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Risk of clogging in localized irrigation systems caused by irrigation water

Riesgo de obstrucción de sistemas de riego localizado por aguas de riego

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ABSTRACT: This study aimed to assess the quality of groundwater from the Javita River basin in the province of Santa Elena (Ecuador), with an emphasis on hardness and the Langelier Saturation Index (LSI), which are determining parameters in the formation of scale and the obstruction of emitters in localized irrigation systems. The research was carried out through three sampling campaigns conducted in 2024 at 25 wells distributed throughout the agricultural area of the basin, where water samples were collected in accordance with Ecuadorian technical standards and analyzed in the laboratory for variables such as pH, electrical conductivity, cation concentration (Ca^{2+}, Mg^{2+}, Na^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}) were analyzed in the laboratory, from which the total hardness and LSI were calculated. The results showed that more than 70% of the sources have water classified as hard or very hard, with hardness values above 500 mg/L of $CaCO_3$ in several cases, while LSI values ranged from 0.20 to 1.35, with an average of 0.60, indicating calcium carbonate supersaturation and a marked tendency to scaling. It is concluded that the combination of hard water and positive LSI represents a high risk of clogging drippers. Preventive measures such as pH correction through acid injection, the use of scale inhibitors, and systematic monitoring of physicochemical parameters are recommended to optimize the sustainability of localized irrigation systems. and pipes, reducing irrigation efficiency and uniformity, and compromising agricultural productivity.
Keywords: Langelier Saturation Index, Water Hardness, Localized Irrigation Systems, Calcium Carbonate Scaling, Emitter Clogging.

RESUMEN: Se evaluó la calidad del agua subterránea proveniente de la cuenca del río Javita, en la provincia de Santa Elena (Ecuador), con énfasis en la dureza e Índice de Saturación de Langelier (LSI), parámetros determinantes en la formación de incrustaciones y en la obstrucción de emisores en sistemas de riego localizado. Se desarrollaron tres campañas de muestreo realizadas en 2024 a 25 pozos distribuidos en la zona agrícola de la cuenca, donde se recolectaron muestras de agua siguiendo las normas técnicas ecuatorianas, analizándose en laboratorio variables como pH, conductividad eléctrica, concentración de cationes (Ca^{2+}, Mg^{2+}, Na^{+}) y aniones (CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}), a partir de los cuales se calcularon la dureza total y el LSI. Los resultados evidenciaron que más del 70 % de las fuentes presentan aguas clasificadas como duras o muy duras, con valores de dureza superiores a 500 mg/L de $CaCO_3$ en varios casos, mientras que los valores del LSI oscilaron entre 0,20 y 1,35, con un promedio de 0,60, lo que indica una sobresaturación de carbonato de calcio y una marcada tendencia a la incrustación. Se concluye que la combinación de aguas duras y LSI positivo representa un riesgo elevado de obstrucción de goteros y tuberías, reduciendo la eficiencia y uniformidad de riego, y comprometiendo la productividad agrícola. Se recomienda implementar medidas preventivas como la corrección de pH mediante inyección de ácidos, el uso de inhibidores de incrustaciones y el monitoreo sistemático de los parámetros fisicoquímicos para optimizar la sostenibilidad de los sistemas de riego localizado.
Palabras clave: Índice de Saturación de Langelier, Dureza del agua, sistemas de riego localizado, incrustaciones de carbonato de calcio, obstrucción de emisores.

INTRODUCTION

Irrigation water quality conditions the viability and sustainability of agricultural production. In its natural state, water contains soluble salts which, at adequate levels, are essential for crop development; however, high concentrations can be detrimental to plants and soil health. Efficient water-resource management-considering both surface and groundwater-is therefore indispensable, particularly for agriculture, a sector with high water demand.

In semi-arid regions where surface water is limited, groundwater plays a central role in meeting crop water requirements (Benmarce et al., 2024). Assessing water suitability for agricultural use is crucial for system sustainability. Key suitability parameters include salinity (commonly evaluated by electrical conductivity, EC), sodicity risk (Sodium Adsorption Ratio, SAR), residual sodium carbonate (RSC), and potential toxicity from specific ions (e.g., chloride, boron, sodium (Jadhav et al., 2025).

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Additional essential indicators include pH, total dissolved solids (TDS), hardness, sodium percentage (%Na), Magnesium Adsorption Ratio (MAR), Kelly's Ratio (KR), Effective Salinity (ES), Potential Salinity (PS), and the Langelier Saturation Index (LSI) (Anyango et al., 2024; Mirzabeygi et al., 2016; Ouhakki et al., 2024).

Developed by Wilfred F. Langelier in the 1930s (Langelier, 1936), LSI is an analytical tool that evaluates $CaCO_3$ saturation equilibrium in water.

Water hardness-defined by concentrations of divalent calcium (Ca^{2+}) and magnesium (Mg^{2+}), expressed as $CaCO_3$ equivalents-is a determining factor in precipitate and scale formation. LSI, in turn, is a predictive index that assesses the tendency of water to form calcareous deposits or to be corrosive (Barceló-Quintal et al., 2023; Shankar, 2014). Table 1 shows a commonly used hardness classification (Almeida, 2011).

Table 1. Water hardness classification

$CaCO_3$ content (mg L^{-1})	Classification
< 70	Soft
70-140	Moderately soft
140-220	Slightly hard
220-320	Moderately hard
320-540	Hard
> 540	Very hard

LSI is used to anticipate scaling or corrosion in irrigation infrastructure-such as emitter plugging in localized systems-and pipeline degradation, because it objectively indicates whether water tends to be corrosive, at equilibrium, or scale-forming with respect to $CaCO_3$ saturation.

Emitter clogging is the primary maintenance challenge in localized irrigation, frequently caused by chemical deposits-particularly Ca and Mg precipitates induced by evaporation (Dehghanisanij et al., 2025). High pH and warm ambient temperatures promote $CaCO_3$ precipitation, a low-solubility salt that can seriously affect system efficiency and durability (Lopes Muniz et al., 2023).

Drip emitters, with narrow flow passages (~1 mm²), are especially susceptible (Lopes Muniz et al., 2023). A positive LSI is a strong indicator of $CaCO_3$ deposition and, consequently, emitter clogging (Mirzaei et al., 2011). Importantly, $CaCO_3$ clogging is driven by a complex interplay of factors, not LSI alone.

A positive LSI indicates supersaturation and a tendency to scale; a negative LSI indicates undersaturation and a tendency to corrosion; LSI ≈ 0 denotes equilibrium (Abbasnia et al., 2019; Almeida, 2011; Ayers & Westcot, 1985; Balkrishna et al., 2024; Faraji & Shahryari, 2024; Hasag Moran et al., 2022; Mirzabeygi et al., 2016).

Positive LSI effects are exacerbated by elevated pH and temperature (Lopes Muniz et al., 2023). Fertilizer compatibility-especially phosphates-can further react with Ca in water to form precipitates, increasing clogging risk where Ca is high (Mirzaei et al., 2011). Effective LSI management thus requires an integrated strategy spanning water chemistry, climatic conditions, and agronomic practices (e.g., fertigation methods).

Proactive LSI monitoring protects irrigation infrastructure from costly, irreversible damage maintaining operational efficiency and water-application uniformity-critical to crop productivity and water conservation.

Interpreting LSI values is vital for decision-making (Benmarce et al., 2024):

- LSI < 0 (negative): undersaturated with $CaCO_3$; corrosive tendency. Values ≤ −0.31 are often considered aggressive.
- LSI = 0: equilibrium-no significant tendency to dissolve or precipitate $CaCO_3$; generally ideal for most irrigation systems.
- LSI > 0 (positive): supersaturated with $CaCO_3$; scale-forming tendency. Values ≥ +0.31 indicate a strong precipitation tendency.

Acceptable ranges near zero (e.g., −0.3 to +0.3, or up to +0.5) are often preferred, with a slight bias toward mild scaling rather than corrosion, since corrosion causes permanent damage, while mild scale is typically manageable (Orenda, 2022). Corrosion and scaling-predicted by LSI-directly affect the performance and service life of irrigation systems. Beyond physical damage, flow reduction and leaks lead to non-uniform water distribution, negatively impacting yield, water-use efficiency, and potentially causing localized soil salinization-underscoring LSI's relevance for productivity and sustainability.

Although LSI focuses on infrastructure, $CaCO_3$ precipitation in irrigation water can indirectly affect soil chemistry by lowering soluble Ca in soil solution and raising the Na:Ca ratio, impairing drainage and aeration and degrading soil structure. Irrigation with sodic waters can increase soil pH, EC, and soluble Na^+ while decreasing or not altering soluble Ca^{2+} and Mg^{2+} (Peker et al., 2024).

Adjusting irrigation water pH by acid injection directly prevents scaling/corrosion, lowering maintenance costs, enhancing system efficiency, and extending service life-an essential element of sustainable agricultural water management.

Based on the above, the objective of this work was to assess the clogging risk in localized irrigation systems supplied by wells within the Javita River basin, Santa Elena, Ecuador.

MATERIALS AND METHODS

The study area (Figure 1) is the Javita River basin, located in the parish of Colonche, Santa Elena Canton, Santa Elena Province. It is bounded by the Rio Viejo basin to the north; the Grande, Zapotal, and Daular basins to the south; the Chongón-Colonche range to the east; and the Pacific Ocean to the west.

Figure 1. Location of the Javita River basin, project area of interest.

The Javita basin covers 81,297 ha (21.5% of the province), includes 15 communities, and has a dry climate (Velasco Andrade & Tamayo Ortiz, 2020). As a coastal-fringe basin on the Pacific slope, it contains small, isolated, poor aquifers (Rodríguez Ayala, 2014). It belongs to the Zapotal hydrographic system (code 1244).

Relief is undulating and of low elevation. The eastern area near the Chongón-Colonche range is classified as tropical megathermal dry, while the coastal zone is tropical megathermal semi-arid. UTM (WGS-84, Zone 17S) planar coordinates for the SW and NE corners are 525000, 9760000 and 580000, 9800000, respectively.

The Javita River rises in the Chongón-Colonche Protected Forest and flows west-east; its flow is intermittent, occurring only during the rainy season. Native vegetation has been indiscriminately cleared, mainly for charcoal. Three sampling campaigns (June, August, and December 2024) were performed at 25 wells in the mid-basin agricultural zone (Figure 2).

Sampling followed Ecuadorian Standard NTE INEN 2176:2013 (INEN, 2013b), One-liter amber glass bottles were used. Handling and preservation followed NTE INEN 2169:2013 (INEN, 2013a). Laboratory determinations and techniques are summarized in Table 2.

Table 2. Analytical procedures used (INIAP laboratory)

Determination	Technique
pH	Potentiometry
Electrical conductivity (EC)	Conductimetry
Sodium (Na^+)	
Calcium (Ca^{2+})	Atomic absorption spectrophotometry
Magnesium (Mg^{2+})	
Sulfate (SO_4^{2-})	Turbidimetry
Carbonate (CO_3^{2-})	
Bicarbonate (HCO_3^-)	Volumetry
Chloride (Cl^-)	

Total hardness was obtained by summing calcium and magnesium hardness (standard approach).

$$D = 2,5[Ca] + 4,1[Mg]$$

Where D = hardness (mg L^{-1} as $CaCO_3$); [Ca] and [Mg] are concentrations in mg L^{-1}.

LSI was determined following Ayers & Westcot (1985), Table 25, p. 103, using Ca^{2+}, Mg^{2+}, Na^+, CO_3^{2-}, and HCO_3^- (all in meq L^{-1}) to compute saturation pH (pHs).

$$pH_s = (pK'_2 - pK'_s) + p\left(Ca^{2+}\right) + p(Alk)$$

Were:
$(pK'_2 - pK'_s) = Ca + Mg + Na$ in meq/L.
$p\left(Ca^{2+}\right) = Ca$ in meq/L.
$p(Alk) = CO_3 + HCO_3$ in meq/L.

Finally, $LSI = pHa - pHs$ where pH_a is the measured water pH.

Table 3 lists the average values (three campaigns) of variables used to compute hardness and LSI.

RESULTS AND DISCUSSION

Table 4 presents water hardness values and classification for the 25 wells. Classification follows Almeida (2011).

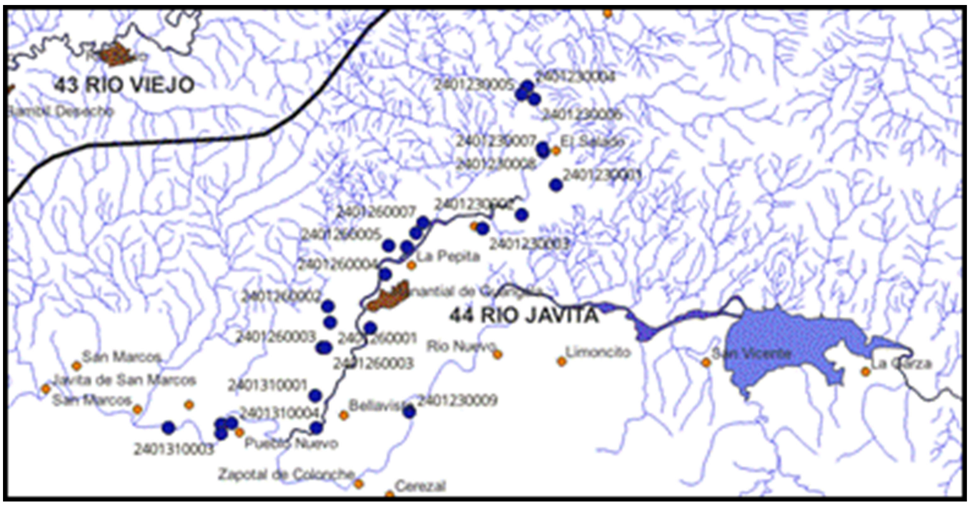

Figure 2. Location of sampled wells.

Table 3. Water characteristics in the Javita basin (average of 2024 campaigns) (concentrations in meq L^{-1} unless noted; pH unitless)

Point	pHa	Ca	Mg	Na	CO_3	HCO_3
		meq.L^{-1}				
P-01	7.70	12.34	5.34	22.15	0.23	3.02
P-02	7.90	8.46	1.88	5.78	0.50	3.20
P-03	8.05	12.23	7.37	33.98	0.24	2.34
P-04	7.70	6.49	1.75	4.66	0.25	1.77
P-05	7.50	11.10	4.46	14.08	0.40	2.71
P-06	7.80	6.93	1.80	4.59	0.40	1.68
P-07	7.90	10.49	2.86	15.48	0.46	2.29
P-08	7.93	13.77	4.05	8.52	0.33	3.00
P-09	7.87	12.57	3.83	6.84	0.27	2.66
P-10	7.80	14.52	4.39	6.98	0.23	2.63
P-11	7.50	20.21	7.61	11.61	0.07	3.02
P-12	7.60	13.65	4.84	9.86	0.30	2.72
P-13	8,05	6,03	1,88	12,26	0,28	2,26
P-14	7,90	5,22	1,33	4,56	0,46	2,00
P-15	8.03	6.04	1.78	5.36	0.29	2.04
P-16	8.23	5.26	1.13	3.43	0.37	1.76
P-17	8.20	4.34	1.46	3.30	0.28	1.88
P-18	8.25	4.68	1.32	2.96	0.29	1.80
P-19	7.93	9.35	2.43	5.85	0.40	2.42
P-20	8.06	5.18	1.04	3.33	0.35	1.57
P-21	8.17	4.86	1.66	3.75	0.31	1.91
P-22	8.14	3.96	1.42	4.59	0.29	1.78
P-23	8.14	4.47	1.17	3.30	0.35	1.57
P-24	8.19	4.48	1.08	3.21	0.36	1.51
P-25	8.25	15.95	5.70	27.16	0.89	3.86

Source: authors, based on laboratory results.

Table 4. Hardness of waters from 25 wells (Aug-Dec 2024), Javita basin

Point	Hardness (mg L^{-1} as $CaCO_3$)	Classification
P-01	884.53	Very hard
P-02	516.87	Hard
P-03	980.64	Very hard
P-04	412.06	Hard
P-05	778.79	Very hard
P-06	436.42	Hard
P-07	667.39	Very hard
P-08	892.86	Very hard
P-09	819.77	Very hard
P-10	945.89	Very hard
P-11	1308.18	Very hard
P-12	924.94	Very hard
P-13	395.16	Hard
P-14	327.33	Hard
P-15	391.31	Hard
P-16	319.56	Moderately hard
P-17	290.51	Moderately hard
P-18	299.52	Moderately hard
P-19	589.11	Very hard
P-20	310.75	Moderately hard
P-21	326.25	Hard
P-22	268.62	Moderately hard
P-23	281.63	Moderately hard
P-24	277.73	Moderately hard
P-25	1082.97	Very hard

More than 70% of sources were hard or very hard, consistent with the hydrogeological characterization of the Javita and Zapotal basins (Rodríguez Ayala, 2014). This is likely related to geology: part of the basin overlies the Javita Member (calcareous remnants of the San Eduardo Formation-coarse-grained calcarenites interbedded with conglomerates/breccias) (Cornejo Martínez, 2006) and alluvial deposits dominated by sandstones (Instituto Espacial Ecuatoriano & Ministerio de Agricultura, Ganadería, Acuacultura y Pesca, 2012).

Figure 3 shows LSI values (0.20-1.35). This variability is expected and reported elsewhere; it can reflect well depth, aquifer heterogeneity, recharge rates, and local infiltration. The outlier at P-25 (1.35) suggests stronger water-rock interaction or lower recharge, concentrating minerals.

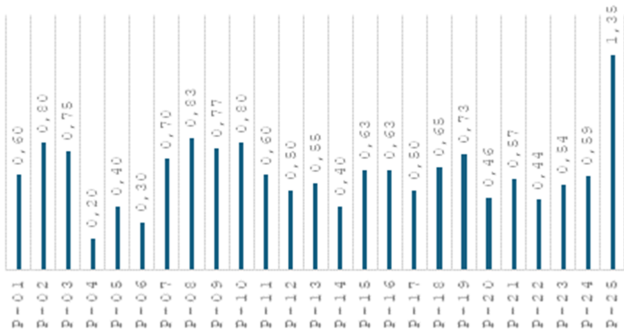

Figure 3. Langelier Saturation Index values for sampled waters.

These waters are supersaturated with $CaCO_3$, indicating high scale potential-especially since >90% of sources exceeded +0.31(Benmarce et al., 2024). Other Ecuadorian studies report positive LSI in wells-particularly in coastal/calcareous substrates-attributed to aquifer mineralogy and low rainfall recharge (De la Torre Ordoñez, 2018; Montenegro Rodríguez, 2013).

By contrast, García-Ávila et al. (2018) found predominantly negative LSI (−1.22 to −1.68) in Azogues' drinking water system (corrosive trend). The Javita wells show the opposite pattern: positive LSI and higher scaling risk-implying differences in water chemistry (pH, calcium hardness, alkalinity, TDS) between regions. In Tamil Nadu, LSI often exceeds zero in irrigation aquifers and correlates with high salinity and alkalinity (Anyango et al., 2024).

In the U.S., large-scale USGS assessments show spatially mixed patterns-some regions corrosive (negative LSI), others neutral or scaling (positive LSI); about one-third of samples were potentially corrosive by LSI (Belitz et al., 2016). The Javita data align with hard/supersaturated waters (positive LSI). Padilla González et al. (2022) reported LSI from slightly negative to positive (−0.005 to 0.76) and confirmed $CaCO_3$ scale by SEM/XRD-consistent with our interpretation that positive LSI associates with observable carbonate deposits.

CONCLUSIONS

The interplay between water hardness and LSI is fundamental in evaluating irrigation water quality.

This relationship-expressed mathematically in LSI and manifested physically as scaling or corrosion-largely determines the technical and economic viability of irrigation systems.

Hardness (divalent cation concentration) directly influences saturation pH and thus LSI. Managing both parameters jointly is essential to optimize hydraulic performance and ensure adequate crop nutrition.

Measured LSI values in Javita basin wells were all positive (mean 0.60), indicating a predominant scaling tendency of groundwater in the area. In modern agriculture-where water-use efficiency is imperative-proper monitoring and management of these parameters are indispensable for sustainable irrigation.

System design and management should account for scaling potential to avoid blockages and reduce maintenance costs. We recommend implementing anti-scaling measures (softening, inhibitors, pH control) and routine monitoring of physicochemical parameters to detect seasonal variability.

REFERENCES

ABBASNIA, A., YOUSEFI, N., MAHVI, A. H., NABIZADEH, R., RADFARD, M., YOUSEFI, M., ALIMOHAMMADI, M.: Evaluation of groundwater quality using water quality index and its suitability for assessing water for drinking and irrigation purposes: Case study of Sistan and Baluchistan province (Iran). *Human and Ecological Risk Assessment: An International Journal*, *25*(4), 2019, 988-1005. https://doi.org/10.1080/10807039.2018.1458596

ALMEIDA, O. Á. DE.: *Qualidade da água de irrigação*. Embrapa Mandioca E Fruticultura Tropical, 2011.

ANYANGO, G. W., BHOWMICK, G. D., SAHOO BHATTACHARYA, N.: A critical review of irrigation water quality index and water quality management practices in micro-irrigation for efficient policy making. *Desalination and Water Treatment*, *318*, 100304, 2024, https://doi.org/10.1016/j.dwt.2024.100304

AYERS, R. S., WESTCOT, D. W. (with Food and Agriculture Organization of the United Nations).: *Water quality for agriculture*. Food and Agriculture Organization of the United Nations, 1985.

BALKRISHNA, A., GHOSH, S., NAGOSE, A., JOSHI, D., SINGH, S., KUMUD, SAXENA, A., TANEJA, S., ARYA, V.: *Evaluation of Suitability Analysis of Gangetic Water from Upper, Middle, And Lower Ganga Rivers* (p. 2024.02.28.582642). bioRxiv.,2024, https://doi.org/10.1101/2024.02.28.582642

BARCELÓ-QUINTAL, I., ESPEJO-MONTES, F., GÓMEZ-NÚÑEZ, J., GÓMEZ-SALAZAR, S., SOLÍS-CORREA, H.: DETERMINACIÓN DEL ÍNDICE DE LANGELIER DEL AGUA DEL ARROYO RÍO PUERTA GRANDE EN LA CDMX. *Ingeniería Revista Académica de la Facultad de Ingeniería Universidad Autónoma de Yucatán*, *27*(3), 63-84. 2023.

BELITZ, K., JURGENS, B. C., JOHNSON, T. D.: Potential corrosivity of untreated groundwater in the United States. En *Scientific Investigations Report* (Nos. 2016-5092). U.S. Geological Survey, 2016, https://doi.org/10.3133/sir20165092

BENMARCE, K., ZIGHMI, K., HADJI, R., HAMED, Y., GENTILUCCI, M., BARBIERI, M., PAMBIANCHI, G.: Integration of GIS and Water-Quality Index for Preliminary Assessment of Groundwater Suitability for Human Consumption and Irrigation in Semi-Arid Region. *Hydrology*, *11*(5),2024, 71. https://doi.org/10.3390/hydrology11050071

CORNEJO-MARTÍNEZ, M.: *Polo de promoción minero ambiental en el contexto de la agenda local 21: Península de Santa Elena (Ecuador)*. CETEM/MCT/CNPq/UIA, 2006.

DE LA TORRE-ORDOÑEZ, D. A.: *DETERMINACION DEL COEFICIENTE DE TRANSFERENCIA DE MASA EN LECHOS DE CONTACTO DE CARBONATO DE CALCIO PARA LA ESTABILIZACIÓN QUIMICA DE AGUAS CORROSIVAS* [Tesis de Grado, Escuela Politécnica Nacional], 2018 https://bibdigital.epn.edu.ec/bitstream/15000/19447/1/CD-8841.pdf

DEHGHANISANIJ, H., MIRLATIFI, S. M., EMAMI, S., RAJABZADEH, T.: Reducing the clogging of emitters in drip irrigation systems using acid washing and ultrasonic technology. *Scientific Reports*, *15*(1), 12499, 2025, https://doi.org/10.1038/s41598-025-95915-w

FARAJI, H., & SHAHRYARI, A.: Assessment of groundwater quality for drinking, irrigation, and industrial purposes using water quality indices and GIS technique in Gorgan aquifer. *Desalination and Water Treatment*, *320*, 100821, 2024, https://doi.org/10.1016/j.dwt.2024.100821

GARCÍA-ÁVILA, F., RAMOS-FERNÁNDEZ, L., ZHINDÓN-ARÉVALO, C.: Estimation of corrosive and scaling trend in drinking water systems in the city of Azogues, Ecuador. *Ambiente e Agua - An Interdisciplinary Journal of Applied Science*, *13*(5), 1, 2018, https://doi.org/10.4136/ambi-agua.2237

HASAG MORAN, E. S., COBOS MORA, F., LOMBEIDA GARCIA, E., UVIDIA, M.: Evaluación De La Calidad De Agua En El Sistema De Riego Cedege, Babahoyo Ecuador. *Journal of Science and Research*, *7,* 2022 (CININGEC II), Article CININGEC II.

INEN: *Agua. Calidad Del Agua. Muestreo. Manejo Y Conservación De Muestras* (Norma Técnica Ecuatoriana No. Nte Inen 2169:2013; Versión Primera revisión), 2013a.

INEN: *AGUA. Calidad Del Agua. Muestreo. Técnicas De Muestreo* (Norma Técnica Ecuatoriana No. NTE INEN 2176:2013; Versión Primera revisión), 2013b.

Instituto Espacial Ecuatoriano, Ministerio de Agricultura, Ganadería, Acuacultura y Pesca: *Memoria Técnica: Proyecto Generación de Geoinformación para la gestión del territorio a nivel nacional, escala 1:25000. Cantón Santa Elena* [Geopedología]. IEE-MAGAP, 2012.

JADHAV, A. B., V.N.NALE, D.S.POTDAR: Consequences of Irrigation Water and Soil Quality: An Overview. *Asian Journal of Soil Science and Plant Nutrition*, *11*(1), 435-453, 2025, https://doi.org/10.9734/ajsspn/2025/v11i1494

LANGELIER, W. F.: The Analytical Control of Anti-Corrosion Water Treatment. *Journal AWWA*, *28*(10), 1500-152, 1936, https://doi.org/10.1002/j.1551-8833.1936.tb13785.x

LOPES-MUNIZ, G., GONÇALVES-OLIVEIRA, A. L., Benedito, M. G., Duarte Cano, N., Pires De Camargo, A., & Da Silva, A. J.: Risk Evaluation of Chemical Clogging of Irrigation Emitters via Geostatistics and Multivariate Analysis in the Northern Region of Minas Gerais, Brazil. *Water*, *15*(4), 790, 2023, https://doi.org/10.3390/w15040790

MIRZABEYGI, M., NAJI, M., YOUSEFI, N., SHAMS, M., BIGLARI, H., MAHVI, A. H.: Evaluation of corrosion and scaling tendency indices in water distribution system: A case study of Torbat Heydariye, Iran. *Desalination and Water Treatment*, *57*(54), 25918-25926, 2016, https://doi.org/10.1080/19443994.2016.1162206

MIRZAEI, F., ALIZADEH, H. A., TAHERI-GRAVAND, A.: Study of water Quality in Different Stations of Karkheh River based on Langelier and Ryzner Indices for Determining Potential Clogging of Droppers. *Research Journal of Applied …*, *3*(1), 61-66, 2011.

MONTENEGRO-RODRÍGUEZ, D. G.: *Evaluación de los factores que afectan a la producción en el campo Iro A del Bloque 16* [Tesis de Grado, Universidad Central del Ecuador], 2013, https://core.ac.uk/download/pdf/71900874.pdf

ORENDA: *Understanding LSI: The Langelier Saturation Index*, 2022, https://blog.orendatech.com/langelier-saturation-index

OUHAKKI, H., EL FALLAH, K., ADIBA, A., HAMID, T., EL MEJDOUB, N.: Assessing Groundwater Quality and its Impact on Agricultural Productivity in Morocco. *Journal of Ecological Engineering*, *25*(9), 81-91, 2024, https://doi.org/10.12911/22998993/190684

PADILLA-GONZÁLEZ, P., BAUTISTA-CAPETILLO, C., RUIZ-CANALES, A., GONZÁLEZ-TRINIDAD, J., JÚNEZ-FERREIRA, H. E., CONTRERAS RODRÍGUEZ, A. R., ROBLES ROVELO, C. O.: Characterization of Scale Deposits in a Drinking Water Network in a Semi-Arid Region. *International Journal of Environmental Research and Public Health*, *19*(6), 3257, 2022, https://doi.org/10.3390/ijerph19063257

PEKER, A. E., ÖZTÜRK, H. S., & MAMEDOV, A. I.: The Effect of Sodic Water Type on the Chemical Properties of Calcareous Soil in Semi-Arid Irrigated Land. *Soil Systems*, *8*(1), 10, 2024, https://doi.org/10.3390/soilsystems8010010

RODRÍGUEZ-AYALA, C. M.: *Caracterización hidrogeológica de las cuencas de los ríos Javita y Zapotal de la península de Santa Elena* [Ingeniero Geólogo, Universidad Central de Quito], 2014, T-UCE-0012-304.pdf. http://www.dspace.uce.edu.ec/handle/25000/2325

SHANKAR, D.: Determination of Scaling and corrosion tendencies of water through the use of Langelier and Ryznar Indices. *Scholars Journal of ENGINEERING AND TECHNOLOGY*, *2*(2), 123-127, 2014.

VELASCO-ANDRADE, P. R., TAMAYO-ORTIZ, C.: Agua en territorios comunales: Gestión del riego en el valle del río Javita, provincia de Santa Elena. *Siembra*, *7*(1), 027-042, 2020, https://doi.org/10.29166/siembra.v7i1.1865