Sammen, S.S. (2024). Developing an ensembled machine learning model for predicting water quality index in Johor River Basin. *Environmental Sciences Europe, 36*(1). https://doi.org/10.1186/s12302-024-00897-7
31. Siti, N., Fatimah, N. S., Sofiyan, S.M., Roslan, M.K.M., & Yan-Fang, S. (2022). Physicochemical assessment of upper catchment within the ayer hitam forest reserve, peninsular Malaysia. *Journal of Sustainability Science and Management, 17*(1). https://doi.org/10.46754/jssm.2022.01.009
32. Sivalingam, K.M., Choramo, I.S., & Chutulo, E.C. (2024). Bacteriological quality and physicochemical analysis of the Kalte River at Wolaita Sodo Town, southern Ethiopia. *BMC Research Notes, 17*(1), 1–8. https://doi.org/10.1186/s13104-024-06854-0
33. Syeed, M.M.M., Hossain, M.S., Karim, M.R., Uddin, M.F., Hasan, M., Khan, R.H. (2023). Surface water quality profiling using the water quality index, pollution index and statistical methods: A critical review. In *Environmental and Sustainability Indicators 18*. https://doi.org/10.1016/j.indic.2023.100247
34. Thanh Giao, N., & Thao Ly, N.H. (2023). Influence of urban and residential areas on surface water quality in the Vietnamese Mekong Delta Coastal

Province. *International Journal of Environmental Science and Development, 14*(4). https://doi.org/10.18178/ijesd.2023.14.4.1439

35. Toniolo, B.P., Simonetti, V.C., Lourenço, R.W., & Da Cunha e Silva, D.C. (2024). Analysis of anthropic interference in the quality of surface water in the Cotia River Basin (SP). *Revista de Gestao Ambiental e Sustentabilidade, 13*(1), 1–35. https://doi.org/10.5585/2024.23004
36. WHO. (2022). Saneamiento. https://www.who.int/es/news-room/fact-sheets/detail/sanitation#:~:text=Un saneamiento deficiente va asociado,la resistencia a los antimicrobianos
37. Zafar, M.M., & Kumari, A. (2024). Spatio-temporal evaluation of the impact of anthropogenic stressors on physico-chemical characteristics and water quality of the River Ganga using GIS-based approach in the middle Gangetic Plains at Patna, Bihar, India. *Water Science and Technology, 89*(5). https://doi.org/10.2166/wst.2024.053