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REVISTA TECNURA

La revista Tecnura es una publicación institucional de la Facultad Tecnológica de la Universidad Distrital Francisco José de Caldas de carácter científico-tecnológico, arbitrada mediante un proceso de revisión entre pares de doble ciego. La periodicidad de la conformación de sus comités Científico y Editorial está sujeta a la publicación de artículos en revistas indexadas internacionalmente por parte de sus respectivos miembros.

PERIODICIDAD

Es una publicación de carácter científico-tecnológico con periodicidad trimestral, que se publica los meses de enero, abril, julio y octubre. Su primer número apareció en el segundo semestre del año 1997 y hasta la fecha ha mantenido su regularidad.

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Las áreas temáticas de interés de la revista Tecnura están enfocadas a todos los campos de la ingeniería, como la electrónica, telecomunicaciones, electricidad, sistemas, industrial, mecánica, catastral, civil, ambiental, entre otras. Sin embargo, no se restringe únicamente a estas, también tienen cabida los temas de educación y salud, siempre y cuando estén relacionados con la ingeniería. La revista publicará únicamente artículos de investigación científica y tecnológica, de reflexión y de revisión.

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La revista Tecnura tiene como misión divulgar resultados de proyectos de investigación realizados en el área de la ingeniería, a través de la publicación de artículos originales e inéditos, realizados por académicos y profesionales pertenecientes a instituciones nacionales o extranjeras del orden público o privado.

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La revista Tecnura está dirigida a docentes, investigadores, estudiantes y profesionales interesados en la actualización permanente de sus conocimientos y el seguimiento de los procesos de investigación científico-tecnológica, en el campo de la ingeniería.

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Tecnura Journal is an institutional scientific-technological publication from the Faculty of Technology at District University Francisco José de Caldas, arbitrated by means of a double-blinded peer review process. The periodicity for its Scientific and Editorial committees line-up is subject to the publication of articles in internationally indexed magazines by its own members.

PERIODICITY

Tecnura journal is a scientific-technological publication with quarterly periodicity, published in January, April, July and October. Its first edition appeared in the second term, 1997 and its editions have normally continued from that year and on.

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Tecnura journal is aimed at publishing research project results carried out in the field of engineering, through the publishing of original and unpublished articles written by academics and professionals from national or international public or private institutions.

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En su calidad de máximos responsables de la revista, el comité y el equipo editorial de Tecnura se comprometen a:

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- Asegurar la calidad del material que se publica.
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- Mantener la integridad académica de su contenido.
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Code of ethics and good practice

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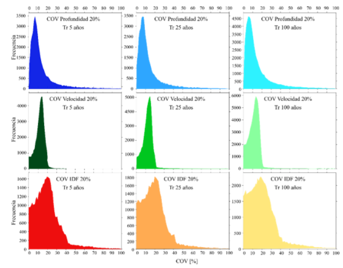

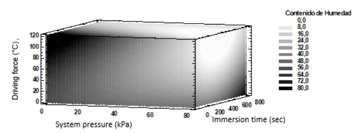

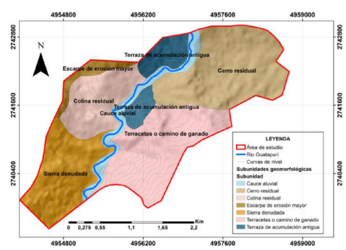

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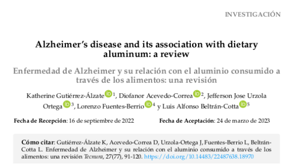
INVESTIGACIÓN

Alzheimer's disease and its association with dietary aluminum: a review

Enfermedad de Alzheimer y su relación con el aluminio consumido a través de los alimentos: una revisión

Katherine Gutiérrez-Álzate[1], Diofanor Acevedo-Correa[2], Jefferson Jose Urzola Ortega[3], Lorenzo Fuentes-Berrio[4] y Luis Alfonso Beltrán-Cotta[5]

Fecha de Recepción: 16 de septiembre de 2022 **Fecha de Aceptación**: 24 de marzo de 2023

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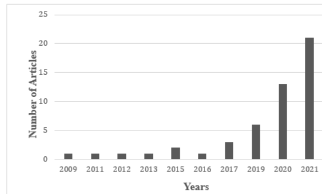

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INVESTIGACIÓN

Time and spatial natural uncertainty integration associated with the Manning's roughness coefficient in two-dimensional flash flood models

Integración de la incertidumbre natural temporal y espacial asociada al coeficiente de rugosidad Manning en modelos bidimensionales de inundaciones rápidas

Alfonso Mariano Ramos-Cañón [1], Lady Carolina Castro Malaver [2] y Nicolás Escobar-Castaneda [3]

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Abstract

Context: The natural spatial and temporal variability (uncertainty) of the inputs involved in hydrodynamic modeling for hazard assessment and delineation of potentially flood-prone areas is propagated in the output variables of the models. In normal practice, only natural temporal variability in terms of return period is usually considered, but the propagation of spatial uncertainty is unknown.

Methodoly: This paper presents the analysis of uncertainty propagation using the first order second moment method of Manning's roughness coefficient in the depth, velocity and flow intensity output variables of the numerical shallow water model implemented in HEC RAS 2D. A simulated flash flood in the municipality of Mocoa (Putumayo) and the corresponding probability of reaching a damage level for different return periods were analyzed, regarding the events occurred in March 2017.

Results: A procedure applicable to flood hazard assessment is obtained where the temporal natural variability associated to hydrographs with different return periods and the spatial natural variability associated to the Manning's roughness coefficient are integrated.

Conclusions: The propagation of uncertainty was able to establish a direct relationship between the increase of flow (return periods) and the increase of uncertainty in the evaluation of the flood hazard indicator.

Keywords: Uncertainty propagation, roughness coefficient, flash flood, flood hazard.

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Resumen

Contexto: La variabilidad natural (incertidumbre) espacial y la temporal de los insumos que intervienen en la modelación hidrodinámica, para la evaluación de la amenaza y la delimitación de las zonas potencialmente inundables, se propagan en las variables de salida de los modelos. En la práctica, suele considerarse la variabilidad natural temporal en términos de periodo de retorno, pero poco se ha analizado la propagación de la incertidumbre espacial del coeficiente de rugosidad.

Metodología: En este trabajo se presenta el análisis de la propagación de la incertidumbre a través del método *primer orden segundo momento* del coeficiente de rugosidad de Manning, en las variables de salida de profundidad, velocidad e intensidad de flujo del modelo numérico de aguas someras, implementado en HEC RAS 2D. Se analizó una inundación súbita simulada en el municipio de Mocoa (Putumayo) y la correspondiente probabilidad de alcanzar un nivel de daño para diferentes periodos de retorno, a propósito de los eventos ocurridos en marzo de 2017.

Resultados: Se obtiene un procedimiento aplicable a la evaluación de la amenaza de inundación, en el que se integra la variabilidad natural temporal asociada a las hidrógrafas con diferentes periodos de retorno, y la variabilidad natural espacial relacionada con el coeficiente de rugosidad de Manning.

Conclusiones: La propagación de la incertidumbre establece una relación directa entre el aumento del caudal (periodos de retorno) y el aumento de la incertidumbre en la evaluación del indicador de amenaza por inundación.

Palabras clave: propagación de la incertidumbre, coeficiente de rugosidad, inundación rápida, amenaza por inundación.

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INTRODUCCIÓN

La delimitación de las zonas susceptibles a inundaciones súbitas forma parte del conocimiento de la amenaza que permite tomar decisiones en cuanto a la gestión del riesgo (Arévalo-Algarra *et al.*, 2021; Castro-Maldonado *et al.*, 2023). Estas zonas se pueden delimitar a través de simulaciones hidrodinámicas en las que intervienen insumos hidrológicos y topográficos. Cada uno de estos insumos tiene asociada una incertidumbre natural que se propaga a través de los modelos y repercute en los resultados de simulaciones (Teng *et al.*, 2017). La cuantificación y análisis de la propagación de la incertidumbre cobra importancia en los mapas de amenaza por inundaciones, en los que se basa el ordenamiento territorial. Por lo general, estos mapas están en función de las variables de salida de la simulación (alturas de inundación, velocidades del flujo); por tanto, su elaboración debería tener en cuenta, además de la variabilidad natural temporal (en términos de periodos de retorno), la influencia de la variabilidad inherente de parámetros físicos incluidos en los modelos (p. ej.: el coeficiente de rugosidad en las ecuaciones de aguas someras).

Con el propósito de cuantificar la propagación de la incertidumbre natural de una variable dentro de un modelo numérico de aguas someras, se propone implementar una evaluación de confiabilidad a través del método *primer orden segundo momento (first order second moment* [FOSM]) evaluado a través de diferencias finitas para funciones matemáticas implícitas (Baecher y Christian, 2003). La variable que se analiza es el coeficiente de rugosidad de Manning, que se usa para calibrar las manchas de inundación. En la evaluación de la amenaza es necesario cuantificar la incertidumbre a través de la función de densidad de probabilidad y de los momentos estadísticos para la variable aleatoria de entrada analizada. Para el caso de estudio, la disponibilidad de información relacionada con la incertidumbre es limitada porque, usualmente, no se considera su variabilidad natural (Horritt y Bates, 2001; Romanowicz y Beven, 2003); por consiguiente, se hace un análisis para asignar un valor representativo de la zona con base en estudios previos que permiten estimar órdenes de magnitud de la incertidumbre natural del coeficiente de rugosidad de Manning (Kim *et al.*, 2010).

La propagación de incertidumbre y evaluación de amenaza se ejecuta sobre las variables de salida de profundidad, velocidad y de intensidad de flujo (Jakob *et al.*, 2012; Ramos *et al.*, 2021) para escenarios hipotéticos de inundación súbita en el municipio de Mocoa (Putumayo), a propósito de los eventos ocurridos en marzo de 2017 (Prada-Sarmiento *et al.*, 2019). Las simulaciones se efectúan en *HEC RAS 2D* para la aproximación de onda difusiva de las ecuaciones de aguas someras bidimensionales (Brunner, 2016). Los resultados permitieron concluir un rango de incertidumbre en términos del coeficiente de variación (COV) para las variables de salida del 0 % al 25 % con mayor incertidumbre para el índice de intensidad de flujo y menor para la velocidad. Se pudo establecer que, a mayor incertidumbre natural del coeficiente de rugosidad de Manning, aumenta la incertidumbre de manera proporcional en las variables de análisis para amenaza por inundación (altura, velocidad e índice de intensidad de flujo).

Método FOSM

La cuantificación de la incertidumbre se puede expresar a través del coeficiente de variación (ecuación (1)), que relaciona la desviación estándar y el valor esperado de la función de desempeño. En este estudio, la función de desempeño corresponde a la profundidad, velocidad e intensidad del flujo (variables de las ecuaciones de aguas someras), y la variable de entrada para la que se hace el análisis de propagación de incertidumbre es el coeficiente de rugosidad de Manning. Existen diferentes métodos para calcular los momentos estadísticos de la función de desempeño; por ejemplo: estimación puntual, primer orden segundo momento, segundo orden segundo momento, método de Hasofer-Lind, simulaciones de Montercarlo (Baecher y Christian, 2003).

El método empleado en este trabajo es primer orden segundo momento (*first order second moment* [FOSM]). Para la estimación del primer y segundo momento estadístico (el valor esperado E[g] y la varianza Var[g]) se usan los dos primeros términos de la expansión de la serie de Taylor de una función de desempeño g con n variables aleatorias X_n (ecuación (3)). En FOSM se supone una diferencia pequeña entre la variable X_i y el valor promedio de la misma μX_i, por lo que el cuadrado o las potencias de orden mayor son más pequeñas y pueden ser ignoradas (Arévalo-Mendoza *et al.*, 2014; Baecher y Christian, 2003).

Para encontrar los momentos estadísticos de la función de desempeño, es necesario conocer información de la función de densidad de probabilidad de las variables analizadas. FOSM permite calcular la esperanza matemática y la varianza de la función de desempeño, sin conocer la función de densidad de probabilidad de las variables de entrada. Estos momentos estadísticos se calculan alrededor del valor medio y la desviación estándar de las variables analizadas. Las ecuaciones (3) y (4) se obtienen de la definición general de E[g] y Var[g], suponiendo que las variables de entrada son independientes entre sí (no hay correlación) y aplicando la expansión de la serie de Taylor para la función de desempeño (Baecher y Christian, 2003; Maskey y Guinot, 2003).

$$COV = \frac{\sigma}{\mu} = \frac{\sqrt{Var[g]}}{E[g]} \tag{1}$$

$$g(x_1, x_2, \ldots, x_n) = g(\mu X_1, \mu X_2, \ldots, \mu X_n) + \frac{1}{1!}\sum_{i=1}^{n}(x_i - \mu x_i)\frac{\partial g}{\partial x_i} + \frac{1}{2!}\sum_{i=1}^{n}\sum_{j=1}^{n}(x_i - \mu x_i)(x_j - \mu x_j)\frac{\partial^2 g}{\partial x_i \partial x_j} + \ldots \tag{2}$$

$$E[p] \approx g(\mu X_1, \mu X_2, \ldots, \mu X_n) \tag{3}$$

$$Var[g] \approx \sum_{i=1}^{n} \left(\frac{\partial g}{\partial x_i}\bigg|_m \right)^2 \sigma_{x_i}^2 \tag{4}$$

En la ecuación (4), las derivadas parciales de la función de desempeño son evaluadas en los valores medios de las correspondientes variables de entrada ($m = \mu X_1, \mu X_2, \ldots, \mu X_n$) y $\sigma_{x_i}^2$ es la varianza de cada una de estas variables. Si hay n variables de entrada, es necesario evaluar n derivadas parciales de la función de desempeño.

Modelo numérico de inundación

La función de desempeño corresponde a las variables de salida del modelo numérico de aguas someras implementado en *HEC-RAS 2D*, solucionadas con el método de volúmenes finitos (Brunner, 2016). Estas ecuaciones son una simplificación de las ecuaciones de Navier-Stokes que describen el movimiento de un fluido en el espacio (x, y, z). Las ecuaciones (5) y (6) corresponden a la ecuación de conservación de masa y las ecuaciones de conservación de *momentum*, respectivamente, que conforman las ecuaciones de aguas someras bidimensionales.

$$\frac{\partial H}{\partial T} + \nabla \cdot hV + q = 0 \tag{5}$$

$$\frac{\partial V}{\partial T} + V \cdot \nabla V = -g\nabla H + v_t \nabla^2 V - c_F V + fk \times V \tag{6}$$

Donde t es el tiempo; H es la elevación de la superficie de agua; ∇ es el vector de derivadas parciales $(\partial/\partial x, \partial/\partial y)$; h es la profundidad del flujo; $V = (u, v)$ es la velocidad vectorial; a la vez, u es el componente horizontal y v el componente vertical; q son fuentes o sumideros de masa; g corresponde a la aceleración de la gravedad; v_t es el coeficiente horizontal de la viscosidad turbulenta; c_f es el coeficiente de fricción de fondo; f es el parámetro de Coriolis, y k es un vector unitario en la dirección vertical.

HEC-RAS 2D implementa la aproximación de Gauckler-Manning-Strickler (Cortés-Zambrano *et al.*, 2022) para calcular el coeficiente de fricción de fondo c_f (ecuación (7)). Al reemplazarlo en la ecuación de *momentum* (6), y a partir de las consideraciones para onda difusiva se obtiene una expresión en función del coeficiente empírico de rugosidad de Manning (n) y del radio hidráulico (R) (ecuación (8)).

$$c_f = \frac{n^2 g ||V||}{R^{4/3}} \tag{7}$$

$$-\nabla H = \left(\frac{n^2 ||V||}{R^{4/3}} V \right) \tag{8}$$

El índice de intensidad de flujo (I_{DF}) no es una variable del modelo numérico de aguas someras, sin embargo, su cálculo depende de la profundidad y la velocidad producto de las simulaciones hidrodinámicas. El I_{DF} propuesto por Jakob *et al.* (2012) relaciona la profundidad y la magnitud de la velocidad al cuadrado (ecuación (9)); los valores para I_{DF} se toman como estimaciones de la severidad del flujo (*véase* Altarejos-García *et al.*, 2012).

$$I_{DF} = H_{\text{máx}}||\vec{V}||^2_{\text{máx}} \tag{9}$$

Recientemente, Ramos *et al.* (2021) plantearon el I_{DF} para la evaluación de amenaza por avenidas torrenciales en Colombia así: si el $I_{DF} \geq 50$, la probabilidad de colapso es alta y corresponde a amenaza alta. Si $1 \leq I_{DF} < 50$, la probabilidad de colapso es baja pero la probabilidad de algún daño estructural es considerable, por lo que se asigna una categoría media de amenaza. Por último, si $0 \leq I_{DF} < 1$, la probabilidad de daño estructural es baja; por tanto, corresponde a amenaza baja.

Incertidumbre del coeficiente de rugosidad de Manning

Para determinar la variabilidad natural del coeficiente de rugosidad de Manning se debe contar con información espacial y temporal detallada de la zona de estudio (Lumbroso y Gaume, 2012; Pappenberger *et al.*, 2005; Trieste y Jarrett, 1987). En las simulaciones hidrodinámicas para inundaciones es común que el valor de este coeficiente sea usado para calibrar las manchas de inundación y que el valor supuesto corresponda a un valor representativo de toda la zona de estudio. En la tabla 1 se presenta el valor medio y el coeficiente de variación (COV) para los coeficientes de rugosidad de Manning reportados por Chang *et al.* (1993); Da Costa *et al.* (2018); Dingman y Sharma (1997), y Kim *et al.* (2010).

Los valores presentados en la tabla 1 reportados por Dingman y Sharma (1997) fueron calculados a partir de una muestra total de 621 datos obtenidos de múltiples estaciones en Nueva Zelanda y Estados Unidos. Por consiguiente, los COV de Dingman y Sharma (1997) corresponden a la variación de la muestra total (sin consideración de su ubicación espacial), lo que justifica la diferencia en el orden de magnitud con los otros COV resumidos en la tabla 1. Para los otros autores, el COV de Manning varía entre 1 % y el 10 % aproximadamente.

Metodología

Caso de estudio

Prada-Sarmiento *et al.* (2019) reportaron que los principales flujos de detritos, flujos de lodos y flujos hiperconcentrados del evento ocurrido el 31 marzo de 2017 se transportaron por el río Sangoyaco y por las quebradas Taruca y Taruquita, afectando la zona nororiental del casco urbano de Mocoa (Putumayo). Luego de estas observaciones y de la delimitación hidrológica para estos cauces, se identificaron catorce subcuencas (microcuencas) que formaron parte de

Tabla 1. Valores reportados en la literatura del valor medio y COV para el Manning

Referencia	Valor medio1	COV (%)	Observaciones	Zona de estudio	Lecho de río
Chang *et al.* (1993)	0,035	8,66	-	Río Santa Cruz, Arizona	Areno-limoso
	0,035	8,66			
	0,03	8,66			
Dingman y Sharma (1997)	0,053	73,58	521 datos	Datos tomados de estaciones ubicadas en Nueva Zelanda (78) y en Estados Unidos (50)	-
	0,059	79,66	100 datos		
Kim *et al.* (2010)	0,12	3,33	Caudales de 37 m^3/s	Río Salcheon, Corea del Sur	Gravoso
	0,121	5,79			
	0,044	2,27	Caudales de 1000 m^3/s		
	0,044	4,55			
Da Costa et al. (2018)	0,0589	1,72	Caudal 37,15 m^3/s	Río Doce, Brasil	-
	0,059	1,38			
	0,0764	0,99	Caudal 418,7 m^3/s		
	0,0749	1,01			
	0,0275	1,29	Caudal 446,8 m^3/s		
	0,0283	1,72			

[1]Las unidades del coeficiente de rugosidad están dadas por la constante de conversión; para SI $k_n = 1\ \mathrm{s/m^{1/3}}$

la iniciación y el transporte del flujo. La delimitación del dominio computacional para la simulación hidrodinámica incluyó la zona de depósito, la quebrada San Antonio y parte del río Mocoa (desembocadura de los cauces ya mencionados) (figura **1**).

Simulación hidrodinámica

Para la simulación en *HEC-RAS 2D* se usó un modelo digital de elevación DEM. Se generó una malla de 5 m de tamaño de celda para el dominio computacional de la figura **1**. En cada punto de cierre de las microcuencas se cargó una hidrógrafa de caudal líquido como condición de borde interna dentro del dominio computacional (fuente de masa). Las hidrógrafas de caudal fueron tomadas del cálculo realizado por Ramos *et al.* (2021). En la figura **2**A se muestran las catorce hidrógrafas que se cargaron para un periodo de retorno de cien años. En la figura **2**b se ilustra la hidrógrafa con el caudal pico para cada periodo de retorno. Se evidencia la diferencia entre los tres periodos de retorno usados; para el de cien años el caudal de entrada en la microcuenca 2 (79,39 m^3/s) es aproximadamente el doble que el del periodo de retorno de 5 años (42,05 m^3/s).

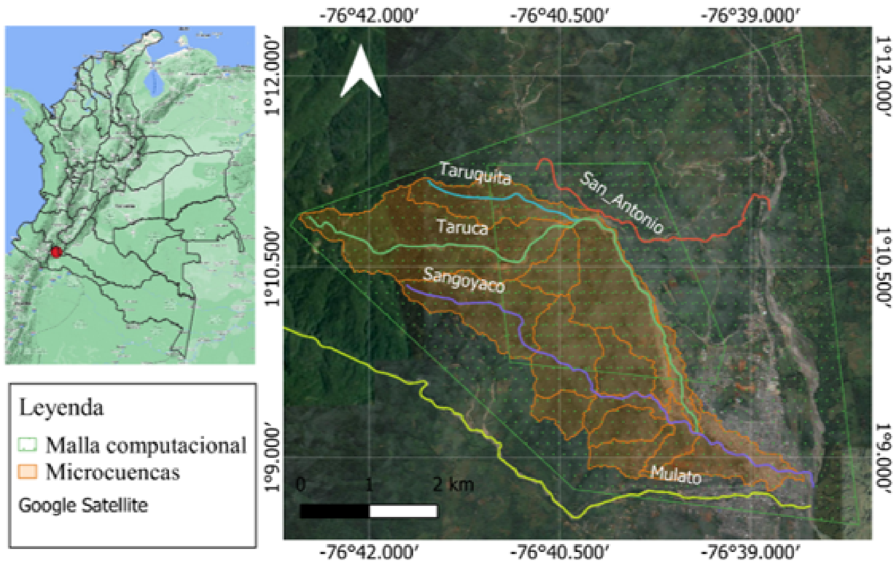

Figura 1. Localización de Mocoa (Colombia) y generalidades de la zona de estudio: microcuencas, dominio computacional y cauces de interés

Fuente: Ramos *et al.* (2020) y Prada-Sarmiento *et al.* (2019).

Cálculo de la propagación de la incertidumbre

El cálculo de los COV para cada variable de salida de las simulaciones hidrodinámicas requiere del primer y segundo momento estadístico. En el segundo se debe evaluar las derivadas parciales de la función de desempeño para cada variable de entrada (ecuación (4)). Cuando la función de desempeño no tiene forma matemática explícita, es necesario implementar un método numérico para evaluar las derivadas parciales (Arévalo-Mendoza *et al.*, 2014). En este estudio se implementó el método de diferencias finitas centrales para calcular la derivada parcial de la profundidad, la velocidad y la intensidad del flujo respecto al coeficiente de rugosidad de Manning. Teniendo en cuenta que las ecuaciones de aguas someras no tienen una forma matemática explícita, la derivada parcial de la ecuación de la varianza (ecuación (4)) en función del coeficiente de Manning se calcula como se muestra en la ecuación (10); donde $g(\mu n \pm \Delta_n)$ es cualquiera de las variables de salida evaluadas en $\mu n + \Delta_n$. La magnitud de Δ_n deber ser lo suficientemente pequeña para encontrar la variación en dicho intervalo. Para este estudio se determinó $\Delta_n = \sigma_n$ (desviación estándar del coeficiente de rugosidad).

Los valores que se suponen en este estudio para μn y σ_n se relacionan con los valores medios y los COV presentados en la tabla 1. Se propone un valor medio del coeficiente de Manning μn representativo ($\mu n = 0.12$) para toda la zona de estudio teniendo en cuenta las similitudes del lecho del río analizado por Kim *et al.* (2010) y el lecho del río Sangoyaco y las quebradas Taruca

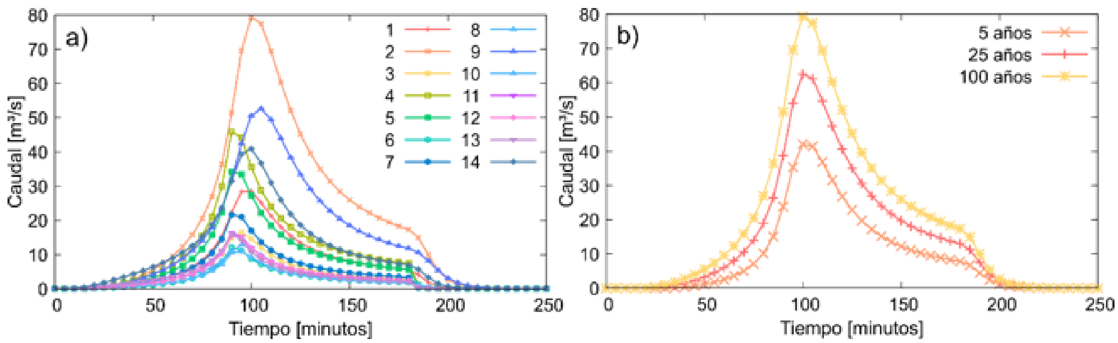

Figura 2. Hidrógrafas de entrada del modelo fluidodinámico para una duración de tormenta de tres horas

a) Hidrógrafas para las catorce microcuencas de la zona de estudio para un Tr = 100 años. **b)** Comparación de las hidrógrafas de la microcuenca 2 para los tres periodos de retorno simulados (5, 25 y 100 años).

Fuente: Ramos *et al.* (2021) y Unidad Nacional para la Gestión del Riesgo de Desastres y Pontificia Universidad Javeriana (2018).

y Taruquita. Para considerar el impacto de la variabilidad natural del coeficiente de Manning, se analiza la incertidumbre para varios COV que están en el rango de la tabla 1: $COV = 2\,\%$, 5 %, 10 %, 15 % y 20 %.

$$\frac{\partial g}{\partial n} \approx \frac{1}{2\Delta_n}[g(\mu n + \Delta_n) - g(\mu n - \Delta_n)] \qquad (10)$$

Las ecuaciones (11), (12) y (14) resumen los cálculos que se realizaron para cada variable de salida del modelo. Estas ecuaciones se aplicaron en cada pixel, resultado de las simulaciones hidrodinámicas mediante una calculadora ráster.

$$\mathrm{COV}_h = \frac{\sigma_h}{\mu_h} \quad ; \quad \mathrm{COV}_v = \frac{\sigma_v}{\mu_v} \quad ; \quad \mathrm{COV}_{I_{DF}} = \frac{\sigma_{I_{DF}}}{\mu_{I_{DF}}} \qquad (11)$$

$$\sigma_h = \sqrt{\left(\frac{\partial h}{\partial n}\right)^2 \sigma_n^2} \quad ; \quad \sigma_v = \sqrt{\left(\frac{\partial v}{\partial n}\right)^2 \sigma_n^2} \quad ; \quad \sigma_{I_{DF}} = \sqrt{\left(\frac{\partial I_{DF}}{\partial n}\right)^2 \sigma_n^2} \qquad (12)$$

$$\frac{\partial h}{\partial n} = \frac{h(\mu n + \sigma_n) - h(\mu n + \sigma_n)}{2\sigma_n} \quad ; \quad \frac{\partial v}{\partial n} = \frac{v(\mu n + \sigma_n) - v(\mu n + \sigma_n)}{2\sigma_n} \qquad (13)$$
$$\frac{\partial I_{DF}}{\partial n} = \frac{I_{DF}(\mu n + \sigma_n) - I_{DF}(\mu n + \sigma_n)}{2\sigma_n}$$

RESULTADOS

La figura **3** muestra la frecuencia de los valores de los coeficientes de variación de la altura (COV_h), de la velocidad (COV_v) y del índice de intensidad de flujo ($COV_{I_{DF}}$) correspondientes a un coeficiente de variación de Manning $COV_n = 20\,\%$ para los tres periodos de retorno (5, 25 y 100 años) en todo el dominio de cálculo del proceso de inundación. En la misma figura se reportan valores de COV_h, v, I_{DF} de hasta 100 %; por consiguiente, los valores máximos de COV_h, v, I_{DF} no se presentan. Se evidencia que la frecuencia de los COV_h, v, I_{DF} no es uniforme y que tanto la dispersión de los datos como la frecuencia máxima se alteran de acuerdo con las variables analizadas y no con el periodo de retorno; por ejemplo, para la profundidad se observa una disminución gradual de la frecuencia después de $COV_h = 8\,\%$ que es aproximadamente la frecuencia máxima en los tres periodos de retorno, para la velocidad se observa una disminución más abrupta después de $COV_v = 13\,\%$ (frecuencia máxima) para los tres periodos de retorno, y para el $COV_{I_{DF}}$ la frecuencia máxima es cercana al 20 %.

La figura **4** ilustra el valor más frecuente de COV_h, COV_v y $COV_{I_{DF}}$. Se observa que a mayor incertidumbre de la variable de entrada (n de manning), consecuentemente se incrementa la incertidumbre en la función de desempeño (altura, velocidad e índice de intensidad de flujo). La línea roja punteada indica una relación 1:1 entre los $COV_{h,v,I_{DF}}$ y el COV_n. Los valores sobre la línea muestran un incremento en la incertidumbre debido al modelo que basa su variabilidad en el coeficiente de Manning.

En la figura **4** los resultados de incertidumbre para el I_{DF} son los únicos ubicados sobre la línea de referencia, sus COV indican que, a mayor incertidumbre en el Manning n y mayor periodo de retorno, mayor incertidumbre habrá para la moda de los resultados.

En las figuras **3** y **4** se observa que la propagación de la incertidumbre del coeficiente de variación a través de un modelo matemático como el de aguas someras para simulación de inundaciones no presenta un resultado trivial y que en algunos sitios del dominio computacional se incrementa la incertidumbre en las variables de salida, y en otros puntos se disminuye. Al aumentar la incertidumbre, necesariamente se incrementa la incertidumbre del nivel de amenaza en cada sitio, de allí la importancia de incluir en el análisis de amenaza tanto la variabilidad natural temporal (periodos de retorno), como la natural espacial de los parámetros de los modelos.

Propagación de la incertidumbre y evaluación de la amenaza en puntos específicos

Se realizó un análisis de la propagación de la incertidumbre en puntos de la mancha de inundación, seleccionados de tal forma que existiera información para todos los periodos de retorno analizados. Los seleccionados fueron: el punto A, en la confluencia de las quebradas Taruca y Taruquita, después del ingreso de la hidrógrafa. El punto B, en la parte baja de la que-

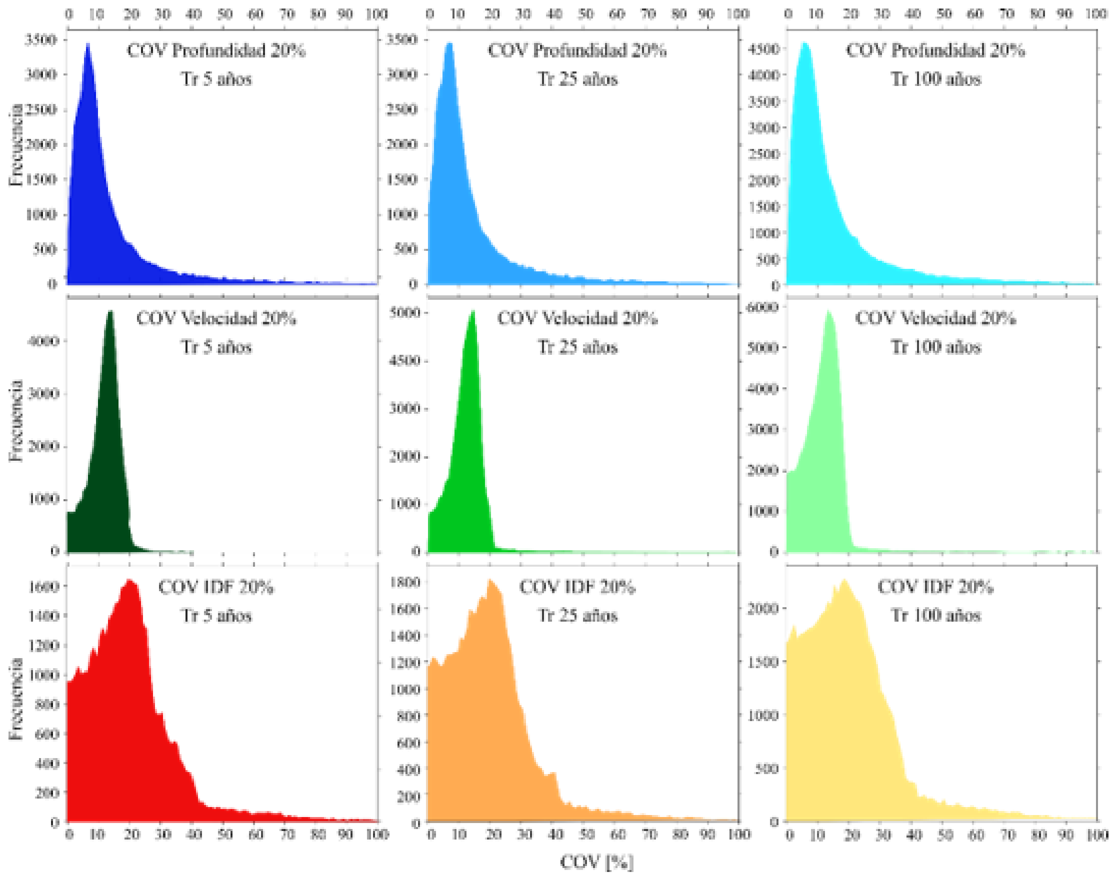

Figura 3. Histogramas de frecuencia para los valores de los pixeles para $COV_{h,v,I_{DF}}$ entre 0 % y 100 %
Nota: $Tr = 5$ años (columna izquierda), $Tr = 25$ años (columna del centro) y $Tr = 100$ años (columna derecha); de cada una de las variables de simulación: COV_h (primera fila), COV_v (segunda fila) e $COV_{I_{DF}}$ (tercera fila) para un COV_n del 20 %.

brada San Antonio, antes de su desembocadura en el río Mocoa. El punto C, en la intersección con la vía y la quebrada Taruca que se desvía hacia el sector de Pueblo viejo. El punto D, en la parte alta del río Sangoyaco, después de la entrada de la penúltima hidrógrafa de esta quebrada. El punto E, en la quebrada Sangoyaco antes de desembocar en el río Mocoa y de la última hidrógrafa. El punto F, entre los puntos A y C, en la zona de mayor dispersión de la mancha de inundación (figura **5**).

La propagación de la incertidumbre también se analizó a través de tres puntos ubicados perpendicularmente a la dirección del flujo (análogos a secciones transversales [ST]), así: (1) en la zona de mayor dispersión sobre la quebrada Taruquita entre los puntos A y F; (2) en la zona

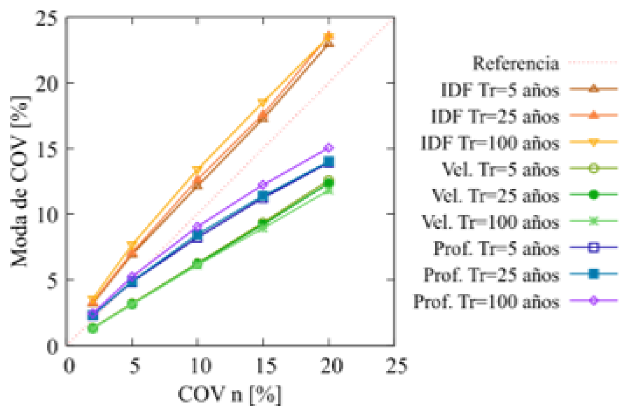

Figura 4. Moda del COV_h, COV_v y $COV_{I_{DF}}$ para cada uno de los periodos de retorno en función del COV_n

Nota: Prof.: profundidad; vel.: velocidad. La línea de referencia punteada corresponde a la relación 1:1 entre las ordenadas y las abscisas.

de menor dispersión del flujo sobre la quebrada Taruca y después de la intersección de esta quebrada con la vía, unos metros abajo del punto C; por último (3) unos metros después del punto D en la quebrada Sangoyaco. Las ST se asumieron de acuerdo con tres puntos: margen izquierda (I), centro (C) y margen derecha (D). La imagen de la derecha de la figura **5** muestra los perfiles de cada una de las ST y la ubicación de los puntos I, C, D dentro de cada ST.

La figura 6 muestra la relación entre el COV_h, COV_v, $COV_{I_{DF}}$ con el COV_n para cada uno de los puntos escogidos (A, B, C, D, E y F), donde se evidencia que a mayor COV_n hay mayor incertidumbre en la profundidad, la velocidad y el I_{DF}. Sin embargo, esta relación no es proporcional y los aumentos reales de incertidumbre se deben observar a través de la línea de referencia (línea punteada): para todos los puntos hay al menos un resultado que supera dicha línea, excepto el punto B. En la figura **6** también se puede identificar que la velocidad es la única variable que no tiene aumento real de la incertidumbre en ninguno de los puntos analizados, mientras que el comportamiento de la profundidad y del I_{DF} varían. Tampoco se identifica un comportamiento de la incertidumbre relacionado con los periodos de retorno para cada variable.

Los resultados mostrados en la figura **6** para los puntos C y E son muy similares, mientras que los resultados de cada variable en el punto D son muy parecidos entre periodos de retorno; en todo caso, estos tres puntos son los que muestran menor dispersión comparados con los puntos A, B y F. Según las figuras 1 y 5, los puntos B y C coinciden con puntos de confluencia en zonas de previa dispersión de la mancha de inundación, pero de diferentes quebradas; mientras que los puntos D y E corresponden a una misma quebrada en una zona uniforme de la mancha

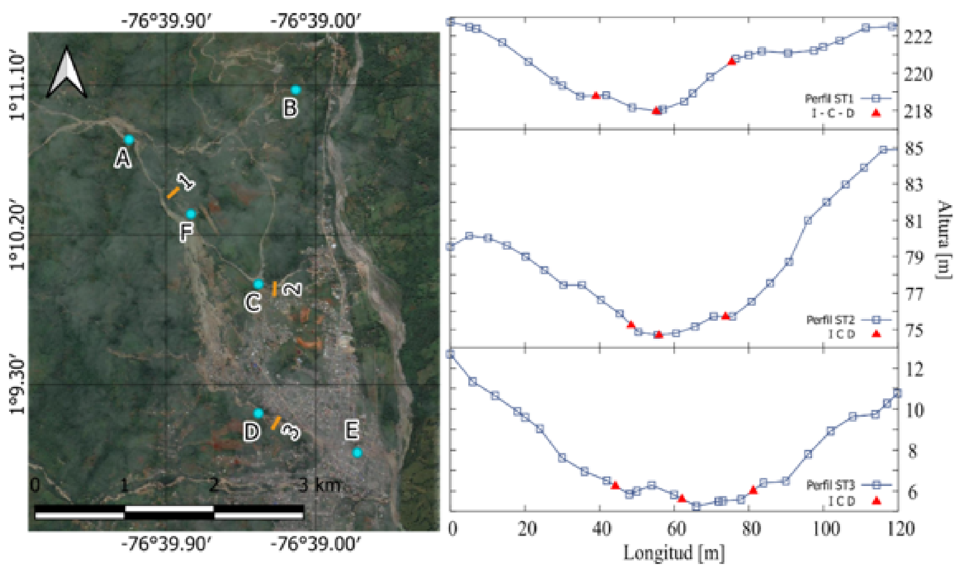

Figura 5. Izquierda: ubicación de los puntos específicos en los que se analiza la propagación de la incertidumbre. Derecha: puntos sobre secciones transversales del dominio ST1, ST2 y ST3

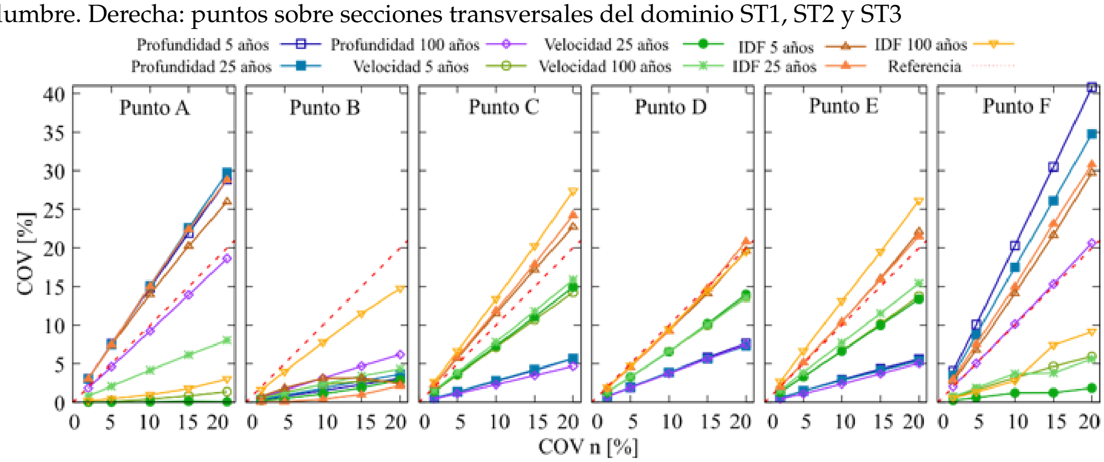

Figura 6. Valor del COV_h, COV_v, $COV_{I_{DF}}$ en función del COV_n para cada uno de los puntos seleccionados de la mancha de inundación (A, B, C, D, E y F)

Nota: La línea de referencia punteada corresponde a la relación 1:1 entre las ordenadas y las abscisas.

de inundación. Por otro lado, los puntos A y F están ubicados en una zona de alta dispersión de la mancha de inundación, la dispersión de los resultados en estos puntos coincide: tanto la profundidad como el I_{DF} para $Tr = 5$ y 25 años tienen incertidumbres ubicadas por encima de la línea de referencia.

En cuanto a los resultados para las ST, la ubicación de los puntos se condicionó de tal forma que existiera información en todos los escenarios, i.e. para los tres periodos de retorno y las tres variables analizadas. La figura **7** muestra los valores de los COV_h, COV_v, $COV_{I_{DF}}$ en función del COV_n para los tres periodos de retorno graficados por cada punto dentro de las ST. De las tres ST de la figura **7**, la ST N. °3 es la de menor incertidumbre (p. ej.: no se sobrepasa la línea de referencia); sin embargo, en esta ST no es sencillo identificar un comportamiento particular para cada variable como sí es posible identificar en las otras ST; en la ST 1, por ejemplo, para el margen izquierdo la profundidad tiene una incertidumbre entre 0-8 % con una relación directa para los periodos de retorno (a mayor Tr, mayor COV), la velocidad entre 0-16 % con una relación inversa para los periodos de retorno y el I_{DF} entre 1-25 %, también con una relación inversa para los periodos de retorno. La ST 2, margen derecho y centro, coincide con la ST 1 en cuanto a los rangos, pero no para la relación de los periodos de retorno: para la profundidad la relación es inversa, mientras que, para la velocidad y el I_{DF} la relación es directa. De acuerdo con la ST 1 y ST 2 de la figura **7**, la variable con mayor incertidumbre es el I_{DF}, solo el margen derecho de la ST 1 indica que la profundidad tiene mayor incertidumbre.

Altarejos-García *et al.* (2012) exponen mapas de desviación estándar y del valor esperado para la profundidad y la velocidad que son resultados de una simulación bidimensional en el *software GUAD-2-D* (ecuaciones de aguas someras-volumen finito) para un tramo de corriente con tres caudales picos. En un cálculo del COV al relacionar los valores máximos de cada uno de los mapas presentados, se obtiene un $0 \leq COV_h \leq 18\,\%$ y $0 \leq COV_v \leq 16\,\%$; el rango de la velocidad coincide con los resultados generalizados para la figura **6**.

La incertidumbre en la evaluación de la amenaza es menor en las partes altas de las cuencas, mientras que en las zonas donde las pendientes son menores, la incertidumbre en la altura, velocidad e intensidad de flujo es mayor. Lo anterior tiene implicaciones serias en el ordenamiento del territorio, dado que típicamente las comunidades habitan en las partes bajas de las cuencas donde, a pesar de que las velocidades y alturas de flujo pueden ser menores, su comportamiento es menos predecible y por ende su incertidumbre aumenta.

Los resultados evidencian que al evaluar la amenaza por inundación, teniendo en cuenta únicamente la incertidumbre o variabilidad natural temporal asociada a los periodos de retorno, se subestima la cuantificación de la amenaza debida a la variabilidad natural espacial de aspectos relacionadas con las propiedades físicas del flujo.

No se observa un incremento significativo de la incertidumbre de las alturas, velocidades o índice de intensidad de flujo cuando aumenta el caudal representado por escenarios de diferentes periodos de retorno; sin embargo, la evaluación de la magnitud del peligro es mayor debido a que los valores esperados de las alturas, velocidades e índice de intensidad de flujo sí se incrementan con los escenarios de periodos de retorno.

Para la evaluación de la amenaza por cualquier peligro natural (inundaciones, avenidas torrenciales), se usa la curva de amenaza que relaciona en las abscisas los valores de periodo

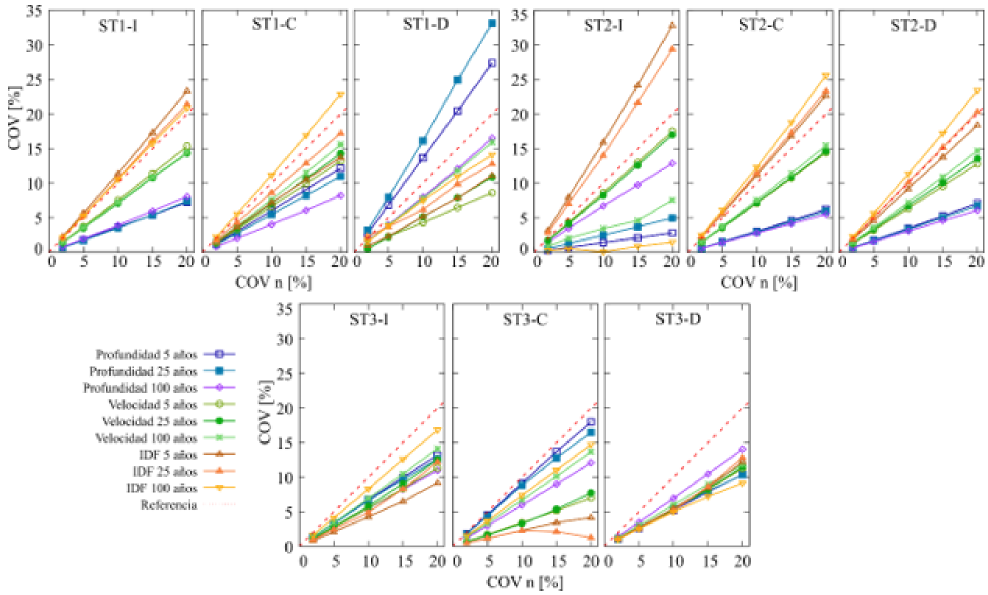

Figura 7. Resultados del COV_h, COV_v, $COV_{I_{DF}}$ en función del COV_n para cada uno de los puntos de las secciones transversales analizadas

Nota: (primera fila), n.º 2 (segunda fila) y n.º 3 (tercera fila); extremo izquierdo (columna izquierda), punto central (columna central) y extremo derecho (columna derecha). La línea de referencia punteada corresponde a la relación 1:1 entre las ordenadas y las abscisas.

de retorno y en las ordenadas se representa la variable que caracteriza la amenaza (altura, velocidades o índices de intensidad de flujo). En la figura **8**A se presenta la curva de amenaza para el I_{DF} de los puntos F y C de la figura **5**. Es claro que la curva del punto C tiene un nivel de amenaza mayor que la curva F y que la incertidumbre natural está dada únicamente por el periodo de retorno, es decir, variabilidad natural temporal. Con el procedimiento acá presentado, se obtiene además la posibilidad de calcular la probabilidad que el I_{DF} sea mayor a un valor determinado (asociado a un nivel de amenaza alta, media o baja $I_{DF-Amenaza}$) dado un periodo de retorno (Tr) $P(I_{DF} \leq I_{DF-Amenaza})/Tr$, debido a que la relación periodo de retorno e I_{DF} no es determinística, sino que existe variabilidad natural espacial debido a los parámetros físicos que se encuentran en el modelo de inundación. La incertidumbre asignada a cada valor del I_{DF} dado un Tr se obtiene de lo reportado en la figura **6**. En la figura **8**b se presenta la función de distribución de probabilidad del I_{DF} para Tr 5, 25 y 100 años del punto C. Se observa claramente que la incertidumbre es mayor en la determinación del I_{DF} a medida que aumenta el periodo de retorno de las hidrógrafas. Para el punto C, se tiene lo siguiente:

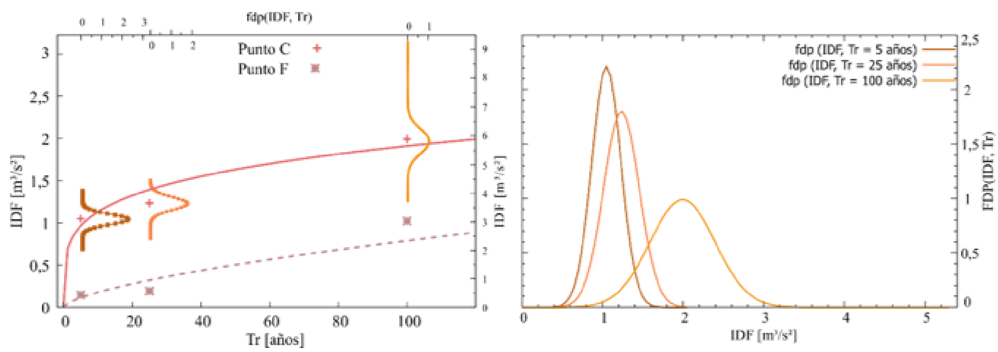

Figura 8. a. Curva de amenaza contra inundación de los puntos C y F en términos del IDF. b. Función de distribución de probabilidad del IDF para tres periodos de retorno (5, 25 y 100 años) en el punto C de la figura **5**

$P[(I_{DF} \leq I_{DF} = 1\ \mathrm{m}^3/\mathrm{s}^2)/Tr = 5$ años$] = 0,39$; $P[(I_{DF} \leq I_{DF} = 1\mathrm{m}^3/\mathrm{s}^2)/Tr = 25$ años$] = 0,14$; $P[(I_{DF} \leq I_{DF} = 1\ \mathrm{m}^3/\mathrm{s}^2)/Tr = 100$ años$] = 0,0069$. Según Ramos *et al.* (2021), un $I_{DF} \leq 1\ \mathrm{m}^3/\mathrm{s}^2$ se encuentra asociado a un nivel de amenaza baja. Por lo tanto, en el punto C de análisis y a manera de ejemplo, se encuentra que a medida que el periodo de retorno aumenta, la probabilidad de estar en un nivel de amenaza baja disminuye. Consistentemente, la probabilidad de estar en un nivel de amenaza medio o alto es superior con el aumento del periodo de retorno de las hidrógrafas.

En resumen, la figura **8**A ilustra la evaluación de la amenaza por inundación en términos del IDF, considerando únicamente la incertidumbre natural temporal dada por la variación de la magnitud de la amenaza en función del periodo de retorno, mientras que la figura **8**B muestra la influencia de la incertidumbre natural espacial en los resultados de la evaluación de la magnitud de la amenaza.

La integración de las dos incertidumbres naturales (espacial y temporal) y la evaluación de la amenaza integrada se efectuarían a través de la ecuación (14):

$$P(I_{DF}) = \sum_{i=1}^{n} P\left(\frac{I_{DF_i}}{TR_i}\right) P(T_{R_i}) \tag{14}$$

Donde las probabilidades $P(I_{DF_i}/TR_i)$ se obtienen con el procedimiento presentado en este artículo para los n periodos de retorno y $P(TR_i)$ están asociados a la probabilidad de excedencia de las hidrógrafas reportadas en la figura **2**.

CONCLUSIONES

El estudio general que se realizó a través de los valores medios de los resultados permitió establecer un rango de incertidumbre entre $0\,\% \leq COV \leq 25\,\%$, con mayores incertidumbres para el I_{DF} y menores para la velocidad, resultado que concuerda con el análisis puntual y por secciones transversales. También fue posible establecer una relación directa con los periodos de retorno: a mayor periodo de retorno, asociado a mayor caudal, se incrementa la incertidumbre en la determinación de alturas y velocidad. Esto se evidencia en los mapas de amenaza donde zonas altas y medias tienen mayor incertidumbre que aquellas delimitadas con amenaza baja.

El análisis de la propagación de la incertidumbre mediante el método FOSM es una manera de obtener la incertidumbre en términos del COV de la función objetivo o de las variables de salida con un costo computacional aceptable, pues no requiere grandes cantidades de simulaciones. Esto se vuelve útil cuando los dominios de computación son grandes y por tanto las simulaciones toman un tiempo considerable (p. ej.: más de cuatro horas).

Se presenta un procedimiento para integrar la incertidumbre natural espacial y temporal en la evaluación de la amenaza por inundaciones. Dicho procedimiento tiene la potencialidad de ser aplicado a peligros que tienen procesos similares como las avenidas torrenciales. A medida que aumenta el periodo de retorno de las hidrógrafas en la zona de estudio, se incrementa la incertidumbre en el parámetro representativo de la amenaza al tener en cuenta la variabilidad natural espacial del coeficiente de rugosidad de Manning.

Agradecimientos

Los autores agradecen a Jorge Escobar, Andrés Vargas, David Trujillo, Paula Solarte y Leandro Durán por su colaboración en la conceptualización y el levantamiento de información para el establecimiento de las simulaciones de prueba iniciales.

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INVESTIGACIÓN

Optimization of the Frying Process by Immersion in Obtaining "*Malus Domestica*" Apple Snacks

Optimización del Proceso de Fritura por Inmersión en la Obtención de Snacks de Manzana "*Malus Domestica*"

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Abstract

Context: In the world, the average apple production from 2015 to 2019 amounted 84,722,560 tons. During this period, Colombia contributed an average of 3,523 tons to the total production, with the department of Santander emerging as the highest producer in the country. Notably, 100 % of the apples produced in this region were consumed fresh. It is therefore necessary to explore other transformation alternatives, such as producing snacks via deep frying, with the control of operating such variables as: driving force (ΔT), process time (t) and pressure of the system (P).

Objective: The objective of this work was to evaluate the effect of pressure in the process of obtaining fried apple slices "*Malus domestica*".

Methodology: Apple slices were subjected to osmotic dehydration (sucrose 45 % and citric acid 1 %) at two temperatures (20°C and 40°C) for 240 minutes. Subsequently, they were subjected to deep frying under control of temperature, immersion time and system pressure. For the experimental design, the response variables evaluated were: color change, moisture content, fat content, and sensory analysis.

Results and conclusion : The optimal conditions found were: $\Delta T = 72{,}5$°C, $t = 662{,}7$ s and $P = 36{,}1$ kPa, which also represents a certain similarity regarding the treatment of the best- rated sensory sample.

Funding: University of Caldas.

Keywords: osmotic dehydration, driving force, pressure, color, fat content, moisture content, response surface.

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Resumen

Contexto: La producción promedio de manzana en el mundo durante el periodo de 2015 a 2019 fue de 84.722.560 toneladas, producción de la cual Colombia aportó un promedio de 3.523 toneladas, con el departamento de Santander siendo el máximo productor de esta fruta en el país. Dado que el 100 % de las manzanas producidas en esta región son consumidas frescas, resulta necesario explorar otras alternativas de transformación como la producción de snacks via fritura por inmersión, con el control de las variables de operación como: fuerza impulsadora (ΔT), tiempo de proceso (t) y presión del sistema (P).

Objetivo: El objetivo de este trabajo fue evaluar el efecto de la presión en el proceso de obtención de rodajas fritas de manzana *"Malus domestica"*.

Métodología: Las rodajas de manzana se sometieron a deshidratación osmótica (sacarosa 45 % y ácido cítrico 1 %) a dos temperaturas (20°C y 40°C) durante 240 minutos. Posteriormente, se sometieron a una fritura por inmersión bajo control de temperatura, tiempo de inmersión y presión del sistema. Para el diseño experimental, las variables de respuesta evaluadas fueron: cambio de color, contenido de humedad, contenido de grasa y análisis sensorial.

Resultados y conclusión: Las condiciones óptimas encontradas fueron: $\Delta T = 72{,}5$ °C, $t = 662{,}7$ s y $P = 36{,}1$ kPa, que además representa cierta similitud sobre el tratamiento de la muestra sensorialmente mejor calificada.

Financiamiento: Universidad de Caldas.

Palabras clave: deshidratación osmótica, fuerza impulsora, presión, color, contenido de grasa, contenido de humedad, superficie de respuesta.

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INTRODUCTION

The apple is the fruit of the apple tree, which belongs to the *Rosaceae* family (Flores Gárate *et al.*, 2015). *Malus domestica* refers to one of the species of the tree that defines the origin of the apple. It is known for its adaptability to a wide range of climatic conditions, diverse soils and various cultivation systems. The cultivation regions of *Malus domestica* include Europe, North America, South America, New Zealand, Australia, and Asia (Vigil Cannon, 2018).

From 2015 to 2019, global apple production averaged 84,722,560 tons (FAO, 2021). In South America, Chile, Brazil, and Argentina stood out as the top apple producers during the same period, producing an average of 1,719,909, 1,252,753, and 973,570 tons per year respectively. Colombia contributed an average of 3,523 tons to the global production, with the department of Santander as the country's top producer (FAO, 2021). Despite these local production figures, Colombia heavily relies on imports, particularly from top producers of the region such as Chile (AGRONET, 2021).

This crop is known for being associated with a high requirement for cold hours. However, genetic modifications have expanded and diversified yields in regions with fewer cold hours, such as Brazil and Colombia. There are more than a thousand different varieties of apple, whose structural and physicochemical characteristics generate various alternatives for technological use. Among the apple varieties are Fuji, Gala, Golden, Red Delicious, Pink Lady, Ana and Granny Smith (Vigil Cannon, 2018). The characteristics of the fruit vary according to various intrinsic factors of the matrix such as the concentration of soluble solids, the percentage of acidity, the percentage of epicarp, the pH, among others, which define the state of maturity and other physicochemical and organoleptic factors of the fruit such as texture, color, flavors and odors (Corona Leo, Hernández Martínez, & Meza Márquez, 2020).

From the nutritional point of view, the apple represents a rich source of water (about 85 % of its total composition), soluble carbohydrates (fructose, glucose and sucrose) and insoluble carbohydrates (fiber); additionally, it presents within its composition micronutrients such as beta-carotene, tocopherol, folic acid and to a lesser extent ascorbic acid; in addition, the presence of potassium as its most representative mineral (Corona Leo *et al.*, 2020; Pires *et al.*, 2018).

Levels of consumption of apples worldwide are very varied. They are frequently consumed fresh and in foods which are subjected to low technological transformation such as jams, juices, compotes, jellies, and dehydrated products (Mignard *et al.*, 2020). In Colombia, apples are primarily consumed fresh given the fact that more processed products are the often imported from powerful countries such as the United States and large apple producers such as Chile (Hernández Ruíz, 2017; Restrepo *et al.*, 2014).

The market for dehydrated fruits in Colombia is in the process of development. Currently, products such as bananas, pineapples, and dehydrated uchuvas are available on the market, popularized due their intense flavors, bright colors, and long shelf life compared to their fresh counterparts (Fuentes Meléndez & Rondón López, 2019). However, the fried and/or dehydrated snack market typically only utilizes more conventional produce such as tubers (Potato, cassava and yam) or bananas, largely neglecting the use of other fruits (Chacón Orduz *et al.*, 2017).

In Colombia, 59 % of the population consumes snack-type products within the context of entertainment, 38 % consume them in family gatherings and among friends, while the rest of the population does so to satisfy a craving or as a reward for a goal achieved throughout the day (Cámara de Comercio de Cali, 2018; Chacón Orduz *et al.*, 2017). Therefore, dehydrated fruit products serve as a viable alternative for consumers (Ochoa Moreno & Ortigoza Micolta, 2018).

Immersion frying is a dehydration process commonly used in the food industry because it prolongs the shelf life of the products and confers pleasant organoleptic characteristics to the consumer's palate (Torres *et al.*, 2018). Among the pretreatments used in the preparation of snack-type products is the osmotic dehydration process, a technique that aims to decrease the initial moisture content in the fruits by means of mass transfer between the food matrix and a hypertonic solution (Acosta Castaño *et al.*, 2020). This process consequently enhances specific flavors (Osorio Gutiérrez *et al.*, 2020).

The use of vacuum pressure in the process of immersion frying fruit slices involves the following: low oil temperatures, as for example in the frying of mango slices according to Acosta Castaño *et al.* (2020); improvement of quality parameters such as color, texture, and organoleptic qualities, as highlighted by Chong, Mazzitelli, and Quintero (2019) in the frying of Taro slices; and, lower fat content, as in the frying of white carrot (*Arracacia xanthorrizha* Bancroft) according to Calderón Marcillo (2019). It also reduces adverse effects on oil quality, preserves natural colors and flavors, and preserves most of the nutritional compounds in the food matrix subjected to the immersion frying process (Yaranga Oncihuay, 2019).

The objective of this work is to evaluate the effect of osmotic dehydration as a pretreatment on apple slices subjected to immersion frying, proposing the response surface methodology as an optimization method where the factors were driving force (ΔT), system pressure (P), and immersion time (t) and the response variables were moisture content, fat content, and color change.

METHODOLOGY

Raw material

To carry out the research, the raw material, apples of the variety *Malus domestica*, were obtained from a local market located in Manizales, Colombia. The fruits were examined to verify that they were free of physical damage and any type of contamination. In addition, the following physicochemical parameters were determined:

Soluble solids content

For the determination of soluble solids, the official method 932.12 of the AOAC was followed (AOAC, 2021). An Atago-brand digital refractometer, model PAL-1 (0-53 %), was used.

Color analysis

For the color analysis, a Konica Minolta model CM-5 colorimeter measuring CIE-L* a * b* color space was used according to the methodology proposed by (Lillote *et al*., 2021).

Moisture content

The moisture content was determined by means of the official method 930.15 of the AOAC (AOAC, 2021) in a Binder-brand natural convection oven, model ED053-UL.

Osmotic dehydration

The apples were processed in an industrial Omega brand slicer, taking a slice thickness of 2 ± 0.2 mm; from each of them pulp fragments were extracted with a punch of 29.4 mm diameter. The cylindrical samples obtained were then immersed in a solution containing 45 % sucrose ($C_{12}H_{22}O_{11}$) and 1 % citric acid ($C_6H_8O_7$).

The dehydration process was carried out at 20°C and 40°C, evaluating the dehydration kinetics on the apple slices during the times (min) 0, 5, 10, 15, 30, 45, 60, 90, 120, 180, 240 by performing moisture analysis and determining the percentage of soluble solids.

The defined response variables for osmotic dehydration of apple slices are listed below:

Soluble solids content

For the determination of soluble solids, the protocol indicated above in the quantification of soluble solids in raw material was again proposed.

Moisture content

For the determination of moisture content, the protocol noted above in the determination of moisture content in raw material was again proposed.

Immersion frying

The immersion frying process of the dehydrated apple samples was performed in a piece of equipment with 7 liters of capacity for oil. The product/oil ratio was 6.67 g/L [15]. The oil used was a blend of refined soybean oil, vegetable oils, and palm oil with antioxidant tert- butyl hydroquinone (TBHQ).

The defined response variables for osmotic dehydration of apple slices are listed below:

Moisture content

For the determination of moisture content, the protocol noted above in the determination of moisture content in raw material was again proposed.

Color analysis

The magnitude of the parameters L*; a*; b* was quantified according to the protocol proposed in the color analysis for raw material. Subsequently the color change (ΔE) was determined with (1) (Obregón & Obregón, 2019).

$$\Delta E = \tag{1}$$

The Δ of each of the coordinates consists of the comparison between the samples subjected to a certain treatment with the standard sample that corresponds to the fresh sample according to the color analysis carried out on the fresh sample.

Fat content

The fat content was determined according to the official method 920.39 of the AOAC in a Centricol-brand Soxhlet extraction apparatus with a capacity for 6 flasks and a Binder-brand natural convection oven, model ED053-UL.

Sensory analysis of apple snacks

They were analyzed by means of a hedonic test, with a scale of 5 points (where 1=I dislike it a lot and 5=I like it a lot). For this test we had the evaluation of 100 consumer judges, according to the methodology proposed by NTC 3925.

Statistical analysis

Osmotic dehydration

In order to determine the osmotic dehydration time for the apple slices, an analysis of variance was performed with a multiple range test, which was then used in the evaluation of the response variables established for osmotic dehydration.

Immersion frying

To determine the most statistically optimal immersion frying process of the apple slices, a response surface analysis was employed using a rotatable composite central design methodology. The data was then analyzed using the Statgraphics Centurion XVI software, where a 3-factor control system, ΔT (°C), P (absolute kPa), and t (s) was proposed. Relating ΔT according to (2).

$$\Delta T = - \tag{2}$$

Table 1. Limits of experimentation factors

Factor	-1	+1
ΔT (°C)	33	93
P (KPa)	24	65
T (sec)	180	540

Source: Own elaboration.

This generates an array of 20 treatments (Chavez Salazar *et al.*, 2017). Each response variable (Y) is generally estimated with (3).

$$Y = +\Delta T + P + t + \Delta + + + \Delta TP + \Delta Tt + tP \tag{3}$$

Here, β_i, from i: 0-9, corresponds to the coefficients estimated by each response variable analyzed based on the behavior of the temperature, immersion time, and pressure of the system during the process. The statistical optimization takes into account the effects and changes observed in each treatment on the response variables which emerged during the immersion frying process.

Sensory analysis

For the sensory analysis, a 95 % confidence level analysis of variance was conducted employing Tukey's test. The Statgraphics Centurion XVI software was used to carry out the statistical treatments proposed for the analysis.

RESULTS

Raw material

Soluble solids concentration (17.13±1.00 ºBrix), moisture content (80.99±0.59 %), and color coordinates L* (24.23±0.98), a* (25.12±1.12), and b* (10.26±0.34) were determined. Measurements were performed in triplicate on different apples, randomly taken from the batch designated for experimentation.

Osmotic dehydration

According to the results obtained, the osmotic dehydration process generated significant changes in the moisture and soluble solids content in the apple slices. Results revealed an increase of soluble solids in the matrix at 240 min of this process. Parallel to this, the moisture content decreased when the dehydration process reached the 240 min mark, at which point the maximum content of soluble solids within the matrix was achieved according to dehydration kinetics (See Figure **2** and Figure **3**). In the analysis of variance conducted at both operating temperatures, p-values below 0.05 were obtained, thus inferring that the temperature and the immersion time are significant in the process. Additionally, a multi- range test was administered which determined that there are significant differences between the temperatures and the time at which osmotic dehydration influences the composition of the samples, namely that a minimum time of 240 minutes at a temperature of 40°C is necessary to reach the maximum concentration of soluble solids in the dehydrated slices.

Similar results were reported by Estrada *et al*. (2018) who concluded from their study on processes of osmotic dehydration of mango and guava pieces that a sucrose solution at a concentration of 40 % w/w and a temperature of 80ºC is the best dehydration treatment for this type of food matrix. On the other hand, Osorio Gutiérrez *et al*. (2020) conducted dehydration processes using three different formulations of solutions (a solution with refined sugar, a sucrose solution-Jamaica extract, and an emulsion of Hi-Cap chili oleoresin starch and sucrose) in apple slices obtaining an increase in the mass transfer mechanisms at a temperature of 40ºC for the three formulations, further defining the constant immersion time of 120 min.

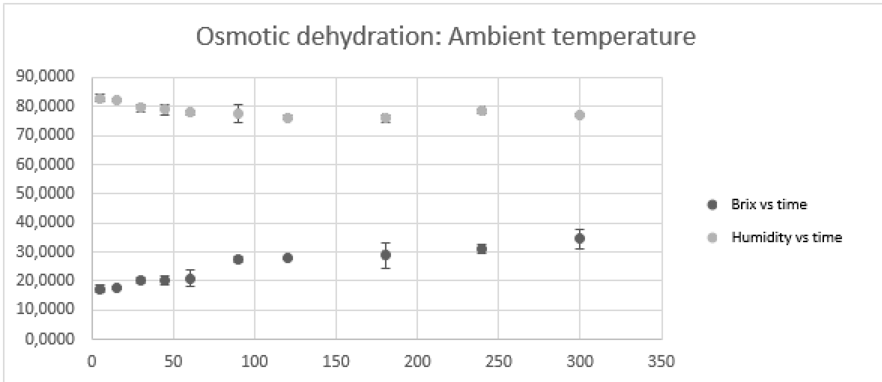

Figure 1. Osmotic dehydration kinetics of apple slices at room temperature

Source: Own elaboration

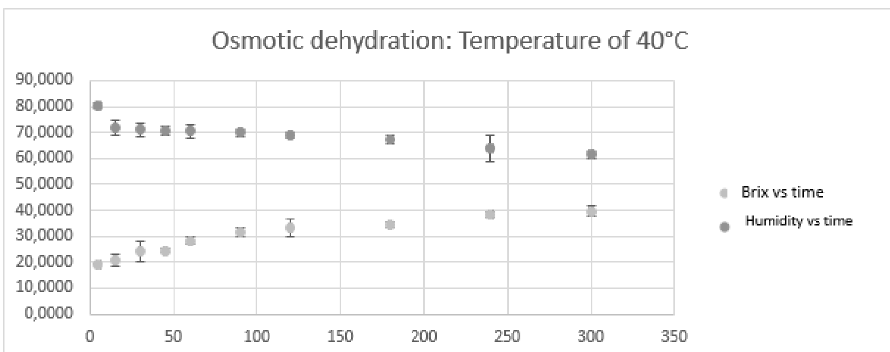

Figure 2. Osmotic dehydration kinetics of apple slices at 40ºC

Source: Own elaboration

Immersion frying

The immersion frying process of osmotically dehydrated apple slices was performed considering the system pressure, immersion time, and driving force. The following response variables were analyzed: color change, moisture content, and fat content. Physically, the apple slices underwent a change that contributed to the sensory evaluation (taste, texture, and aroma) of palatability of the product; in addition to the shelf life of the product under standard conditions, that is, without requiring refrigeration or other conditions that preserve the conditions of the fresh fruit over time for the consumer.

Table 2. Matrix of statistical treatments in the immersion frying process

Treatments	Factors			Color analysis			Response Variables		
	P	t	ΔT	L*	a*	b*	Δ Color	Humidity	Oil
UNITS	kPa	Sec	°C	N/A	N/A	N/A	N/A	%	%
1	44.5	360.0	63.0	39.0	15.1	23.1	22.1±1.19	4.6 ± 1.3	36.6 ± 2.3
2	44.5	360.0	63.0	41.2	14.4	22.5	23.6±1.18	4.7 ± 0.6	32.1 ± 1.9
3	44.5	360.0	63.0	41.9	9.8	20.9	25.9 ± 1.00	5.1 ± 1.3	42.2 ± 4.1
4	44.5	360.0	63.0	37.3	14.5	20.6	19.9± 0.86	7.1 ± 1.9	47.1 ± 1.9
5	44.5	360.0	63.0	37.1	14.4	20.5	19.8± 0.87	5.4 ± 1.3	39.6 ± 2.6
6	44.5	360.0	63.0	41.9	14.2	24.4	25.3± 1.17	3.8 ± 1.6	43.6 ± 3.2
7	24.0	180.0	33.0	52.6	5.1	32.7	41.4± 1.10	24.6 ± 5.0	16.2 ± 3.6
8	65.0	180.0	33.0	51.8	4.0	25.7	38.2± 0.87	20.7 ± 2.3	22.0 ± 3.5
9	24.0	540.0	33.0	56.3	3.7	32.8	44.8± 1.15	8.8 ± 0.7	17.7 ± 1.9
10	65.0	540.0	33.0	48.3	9.9	27,	33.4 ± 1.16	8.6 ± 3.3	31.1 ± 3.4
11	24.0	180.0	93.0	35.4	13.6	14.4	17± 1.04	46.4 ± 0.1	32.5 ± 3.6
12	65.0	180.0	93.0	26.0	4.4	3.2	22± 2.87	3.3 ± 0.8	33.6 ± 1.1
13	24.0	540.0	93.0	27.1	5.5	3.8	21± 2.71	5.1 ± 0.9	31.3 ± 1.8
14	65.0	540.0	93.0	25.8	1.9	1.4	25± 2.96	2.6 ± 1.6	35.9 ± 4.6
15	10.0	360.0	63.0	63.8	4.1	31.2	49.5± 1.36	3.3 ± 1.6	16.3 ± 0.8
16	79.0	360.0	63.0	35.0	12.2	13.6	17.4± 0.89	10.1 ± 3.0	18.6 ± 0.4
17	44.5	57.3	63.0	51.6	3.8	24.9	37.8± 0.83	22.3 ± 2.5	20.2 ± 1.4
18	44.5	662.7	63.0	32.4	13.8	12.7	14.4 ± 1.08	5.4 ± 1.2	18.4 ± 2.7
19	44.5	360.0	12.5	48.6	4.6	29.7	37.4± 0.96	19.4 ± 0.9	21.4 ± 3.4
20	44.5	360.0	113.5	25.2	0.6	0.1	26.7± 2.95	2.7 ± 1.3	64.1 ± 2.7

Source: Own elaboration

The mean values with their standard deviation and the ANOVA of the quality parameters of the fried apple slices as a function of the factors ΔT (°C), P (kPa absolute), and t (s) are shown in Table 2 and Table 3 respectively. Likewise, Figures **4**, **5**, and **??** present the behaviors in three dimensions of the response volumes of each quality parameter depending on independent variables or factors.

The behavior of the color change (ΔE) presented significant differences with respect to the driving force ΔT (main effect) and independent term (constant) (see Table 3), fluctuating in average values between 17 and 49.5 (See Table 2). As Mendoza Hurtado and Mendoza Borges (2015) noted, there are certain ranges of appreciation of color changes: negligible ($0{,}0 < \Delta E < 0{,}5$), slightly perceptible ($0{,}5 < \Delta E < 1{,}5$), remarkable ($1{,}5 < \Delta E < 3{,}0$), appreciable ($3{,}0 <$

Table 3. ANOVA for osmo-dehydrated apple slices subjected to immersion frying

Item	Parameter	ΔE	Moisture Percentage	Fat Percentage
Independent Term	*Constant*	22.6*	5.0*	40.1*
Main effect	*A: Pressure*	-8.7	-5.6	4.2
	B: Immersion time	-5.0	-14.5*	1.3
	C: Driving force	-13.4*	-4.9	17.3*
Quadratic effect	AA	7.3	2.9	-15.3*
	BB	2.1	7.9	-14.0*
	CC	6.4	5.9	2.6
Interaction Effect	AB	-2.3	11.0	2.8
	AC	6.0	-10.4	-3.3
	BC	2.1	-3.5	-2.4
Linear fit	**r (%)**	**82.8**	**86.7**	**94.0**

* Statistically significant parameter ($p < 0.05$)

Source: Own elaboration

$\Delta E < 6{,}0$), and very appreciable (ΔE more than 6.0). Following this categorization, all samples of the 20 experimental treatments have very appreciable color changes. In Figure **3**, it is evident that in the range of ΔT greater than 40°C, P greater than 40 kPa, and t below 800 s treatments with smaller color changes are presented.

According to the study by Pillajo *et al*. (2019), which involved vacuum immersion frying of mashua chips, the color behavior of the chips is mainly determined by the temperature of the frying medium. On the other hand, Acosta Castaño *et al*. (2020) point out that temperature is the determining variable in vacuum immersion frying of mango chips because the color change is mainly disturbed on the b* parameter. Consequently, the frying process at sub- atmospheric pressures with lower oil temperatures generates an alternative in the improvement of the organoleptic qualities related to the visual component of the product.

Regarding the moisture content, the parameters with significant differences as represented in Table 3 were the independent term (constant) and the immersion time (main effect); this parameter fluctuated between 2.6 % and 46.4 % (See Table 2). Likewise, according to Arrazola *et al*. (2021) the moisture contents of fried products, such as potato and yam, are 1.5 % to 3 % moisture, which aligns with some of the results presented in Table 2.

Figure **4** illustrates low humidity in the apple snacks when subjected to pressure values above 20 kPa, driving force below 40°C, and immersion times below 600 s. It should be noted that some of the values of the response surface fall outside the range of average fluctuations; this may be due to the processing conditions in addition to the structural and chemical charac-

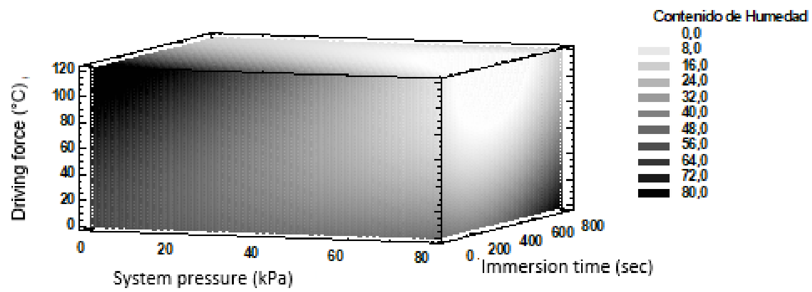

Figure 3. Color change response surface 3d mesh chart in apple snack

Source: Own elaboration

teristics of the apples. However, Trejo Escobar *et al.* (2019) posit that the effect of the pressure and the immersion time of the potatoes in the fryer significantly affect the moisture content, concluding that the best operating conditions are sub-atmospheric pressures and low oil temperatures.

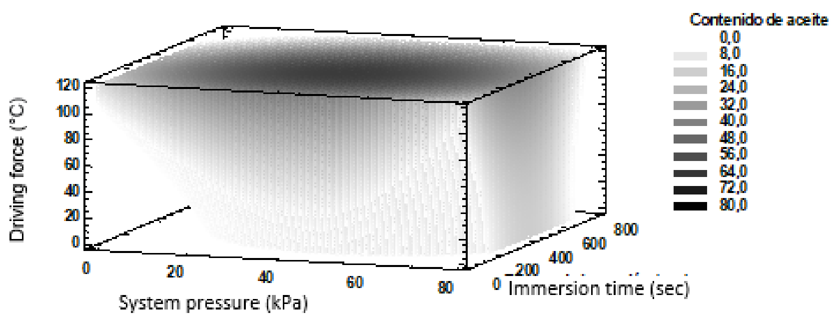

Figure 4. 3D mesh graph of moisture content response surface in apple snack

Source: Own elaboration

Regarding fat content, the most influential variables were the independent term (constant), ΔT (main effect and square effect), P (square effect) and t (square effect) (see Table 3). Additionally, the average values of fat content ranged between 16.2 % and 64.1 % (see Table 2). In Figure **5**, the areas representing lower fat contents in the apple snacks correspond to system pressure values (20-60) kPa, driving forces above 80°C, and immersion time (100-600) s. The above behavior may be due to the osmotic dehydration pretreatment effect on the apple slices. Some authors have reported results in the same trend: Gallon Bedoya (2017) in frying by vacuum immersion in potato, Acosta Castaño *et al.* (2020) in frying by vacuum immersion of mango, and Arteada Medina *et al.* (2019) in frying processes by vacuum immersion of lulo, where the matrices when subjected to a frying process at sub-atmospheric pressures generate products of low fat content and of more favorable organoleptic characteristics, typical of snacks such as the texture and/or crunchiness of the product.

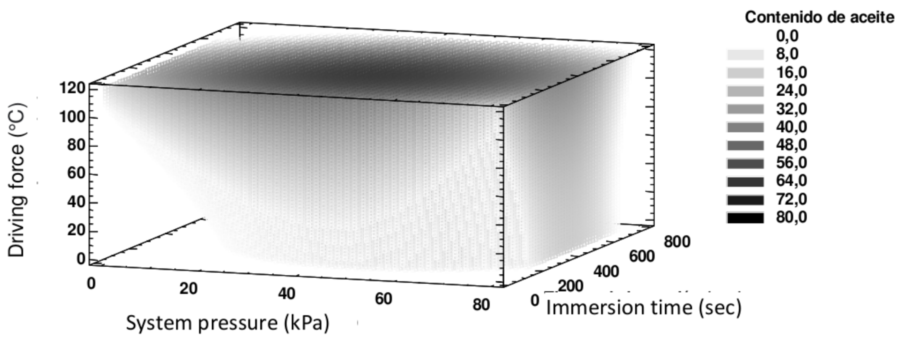

Figure 5. Oil content response surface 3d mesh graph in apple snack

Source: Own elaboration

Immersion frying with the use of low pressure differentials acts as a method of transformation and conservation of fried slices. However, the technique enhances its effect in matrices with low humidity (Dehghannya & Ngadi, 2021), which is the reason why osmotic dehydration stands out as a suitable technique for reducing water on apple slices. Furthermore, the technique allows for the formation of a film around the matrix, a phenomenon that prevents molecular disintegration and losses in frying operation yields, as reported by Arshied *et al.*, (2021) in the osmotic dehydration of apple cubes.

Finally, Table 4 summarizes the optimal values of the process conditions in obtaining apple snacks by vacuum immersion frying, where the moisture content, color change, and fat content are minimized with an impact of 3.0 each.

Table 4. Optimal values of process variables in the immersion frying of osmo-dehydrated apple slices

Factor	Optimum value
Driving force (ΔT)	72.45
System Pressure (kPa)	36.06
Immersion time (sec)	662.72

Conclusions

Osmotic dehydration as a pretreatment prior to immersion frying is a technique of interest for enhancing the organoleptic characteristics and the evaluable physicochemical characteristics or quality parameters of the final product, as well as for the preservation of the frying medium.

Taking into account the optimal values for frying determined from this course of study, ΔT (72°C), pressure (36 kPa) and time (663s), vacuum frying can be considered to be an agro-industrial transformation process suitable for dehydration in the production of fruit snacks since, by modifying the pressure of the operating system, the use of high temperatures in the oil is reduced. Monitoring system pressure and osmotic dehydration during the vacuum frying process of fried apple slices proves to be beneficial in terms of the enhanced sensorial value of the product as well as its increased shelf life.

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INVESTIGACIÓN

Análisis de susceptibilidad por movimientos en masa implementando el método Mora-Vahrson modificado para el corregimiento de Chemesquemena (Cesar, Colombia)

Analysis of susceptibility by mass movements implementing the modified Mora-Vahrson method for the district of Chemesquemena, Cesar, Colombia

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Abstract

Objective: Analyze the susceptibility of the slopes to the occurrence of mass movements, implementing the Mora-Vahrson methodology adapted for the district of Chemesquemena located within the Kankuamo indigenous reservation, department of Cesar (Colombia).

Methodology: Initially a review of the state of the art was carried out in academic and scientific databases. Subsequently, field phases were carried out to take samples of rock, soil and cartographic survey at a scale of 1:100.000, allowing to know and identify the geological, geomorphological aspects and general characteristics. With the ArcGIS software, the images were analyzed using digital elevation models (3D effect), in the processing, maps at a scale of 1:100.000 were obtained.

Results: The areas with the greatest susceptibility are located to the NW of the district of Chemesquemena (Colombia), representing 70 % of the total areas due to high slopes, high rainfall, lithology, soil type, vegetation cover, permanent crops and subunits. geomorphological such as denuded mountain ranges and residual hills; and 30 % low to very low susceptibilities.

Conclusions: The conditioning factors that generate the greatest influence on susceptibility correspond to the lithology, high slopes characteristic of the land, permanent crops and grass as the main cover. The lithological units

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were classified mainly as intrusive igneous rocks with an advanced state of alteration, generating weakening of the materials. Crops require periodic irrigation systems, resulting in a constant supply of water to soils and slopes (over- saturation), and changes in mechanical properties; In addition, the grass does not contribute to favoring the stability of the soil.
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Keywords: Colombia, Chemesquemena, Mora-Vahrson method, Mass movements, Susceptibility.

Resumen

Objetivo: Analizar la susceptibilidad de las laderas frente a la ocurrencia de movimientos en masa, con la implementación de la metodología Mora-Vahrson adaptada para el corregimiento de Chemesquemena, ubicado dentro del Resguardo Indígena Kankuamo, departamento del Cesar (Colombia).
Metodología: Inicialmente se realizó revisión del estado del arte en bases de datos académicas y científicas. Luego, se realizaron fases de campo para toma de muestra de roca, suelo y levantamiento cartográfico a escala 1:100 000; de esta manera se conocieron e identificaron los aspectos geológicos, geomorfológicos y características generales. Con el *software ArcGIS* se analizaron las imágenes mediante modelos de elevación digital (efecto 3D), en el procesamiento, se obtuvieron mapas a escala 1:100 000.
Resultados: Las zonas con mayor susceptibilidad se localizan hacia el noroeste del corregimiento de Chemesquemena (Colombia), las cuales representan el 70 % de las áreas totales debido a las altas pendiente, alta pluviosidad, litología, tipo de suelo, cobertura vegetal, cultivos permanentes y subunidades geomorfológicas como sierras denudadas y colinas residuales; y el 30 % susceptibilidades bajas a muy bajas.
Conclusiones: Los factores condicionantes que generan mayor influencia de susceptibilidad corresponden a la litología, altas pendientes características del terreno, cultivos permanentes y pasto como cobertura principal. Las unidades litológicas fueron clasificadas mayoritariamente como rocas ígneas intrusivas en avanzado estado de saprolitización que producen debilitamiento de los materiales. Los cultivos requieren sistemas de riegos periódicos, lo que implica un aporte constante de agua a los suelos y taludes (sobresaturación), y una alteración en las propiedades mecánicas; además, el pasto no favorece la estabilidad de los suelos.
Financiamiento: Fundación Universitaria del Área Andina.

Palabras clave: Chemesquemena, Colombia, método Mora-Vahrson, movimientos en masa, Susceptibilidad.

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INTRODUCTION

El aumento de la población, la exigencia de usos de suelo y la inoperancia por parte de las autoridades gubernamentales han causado un desarrollo urbanístico incalculable y descontrolado, lo cual produce la ocupación de terrenos susceptibles a fenómenos de remoción en masa que pueden tener potencial de pérdidas humanas, económicas y materiales (Aristizábal *et al.*, 2019; Vargas-Cuervo, 2000; Galindo Serrano y Alcántara Ayala, 2015; Ayala y García, 2008; Moreno *et al.*, 2006; Quintana-Cabeza *et al.*, 2022). Los movimientos en masa han sido definidos como desplazamientos del terreno a favor de la pendiente que suelen generarse por acción de la fuerza de gravedad e inestabilidad de los taludes, bajo la influencia de algunos factores geológicos, ambientales, sociales, antrópicos, como el agua, actividades sísmicas, la aplicación de carga excesiva, excavaciones para la adecuación de viviendas o la apertura de senderos y vías, entre otros. Según Cruden (1991), cuando se habla de *movimientos en masa* se refiere principalmente a todo proceso ladera abajo de una masa ya sea de detritos o rocas. "Estos movimientos producen cambios visibles en el terreno como grietas, hundimientos e incluso desprendimientos de grandes cantidades de material, de ahí que puedan ocasionar la destrucción y el posible deterioro de la infraestructura pública" (Alcaldía de Medellín., 2020).

El departamento del Cesar se encuentra constituido por accidentes geográficos, entre ellos la Sierra Nevada de Santa Marta (SNSM) y la serranía del Perijá (SP); por tanto, el Cesar en conjunto con otros departamentos de la región Caribe se encuentran ubicados en zonas categorizadas como susceptibles a la ocurrencia de procesos geológicos asociados a la geodinámica externa (López *et al.*, 2020). Según Serpa-Silva (2017), "en el flanco oeste de la SNSM los procesos no surgen espontáneamente, al contrario, el tiempo es el factor más importante, junto con otras variables (litología, lluvias, erosión) que en conjunto forman un escenario propicio para el desencadenamiento del desastre". Este estudio tiene como objetivo analizar la susceptibilidad de las laderas frente a la ocurrencia de movimientos en masa, a través de la metodología Mora-Vahrson adaptada para el corregimiento de Chemesquemena ubicado dentro del Resguardo Indígena Kankuamo, departamento del Cesar (Colombia) (figura **1**).

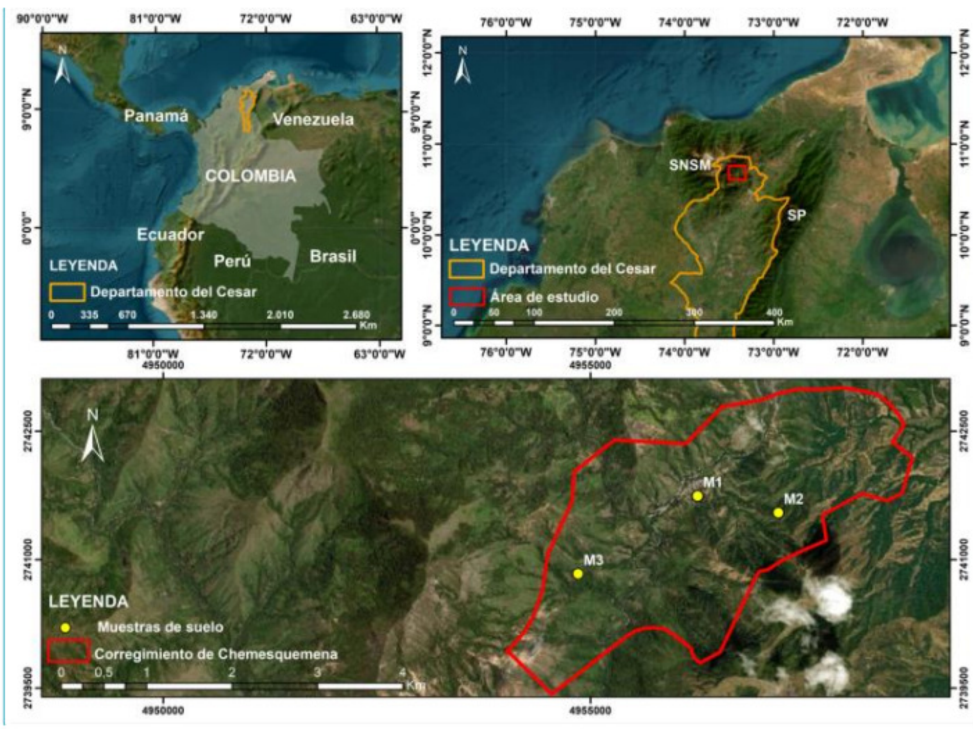

Figura 1. Localización del área de estudio

Metodología

Inicialmente se efectuaron revisiones del estado del arte en bases de datos académicas y científicas, así como la consulta de antecedentes relacionadas con eventos de susceptibilidad ocurridos en el área de estudio. Posteriormente, se adelantaron fases de campo para toma de muestra y levantamientos cartográficos a escala 1:100 000; de esta manera se conocieron e identificaron aspectos geológicos, geomorfológicos y características generales propuestas por la metodología del Servicio Geológico Colombiano (SGC) (Carvajal Perico, 2012a; Carvajal Perico, 2012b). Se tomaron tres (3) muestras (M1, M2 y M3) de suelo con un peso promedio de 3 kilogramos cada una para análisis fisicomecánicos (granulométrico, humedad, peso específico y límites de Atterberg) según la norma I.N.V. 2012, con el fin de corroborar los datos obtenidos en campo y los resultados producto del uso de la metodología de Mora y Vahrson (1994). Esta metodología permite la superposición de diferentes capas que son representadas por factores pasivos o condicionantes, y factores activos o detonantes, y la evaluación de susceptibilidad dividida en tres partes: el grado de susceptibilidad por elementos pasivos, el análisis por elementos activos y el análisis de evaluación de la susceptibilidad resultante al superponer todas las capas: Esto permite la asignación de valores o pesos a cada una de las variables que condicionan la ocurrencia de los movimientos (Barrantes-Castillo *et al.*, 2011).

$$S = P \times D \tag{1}$$

Donde:

S: grado de susceptibilidad a deslizamientos.

P: valor producto de la combinación de los parámetros pasivos.

D: valor del factor de disparo de los parámetros activos.

Para la determinación de la cobertura vegetal se basó en la metodología de Corine Land Cover adaptada por el Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM) (IDEAM, 2010), lo cual posibilita la elaboración de capas temáticas de cobertura de suelo a partir de la interpretación de imágenes satelitales tipo Landsat 8, y la clasificación supervisada con combinación de bandas roja, verde y azul.

Para la construcción del mapa de precipitación se analizaron los promedios mensuales y anuales de precipitación de las estaciones pluviométricas de los municipios de Patillal, San Sebastián y Atánquez, del IDEAM, bajo el método de interpolación IDW a través del software *ArcGIS 10.5*. Posteriormente se realizó una conversión de formato ráster a polígono que asignó los índices de susceptibilidad para elementos pasivos y activos. Para el análisis de la susceptibilidad por elementos pasivos se superpuso cada parámetro, al otorgarles valores a los porcentajes según los factores con mayor influencia en la susceptibilidad; y para el análisis de la susceptibilidad por elementos activos o condicionantes, se establecieron valores porcentuales a cada capa temática elaboradas para el mapa de precipitación y sismicidad, de igual manera que se hizo para los parámetros pasivos.

Para el factor de sismicidad se tomó como referencia el catálogo sísmico del Servicio Geológico Colombiano (SGC, s. f.), del 1 de marzo de 2018 hasta la actualidad; se identificaron los puntos sísmicos más cercanos al área de estudio y, posteriormente, se realizó una simulación mediante la herramienta Buffer (*ArcGIS 10.5*) con un radio de 2 km; así se determinaron las zonas geográficas del corregimiento que se encuentran dentro del área de influencia de los epicentros sísmicos. Además, con ArcGIS 10.5 se analizaron las imágenes mediante modelos de elevación digital (efecto 3D), en el procesamiento, y se obtuvieron mapas a escala 1:100 000.

Para el respectivo estudio de los modelos se recurrió a curvas de nivel cada 5 m que fueron obtenidas a través de un modelo de elevación digital (DEM, por su sigla en inglés) mediante la aplicación ALOS PALSAR con una resolución de 12,5×12,5. Una vez delimitada el área correctamente y con el *software ArcGIS 10.5*, se obtuvo una red irregular triangular (TIN) que permitió apreciar previamente las alturas características del terreno. Para la teleinterpretación se tuvieron en cuenta los parámetros estipulados por el SGC (2012) y Carvajal Perico (2012b); para la diferenciación de las subunidades geomorfológicas y agentes morfodinámicos, la nomenclatura de las dichas subunidades se basó en las estipuladas por el SGC (2012) y Carvajal-Perico (2012b).

Resultados

Parámetros utilizados para el cálculo de la susceptibilidad

Factor pendiente

El área del corregimiento se caracteriza por presentar pendientes medias a muy fuertes que oscilan entre 30° a >45° con presencia de procesos denudacionales, según Mora y Vahrson (1994) con valores de susceptibilidad entre 4 y 5 que abarcan el 55 % del área; las zonas con pendientes moderadas que oscilan entre 12° a 30° corresponden a áreas de deslizamientos donde pueden llegar a ser ocasionales, debido a que los factores de susceptibilidad obtienen un valor de 3; las planicies y zonas ligeramente inclinadas son casi ausentes en el corregimiento con pendientes que oscilan de 3° a 12° (figura **2**).

Geología regional

El departamento del Cesar está compuesto por tres áreas de importancia geológica: el macizo de la Sierra Nevada de Santa Marta (SNSM), la Serranía del Perijá y la cuenca del Río Cesar (De los Reyes-Díaz *et al.*, 2022). La SNSM es un macizo montañoso de forma triangular localizado en la región Caribe de Colombia, entre las latitudes 9º 55'N y 11º 22'N y longitudes 72º 30' W y 74º 12'W; cubre áreas de los departamentos de Magdalena, Cesar y La Guajira; se levanta desde el nivel del mar y llega a tener elevaciones cercanas a los 5800 m. Es el macizo montañoso costero más elevado del mundo (Colmenares *et al.*, 2007); limita al este con los lineamientos del Cesar, norte Falla Oca y suroeste Falla de Santa Marta- Bucaramanga.

Geología local

Esta investigación se centra principalmente en la geología del corregimiento de Chemesquemena, municipio de Valledupar, constituida mayoritariamente por rocas ígneas (60 %) y

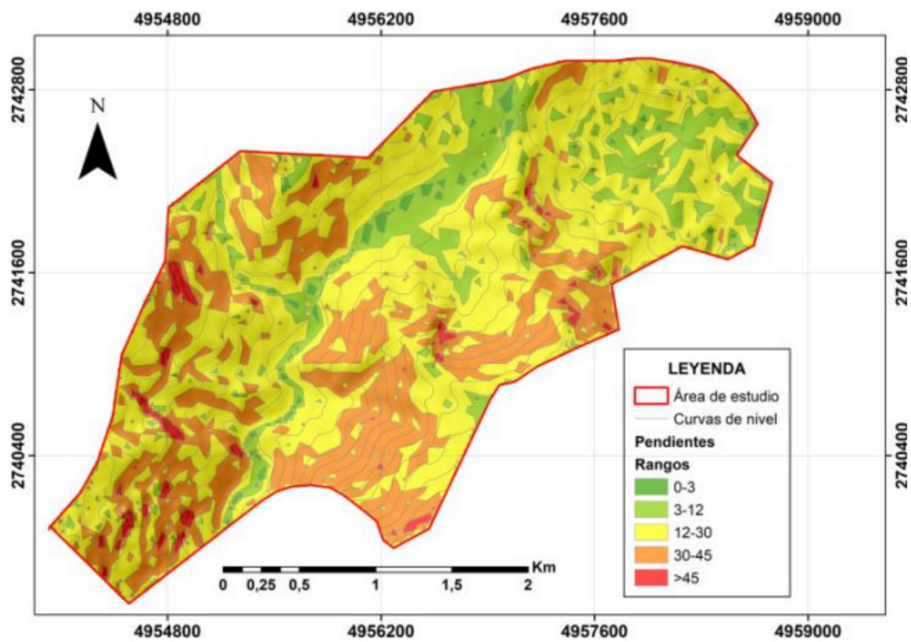

Figura 2. Mapa de pendientes

minoritariamente por sedimentarias (figura **3**), correspondientes al Batolito de Atánquez, cuyas edades varían del Jurásico, Jurásico medio y superior.

A continuación, se describen las unidades litológicas presentes en la región del norte de Valledupar, específicamente en el Batolito de Atánquez (Ja) y aluviales recientes.

Batolito de Atánquez (ja)

El Batolito de Atánquez se encuentra aflorando en el sector oeste del corregimiento de Chemesquemena, principalmente en la parte alta del Río Guatapurí con coordenadas 10°42’63”N 73°24’54”W. Esta unidad ha sido estudiada y caracterizada por el SGC en la parte nororiental de la plancha 27 en la transecta 15 (Colmenares *et al.*, 2007) que corresponde a Patillal-Atánquez-Chemesquemena a Sabana Crespo, y descrita originalmente por Tschanz *et al.* (1969). Para estos autores, la edad del batolito, obtenida mediante dataciones radiométricas, indica que es contemporáneo a otros batolitos pertenecientes al cinturón nororiental del Jurásico medio y cercano a la edad del Batolito de Aracataca con aproximadamente 166±12 Ma.

Se identificaron rocas plutónicas de composición granítica constituida principalmente por feldespatos y cuarzos (figura **4**A). Los granitos presentan una textura fanerítica, son hipidiomórficos y con tamaño de grano fino. En este sector se observó la presencia de un dique de composición basáltica, con textura afanítica, tamaño de grano casi imperceptible y un espesor aproximado de 50 cm (figura **4**B).

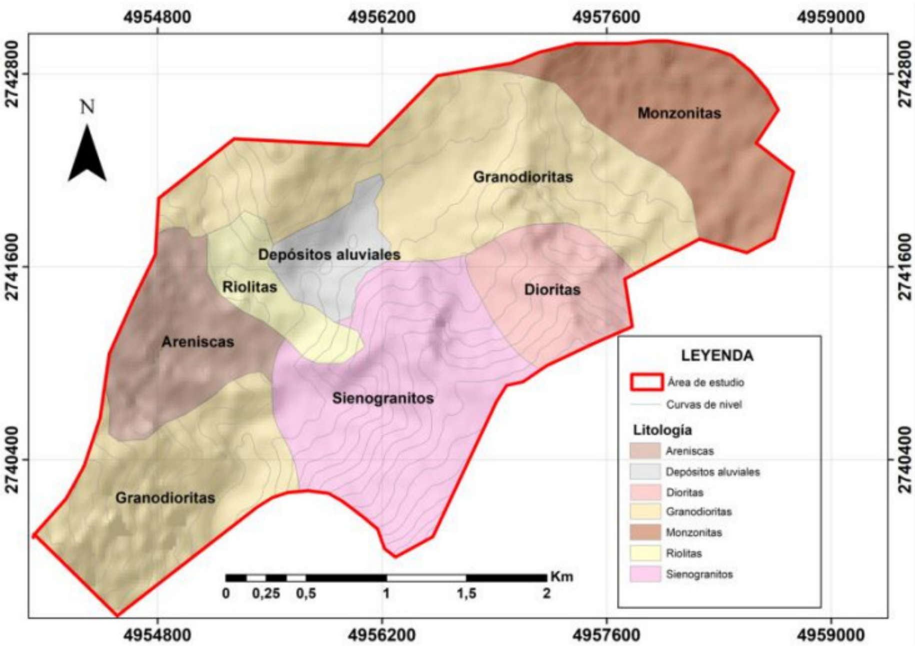

Figura 3. Mapa litológico del corregimiento de Chemesquemena

Figura 4. A. Granito (textura fanerítica). B. Aflorando en la cuenca alta del Río Guatapurí, presencia de diques de composición máfica de 40 cm a 50 cm de espesor

Aluviales recientes (qal)

Corresponde a los depósitos ubicados en las coordenadas 10°42′65″N, 73°24′2″W como consecuencias de la dinámica de todos los drenajes superficiales del Río Guatapurí. Este tipode depósito presenta materiales con granulometría que oscilan entre guijarro a bloques de composición ígnea.

Factor geomorfología

Cerro residual (dcrs)

Esta subunidad geomorfológica fue cartografiada hacia la zona noreste del corregimiento de Chemesquemena con coordenadas 10°43′05″N 73°23′23″W. Los cerros residuales corresponden a terrenos topográficamente preponderantes, con una morfología de cimas redondeadas con pendientes muy inclinadas, producto de severos procesos de meteorización que se dan en climas tropicales húmedos (SGC, 2012). Esta subunidad muestra pendientes escarpadas y abruptas asociadas con suelos residuales gruesos de origen metamórfico e ígneo; también se observan, hacia la cima, los intensos procesos de meteorización y erosión que se ven influenciados por la poca cobertura vegetal (SGC, 2012) (figura **5**).

Colina residual disectada (dcrd)

Las colinas residuales disectadas son cimas redondeadas que culminan en pendientes moderadamente inclinadas que registran un índice de relieve de bajo a medio. Su formación está asociada a actividades tectónicas y de erosión y meteorización que se distinguen por el desarrollo de una red de drenaje con un leve grado de disección (SGC, 2012). Esta fue cartografiada hacia la zona noroeste del área de estudio correspondiente a las coordenadas 10°42′72″N; 73°24′56″W; se caracteriza por pendientes que oscilan entre los 30° y 35°, donde los procesos denudacionales suelen ser bastante intensivos (figura **5**).

Colina remanente (dcre)

Esta geoforma correspondiente a las coordenadas 10°42′17″N; 73°24′73″W presenta una cima redondeada y bordeada que se encuentra limitada por laderas con pendientes abruptas a escarpadas, con un índice de relieve bajo a medio. Este tipo de subunidad es característico de zonas aisladas en las que topográficamente sobresalen. Las colinas remanentes se originan por denudaciones intensas (SGC, 2012) (figura **5**).

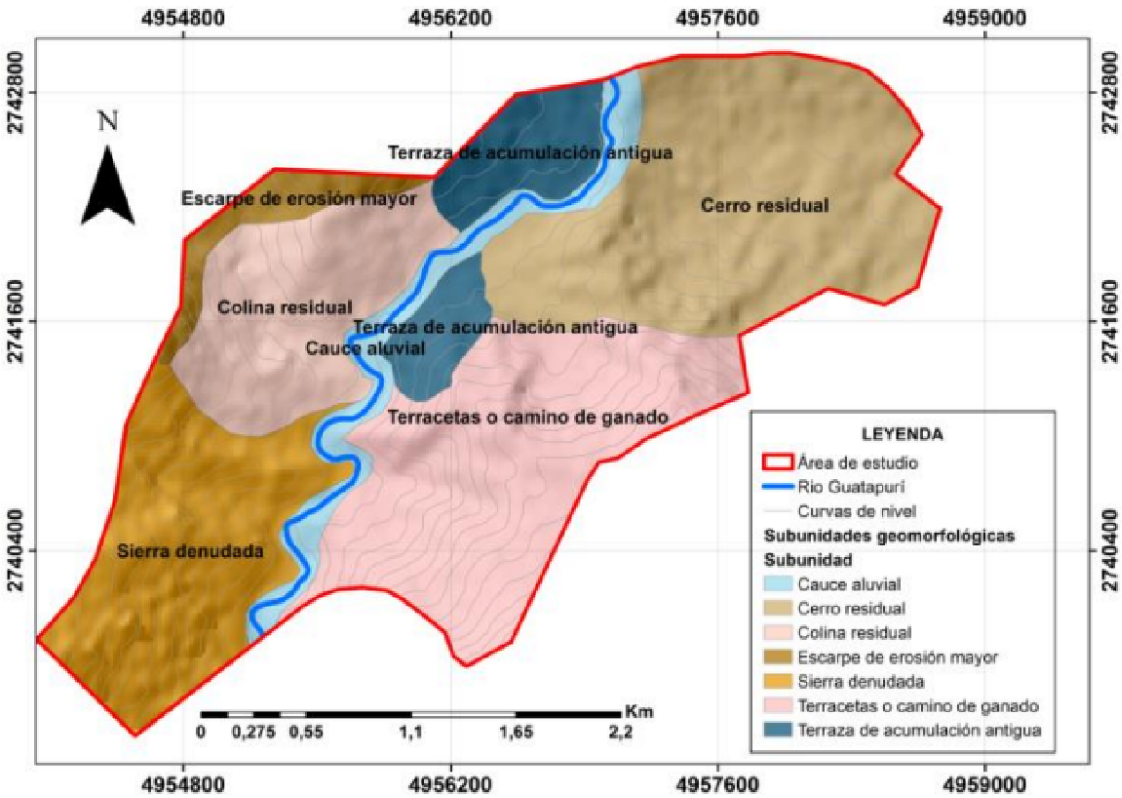

Figura 5. Mapa geomorfológico

Geoformas de ambiente fluvial

Los depósitos cuaternarios en el área de estudio se ubican hacia la zona central con coordenadas 10°42’63”N 73°24’16”W. Se caracterizan por gravas y conglomerados redondeados como producto del transporte propiciado por el cauce del Río Guatapurí (figura **5**).

Rasgos geomorfológicos de origen antrópico

La zona de estudio está marcada por una gran cantidad de procesos erosivos como las terracetas, o camino de ganado, más evidenciables hacia el sureste con coordenadas 10°42’25”N 73°23’92”W. Este rasgo se encuentra en el área de trabajo debido a que el pastoreo y la práctica de la ganadería son frecuentes, puesto que constituye una de las principales fuentes de economía de la región (figura **5**).

Factor de uso y cobertura del suelo

Las variaciones en la cobertura vegetal inciden directamente en la susceptibilidad de los deslizamientos de tierra. El corregimiento de Chemesquemena comprende, en su mayoría, zonas agrícolas y cultivos permanentes como caña, café y cacao, como actividad económica principal, además, pastos y vegetación secundaria y zonas arborizaciones escasas; esto indica que la cobertura vegetal incide como factor condicionante de los movimientos en masa y denudaciones intensas (figura **6**).

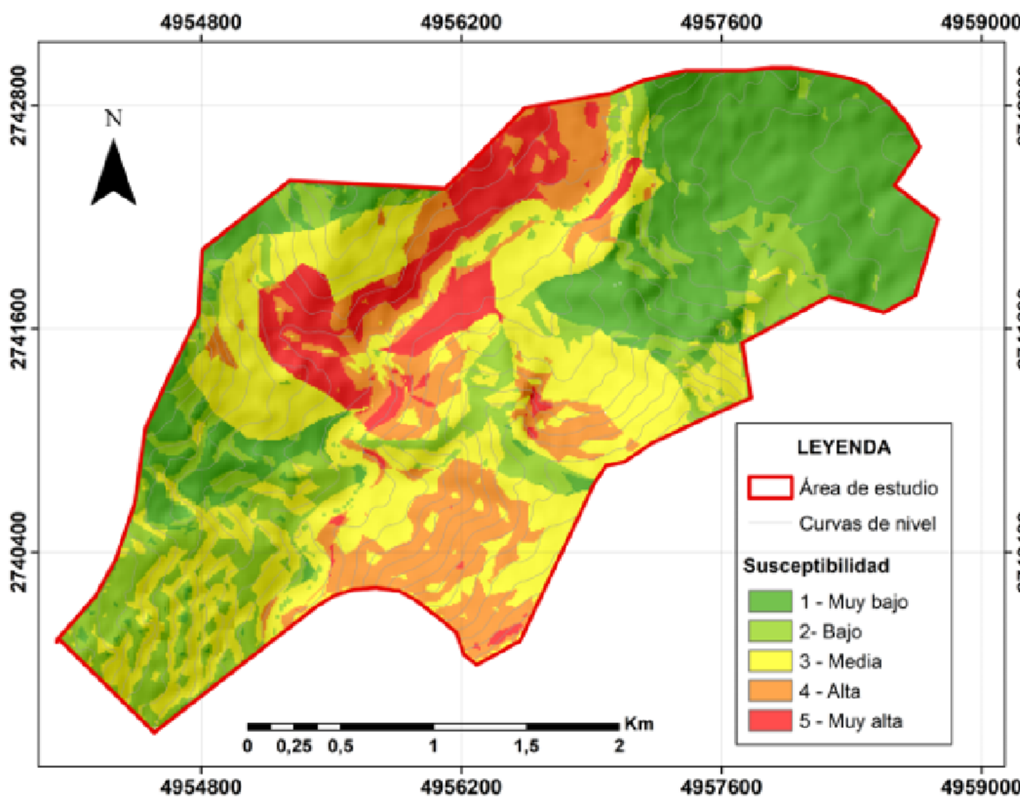

Figura 6. Mapa de cobertura del suelo

Susceptibilidad por elementos pasivos

Las zonas noreste y suroeste concentran las categorías más bajas de susceptibilidad, mientras que la zona central del corregimiento varía de media a muy alta; estas se catalogan como áreas propensas a procesos naturales en lo que a factores condicionantes se refiere (figura **7**). Adicional a ello, el resultado obtenido en este estudio permitió corroborar la información y datos históricos referentes a movimientos en masa en el corregimiento, donde el factor con mayor influencia en su generación corresponde a las unidades litológicas altamente meteorizadas y a suelos alterados por procesos asociados a la agricultura. Las zonas con mayor susceptibilidad a movimientos en masa corresponden a las zonas rojas y naranjas, las medias a las tonalidades amarillas y las bajas a los tonos verdes (figura 7). Los parámetros evaluados fueron geomorfológicos (20 %), litológicos (30 %), pendiente (30 %), cobertura vegetal (20 %).

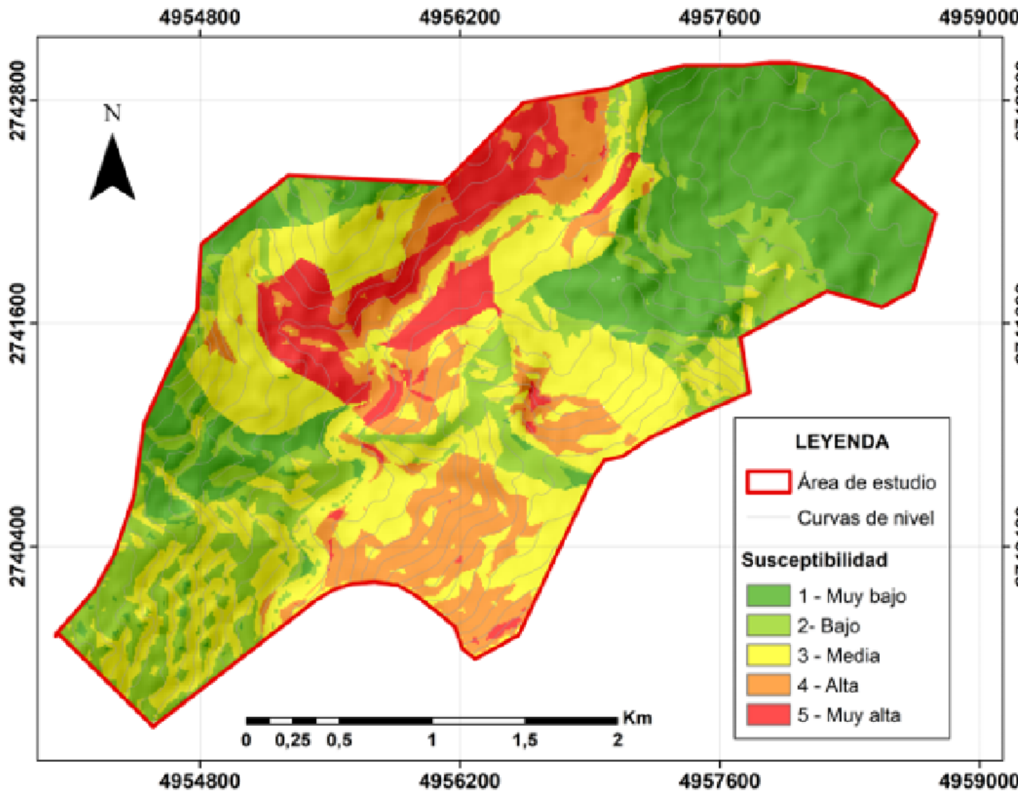

Figura 7. Mapa de susceptibilidad por elementos pasivos

Factor precipitación

Los valores obtenidos e ilustrados en la figura **8** indican que la zona noroccidental presenta mayor pluviosidad (504 mm a 544 mm), por lo que es más susceptible a fenómenos de movimientos en masa, contrario a la zona nororiental (385 mm a 425 mm).

Factor sismicidad

Analizada la información del catálogo sísmico del SGC, se evidenció que no hay registro de epicentros de actividad sísmica en el área de estudio, por lo que fue necesario tomar los últimos epicentros y más cercanos a la zona de estudio ocurridos en el cerro Yosagaka con magnitud de 1,5, y el cerro Macuamaque con magnitud de 1,9 en la escala de Richter (figura **9**). Las zonas

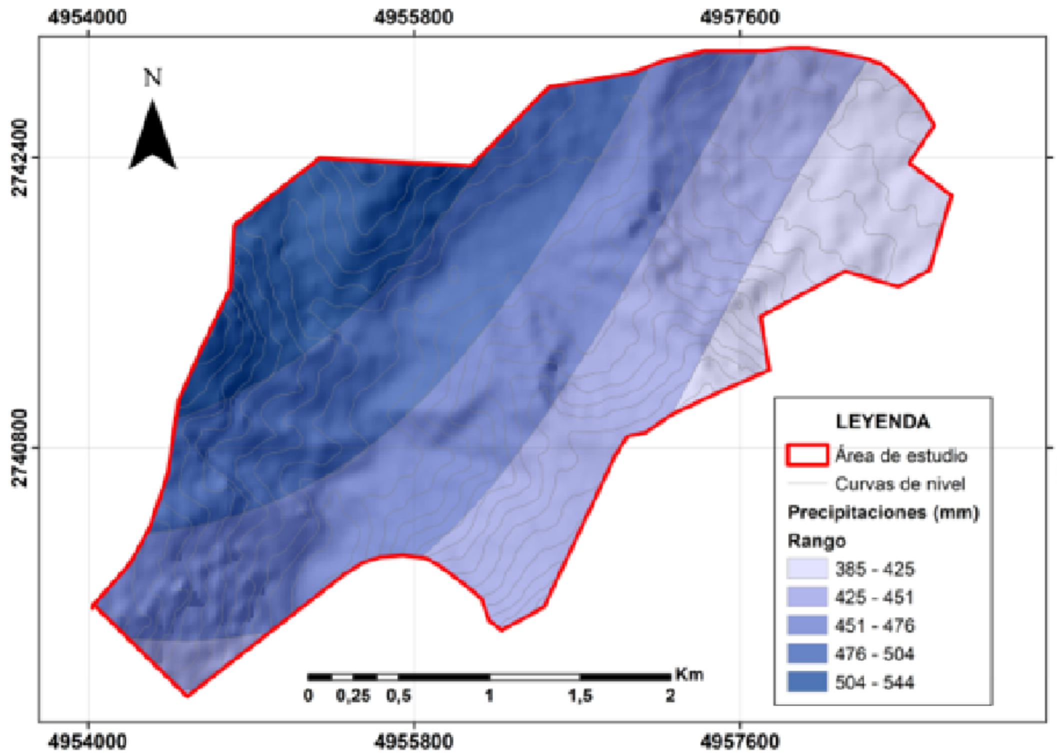

Figura 8. Mapa de precipitación

color verde oscuro representan la influencia directa de los sismos ocurridos con anterioridad, y el área con tonalidad verde claro corresponde a la zona de sismicidad baja (figura **9**).

Susceptibilidad por elementos activos

El 78,94 % del área del corregimiento representa una susceptibilidad media de acuerdo con los factores desencadenantes, 10 % susceptibilidad alta, 4,61 % susceptibilidad muy baja y 6,45 % baja, debido a la baja actividad sísmica y niveles de precipitación (figura **10**). Los parámetros evaluados fueron precipitación (80 %) y sismicidad (20 %).

Susceptibilidad del corregimiento de Chemesquemena

Una vez analizados los parámetros detonantes o activos, se elaboró el mapa de susceptibilidad final del corregimiento de Chemesquemena, en el que se incorporaron todos los factores indicados por Mora y Vahrson en su metodología y que fueron establecidos a lo largo de la investigación. Para esto, se utilizaron las capas ráster de los mapas elaborados. La ponderación final dada a cada capa contempla los porcentajes de cada parámetro de susceptibilidad (tabla 1).

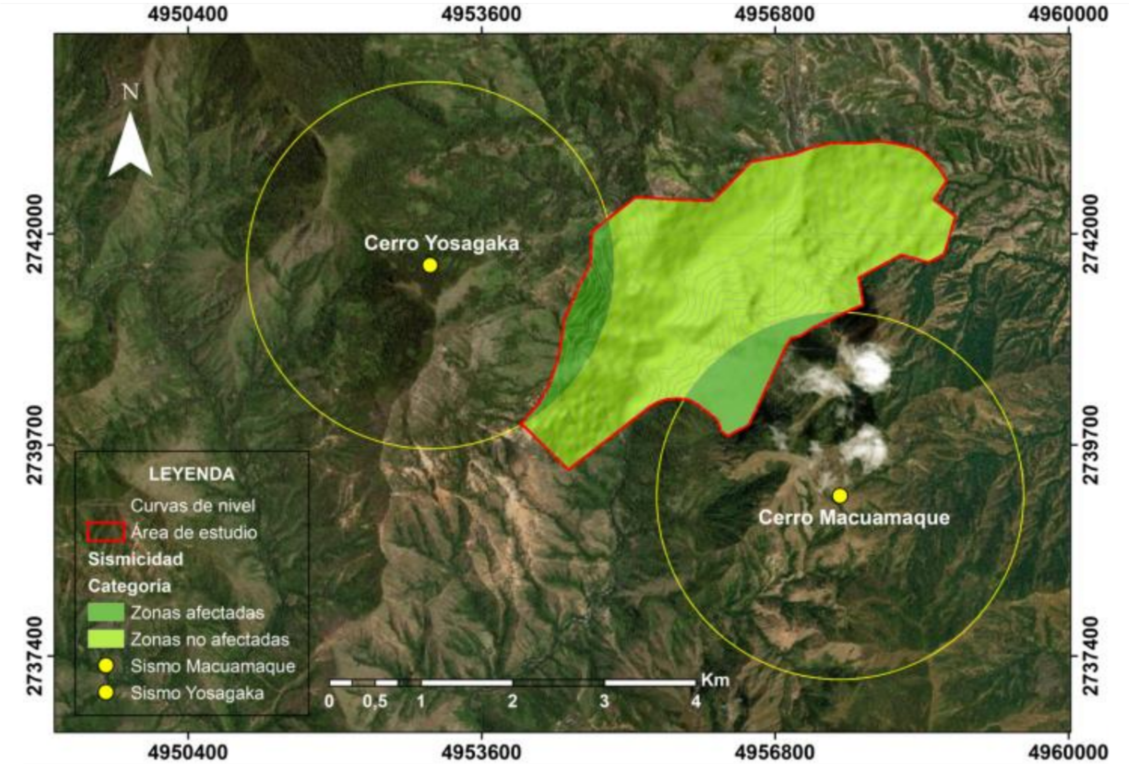

Figura 9. Mapa de sismicidad

Tabla 1. Porcentaje de los parámetros evaluados en la susceptibilidad

Parámetros de la susceptibilidad final		
Tipo de parámetro	**Parámetro evaluado**	**Porcentaje (%)**
Condicionante o pasivo	Geología	20
	Geomorfología	20
	Pendiente	20
	Cobertura vegetal	15
Detonante o activo	Precipitación	20
	Sismicidad	5
Total	6	100

La zona noreste del corregimiento evidencia áreas con menor susceptibilidad a la ocurrencia de los movimientos en masa, mayor concentración de susceptibilidades medias, altas y muy

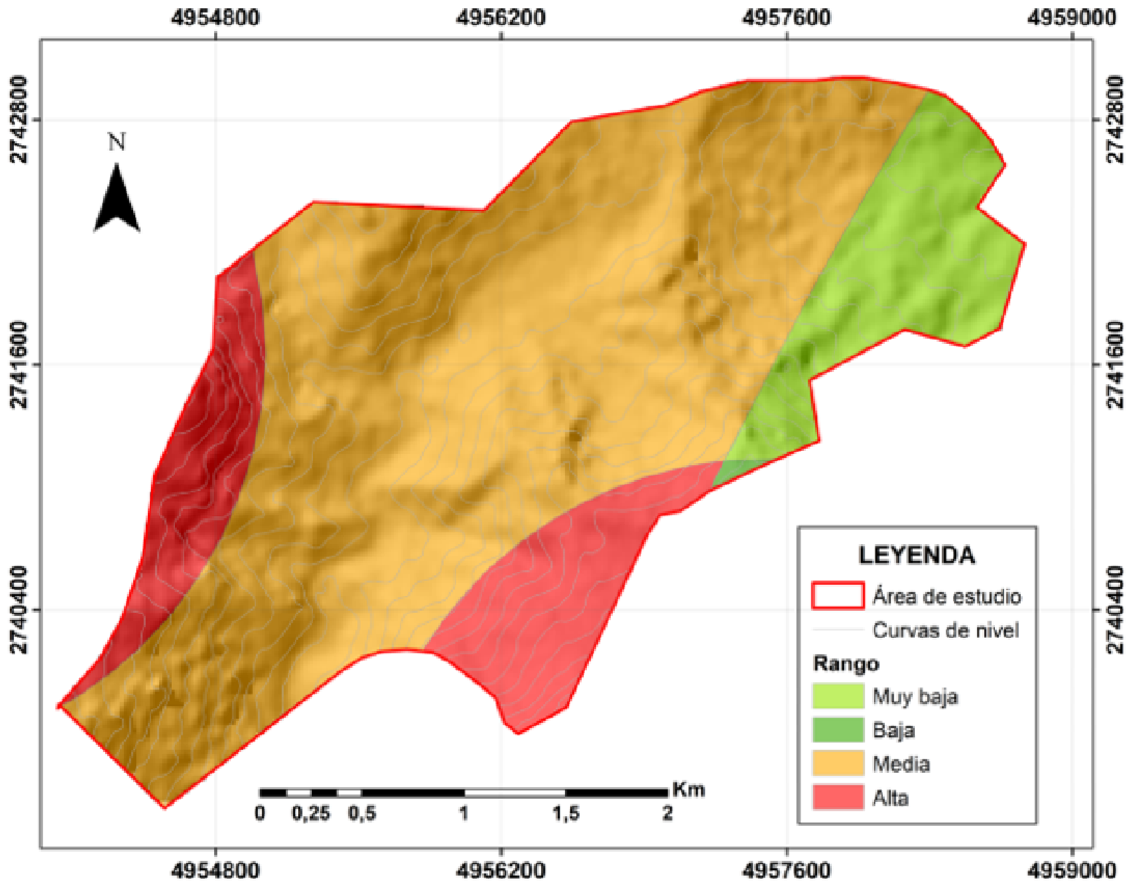

Figura 10. Susceptibilidad por elementos activos

altas hacia la zona central y noroeste del área de estudio. Estas distribuciones permiten observar que al menos el 70 % del área total del corregimiento registra una susceptibilidad desde media a muy alta a la ocurrencia de este tipo de procesos (figura **11**) (tabla 2).

El 30 % del área de estudio presenta susceptibilidad baja y muy baja, es decir, con muy bajo potencial a movimientos en masa, debido a que los terrenos tienen condiciones de poca inclinación. Se evidencian áreas con susceptibilidad media equivalentes a un 21 %, que corresponden a zonas con pendientes moderadas, además, áreas con susceptibilidad alta y muy alta representadas en un 49 %, que constituyen zonas con pendientes abruptas, donde factores como la exposición e intemperismo generan un mayor debilitamiento de los materiales y las denudaciones son más intensiva, pues provocan que la litología cumpla un papel fundamental en la susceptibilidad, en conjunto con las subunidades geomorfológicas de mayor grado de pendiente.

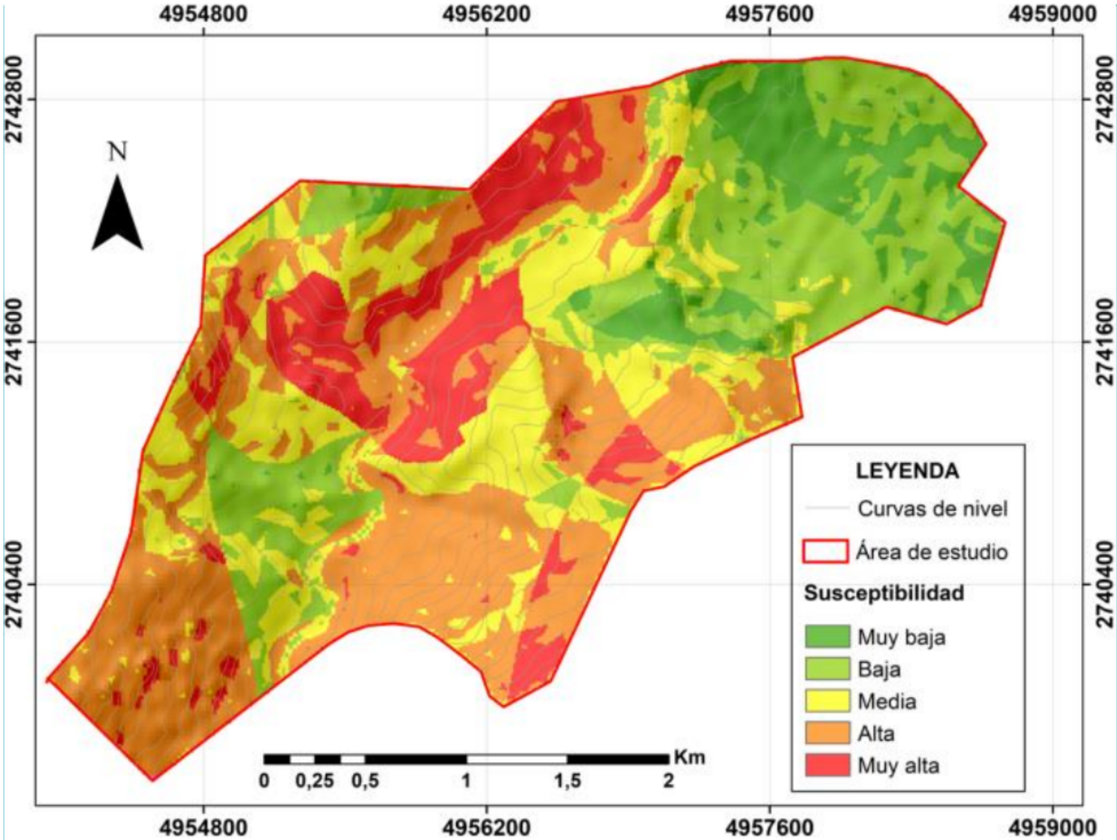

Figura 11. Mapa de susceptibilidad total del corregimiento de Chemesquemena

Tabla 2. Caracterización del corregimiento de Chemesquemena con base en la susceptibilidad

Índice de susceptibilidad	**Grado de susceptibilidad**	**Área (ha)**	**Porcentaje (%)**
1	Muy baja	78,92	8
2	Baja	189,19	22
3	Media	180,29	21
4	Alta	297,31	36
5	Muy alta	112,89	13
Total	5	858,6	100

Ensayos de suelo

Granulometría

Se clasificaron tres muestras de suelo, de las que se especificó el porcentaje en que están distribuidas las partículas según su tamaño de grano, el porcentaje de humedad natural de cada una, y se definió el grupo al que pertenecen dentro de los sistemas de clasificación de suelo AASTHO y unificado (tabla 3) (Manco-Jaraba *et al.*, 2018, 2019).

Tabla 3. Análisis granulométrico

Tamiz	**Diámetro (mm)**	**Peso retenido (g)**	**% retenido**	**% retenido acumulado**	**% que pasa**
3"	76,2	0	0	0	100
2"	50,8	0	0	0	100
1½"	38,1	0	0	0	100
1"	25,4	0	0	0	100
3/4"	19,05	0	0	0	100
3/8"	9,53	0	0	0	100
No. 4	4,75	430,81	28,73	28,73	71,27
10	2	344,81	23	51,73	48,27
20	0,84	241,81	16,13	67,85	32,15
40	0,42	205,81	13,73	81,58	18,42
60	0,25	89,81	5,99	87,57	12,43
140	0,106	114,81	7,66	95,22	4,78
200	0,075	46,81	3,12	98,35	1,65
Fondo	-	24,81	1,65	100	0
Total	-	1499,48	100	-	-

Según el Sistema Unificado de clasificación de suelos (SUCS), la muestra M1 es una arena bien gradada (tabla 4). Esta clasificación permite establecer que, al tratarse de suelos no cohesivos en su mayoría, el material por ende va a tender a desplazarse con mayor facilidad debido a su bajo contenido de arcillas, y además, estos suelos pueden cambiar sus características geotécnicas bajo las variaciones climáticas abruptas.

Las muestras M1, M2 y M3 registraron una humedad natural promedio de %W=9,527 gr, densidad en muestra húmeda 16 gr/cm^3, densidad muestra seca 1,10 gr/cm^3, y ninguna reportó plasticidad. Los límites líquidos obtenidos arrojaron valores de humedad promedio de 34,2, los cuales representan un alto valor generado por la alta pluviosidad y posiblemente por la frecuencia de riego (tabla 5).

Tabla 4. Resultados de los ensayos de granulometría

Tabla de resultados	
% de gravas	28,73
% de arena gruesa	23
% de arena media	29,85
% de arena fina	16,77
% total de arena	69,61
% de finos	1,65
Clasificación "SUCS"	**SO**

Tabla 5. Resultados de límite líquido

Muestra	**M1**	**M2**	**M3**
SPT	15-25	20-30	25-35
# Golpes	18	30	32
Peso tara (gr)	12,9	14,5	13,3
Tara + muestra (gr)	32,89	32,73	28,28
Peso muestra húmeda (gr)	19,99	18,23	14,98
Peso seco+ tara (gr)	27,6	28,1	24,6
Peso muestra seca	14,7	13,6	11,3
% de agua	5,29	4,63	3,68
Límite líquido	0,36	0,34	0,33
Humedad	35,99	34,04	32,57

CONCLUSIONES

Las áreas con mayor susceptibilidad se localizan hacia el noroeste del corregimiento de Chemesquemena (Colombia), y representan el 70 % de las áreas totales debido a las altas pendientes, alta pluviosidad, litología, tipo de suelo, cobertura vegetal, cultivos permanentes y subunidades geomorfológicas, como sierras denudadas y colinas residuales; y el 30 % susceptibilidades bajas a muy bajas.

Los factores condicionantes que generan mayor influencia de susceptibilidad corresponden a la litología, altas pendientes características del terreno, cultivos permanentes y pasto como cobertura principal. Las unidades litológicas fueron clasificadas mayoritariamente como rocas ígneas intrusivas con avanzado estado de alteración que generan debilitamiento de los materiales. Los cultivos requieren sistemas de riego periódicos que hagan un aporte constante de agua a los suelos y taludes (sobresaturación), y alteren las propiedades mecánicas; además, el pasto no favorece la estabilidad de los suelos.

Los resultados en los ensayos de laboratorio de suelos indican que el factor detonante que genera mayor influencia en la susceptibilidad corresponde a la precipitación, debido a los altos valores de humedad que son constantes en el área de estudio y que se relacionan directamente con los altos valores de precipitación. Además, los ensayos de granulometría evidencian que los suelos predominantes en el corregimiento corresponden a arenas bien gradadas, no cohesivos y con un contenido bajo de arcilla, debido a las fuertes precipitaciones características de la zona, lo que genera condiciones inestables que pueden desencadenar deslizamientos.

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INVESTIGACIÓN

Landslides in Tijuana, Mexico: hazard assessment in an urban neighborhood

Deslizamientos de tierra en Tijuana, México: evaluación de la amenaza en un barrio de la zona urbana

Aldo Onel Oliva González [1], Romel Jesús Gallardo Amaya [2] y Pedro Nel Angarita Uscátegui [3]

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Abstract

Context: Landslides in Tijuana, Mexico, destroy a large number of structures and infrastructures each year, producing large losses in various economic sectors.

Method: In this study, we carry out a quantitative assessment of the hazards of landslides in a Tijuana neighborhood that was affected by a landslide in 2010 and currently shows signs of terrain instability, raising concerns about potential future landslides. The hazard assessment was calculated using the spatial probability, based on how susceptible the terrain was to landslides, and the temporal probability using a database of events that occurred at sites near te study area. We apply deterministic methods based on the analysis of slope stability to calculate susceptibility and estimate the temporal probability using probability models that consider the instances of independent random events.

Results: It was found that more than 50 % of the studied area presents a high hazard of landslides for return periods of 5, 10, 15, and 20 years. Moreover, findings demonstrated that the seismicity, topography, and the geotechnical characteristics of the soils are the factors with major influence on ground instability. In addition, it was determined that the areas of potential landslides are in soils whose resistance has been reduced due to the presence of underground flows produced by the infiltration of water through existing cracks and fractures in the terrain.

Conclusions: The application of the described procedure made it possible to quantify the hazards of landslides in the Laderas de Monterrey neighborhood for four return periods and to determine the factors that most influence the occurrences of these phenomena. The results obtained are an important step to analyze and evaluate the risk that landslides represent for structures, infrastructures, and people exposed to the impact of these phenomena. They are

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also a valuable tool for making informed decisions regarding risk management and the establishment of regulations on land use.

Keywords: landslides, landslide hazard, urban landslides, hazard assessment.

Resumen

Contexto: Los deslizamientos de tierra en Tijuana, México, provocan cada año la destrucción de una gran cantidad de estructuras e infraestructuras, produciendo cuantiosas pérdidas en diversos sectores de la economía.
Método: En este estudio, se realiza una evaluación cuantitativa del peligro de deslizamientos de tierra en un barrio de la ciudad de Tijuana, el cual fue afectado por un deslizamiento en el año 2010 y actualmente presenta indicios de inestabilidad del terreno, alertando sobre la posibilidad de que ocurran nuevos deslizamientos. La amenaza fue calculada utilizando la probabilidad espacial, a partir de la susceptibilidad del terreno a los deslizamientos de tierra, y la probabilidad temporal se calculó utilizando una base de datos de eventos ocurridos en sitios cercanos al área de estudio. Se aplicaron métodos determinísticos basados en el análisis de estabilidad de taludes para calcular la susceptibilidad del terreno y se estimó la probabilidad temporal utilizando modelos de probabilidad que consideran la ocurrencia de eventos aleatorios independientes.
Resultados: Se encontró que más del 50 % del área de estudio presenta una alta amenaza de deslizamientos de tierra para períodos de retorno de 5, 10, 15 y 20 años. Se comprobó además que la sismicidad, la topografía y las propiedades geotécnicas de los suelos son los factores que más influyen en la inestabilidad del terreno. Adicionalmente, se determinó que las áreas de potenciales deslizamientos de tierra se encuentran en suelos cuya resistencia se ha reducido debido a la presencia de flujos subterráneos producidos por el movimiento de agua a través de grietas y fracturas existentes en el terreno.
Conclusiones: La aplicación del procedimiento descrito permitió cuantificar la amenaza de deslizamientos de tierra en el barrio estudiado para cuatro períodos de retorno. También permitió identificar los factores que más influyen en la ocurrencia de estos fenómenos. Los resultados obtenidos son un paso importante para analizar y evaluar el riesgo que representan los deslizamientos de tierra para las estructuras, infraestructuras y personas expuestas al impacto de estos fenómenos; y son una valiosa herramienta para tomar decisiones relacionadas con la gestión del riesgo y el establecimiento de regulaciones sobre el uso de suelo.

Palabras clave: deslizamientos de tierra, amenaza de deslizamientos, deslizamientos urbanos, evaluación de amenaza.

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INTRODUCTION

In general, a hazard is a potentially harmful physical event or human activity that can cause loss of life, property damage, economic and social disruption, and environmental degradation (UN-ISDR, 2004). In the case of landslides, the event has a certain probability of occurrence within a specific period of time, in an established area, and with a determined intensity (Van Westen *et al*., 2011). This probability can be calculated using the following equation (Guzzetti *et al*., 2006):

$$H = P(S) \cdot P(N_L) \cdot P(A_L) \quad (1)$$

Here, H expresses the hazard probability, $P(S)$ the probability of landslide spatial occurrence based on the local environmental setting, $P(N_L)$ a probability of landslide occurrence within an established period, and $P(A_L)$ denotates the probability of landslide size.

Landslides spatial probability

Landslides spatial probability is based on the concept of landslides susceptibility and refers to the classification, area, volume, and distribution in space of events that occurred or may occur within a designated study area. The methods for assessing landslides susceptibility are classified into qualitative and quantitative approaches. Qualitative susceptibility assessment is carried out based on a compilation of landslides data, relying on geomorphological maps, parameters, and indices, and it requires the analysis of experts. These methods are widely used (Fell *et al.*, 2008; Van Westen *et al.*, 2008; Guzzetti *et al.*, 2012; Sheng *et al.*, 2020). In the quantification of landslides susceptibility, prominent methods include data processing (statistical) techniques and deterministic analysis. Data-driven analyses involve the statistical evaluation of combined factors that have produced landslides in the past, resulting in quantitative predictions for areas with similar conditions where landslides have not occurred. These methods assume that the conditions that led to landslides in the past will continue to do so in the future, and as a result, they are widely used (Guzzetti *et al.*, 2005; Brenning, 2005; Catani *et al.*, 2013; Reichenbach *et al.*, 2018; Abhirup *et al.*, 2020). Deterministic methods model and simulate landslide processes using models based on slope stability analysis (Silva *et al.*, 2008; Oliva & Gallardo, 2018; Oliva-González *et al.*, 2019; Mavrouli *et al.*, 2019; Quiau *et al.*, 2019; Parra *et al.*, 2022). These methods are applicable only when there is enough topographic, geological, and hydrological data available to develop an adequate geotechnical database for the study area.

Landslide temporal probability

Although landslides are events that do not follow a particular probability model, their frequency of occurrence can be estimated using different methods. When detailed multitemporal landslide inventory maps are available, the temporal probability of landslides can be estimated through the analysis of the empirical recurrence of slope failures (Guzzetti *et al.*, 2006), using statistical or heuristic methods. The resulting classes are then associated with the temporal probability of the triggering events (Van Westen *et al.*, 2011). Some authors have established, through expert judgment, relationships between the factor of safety to the landslide and the annual probability of slope failures (Silva *et al.*, 2008).

When there is no multitemporal inventory of landslides or maps linking landslides with their triggering events, the temporal probability can be evaluated using probabilistic models that consider the occurrence of independent random events in the time (Crovelli, 2000; Guzzetti *et al.*, 2006; Sheng *et al.*, 2020).

Probability of landslide size

The probability of landslide size is calculated by observing the relationship between the volume of landslides and their cumulative frequency, using the information obtained from the multitemporal landslide inventories that exist for the study area. To determine the probability densities, the double Pareto and inverse Gamma distributions are widely employed (Stark & Hovius, 2001; Malamud *et al.*, 2004; Guzzetti *et al.*, 2006) but some authors have used distributions obtained through the use of the ordinary least squares method (Sheng *et al.*, 2020).

Landslides in Tijuana urban area

On average, in the urban area of Tijuana, Mexico, more than two landslides occur per year. These phenomena produce direct and indirect adverse effects on physical infrastructure, lifelines, and people, causing chaos, suffering, and a sense of helplessness wthin the affected communities, as well as large material losses in various economic sectors (Figure **1**). Due to their frequency and magnitude, these events themselves constitute emergencies, the effective management of which poses growing challenges for authorities. Furthermore, they negatively impact the socio-economic structure of the municipality.

Figure 1. Some urban landslides occurred in Tijuana.

Note. (a) Lomas Conjunto Residencial Landslide, 2009; **(b)** Laderas de Monterrey Landslide, 2010; **(c)** Liberal Lomas del Rubí Landslide, 2018; **(d)** Cumbres del Rubí Landslide, 2019.

Source: authors.

From 1990 to September 2020, more than seventy landslides have been registered in the urban area of Tijuana. These incidents have resulted in the complete or partial destruction of over a thousand buildings, mainly homes, along with extensive damage to essential infrastructure such as road networks, electricity, drinking water, and drainage (Table 1).

The Tijuana city was built on terrain with complex geological, geomorphological, and hydrological characteristics, situated within a region of great seismic activity. These factors were

Table 1. Summary of landslides that occurred in Tijuana urban area from January 1990 to September 2020, and their impacts on homes.

Time period	Landslides occurred	Homes totally or partially damaged
1990 – 1999	22	67
2000 – 2009	27	221
2010 – 2020	22	651

Source: authors.

not adequately considered during urban planning, leading to a rapid and haphazard expansion of the city. Consequently, the city spread into hillside areas potentially unstable, as well as soils and fillings affected by previous landslides (Oliva *et al*., 2019). The main objective of this study is to assess the hazard landslides in a neighborhood of the Tijuana city, using deterministic methods based on slope stability models and probabilistic methods based on landslides that occurred in nearby sites with similar characteristics.

Methodology

This section describes the study area and presents a summary of the methods used to quantify the landslides hazard in the studied neighborhood.

Study area and data

The study area encompasses the Laderas de Monterrey neighborhood (32 ° 30′25.29 "N - 117 ° 1′27.23"W), located in the center of the Tijuana urban area. The urbanized area of the neighborhood occupies an area of approximately 62,000 m^2 and was built in the 1990s on land characterized by its irregular topography. The neighborhood's buildings are individual homes averaging two levels in height and more than 150 m^2 of the living area each. On May 3rd of 2010, a landslide occurred in this neighborhood destroying a total of eleven homes and causing significant damage to another eight. In addition, the road network and public services were seriously affected by the destruction of three streets and damage to the drinking water, electricity, and drainage networks (Figure **2**).

The study area was selected because it was affected by the 2010 landslide and because it currently shows signs of geotechnical and structural pathologies which are evidence of terrain instability and warn of the possibility of new landslides, increasing concerns about the dan-

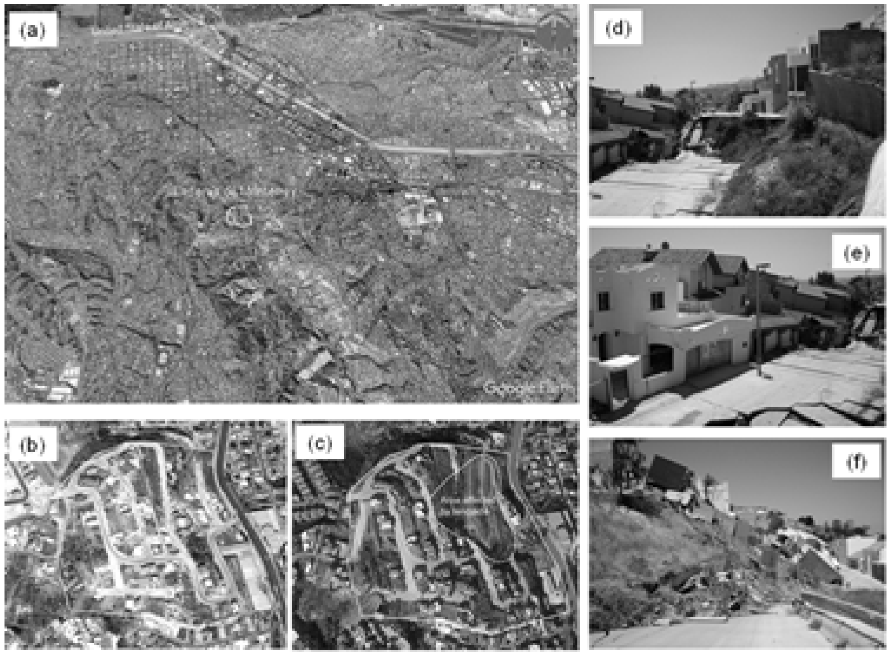

Figure 2. Laderas de Monterrey neighborhood before and after the landslide.

Note. (a) Location of the neighborhood in the urban area; **(b)** neighborhood in 2006; **(c)** neighborhood in 2019; **(d)** main escarp, **(e)** body and **(f)** foot of the landslide.

Source: authors.

gers that these phenomena pose for at least 46 homes and the more than 163 residents of the neighborhood. From the analysis and interpretation of the results of different studies and investigations carried out in the area from 2010 to date, data, parameters, and information related to the topography, geomorphology, geology, geotechnics, and hydrology of the study area were obtained.

Topography and geomorphology

The study area is located on a hill cut by erosion channels, indicative of the land's susceptibility to physical and morphological transformations. The neighborhood has been established on a hillside with an average slope of 39 % that is part of the tributary micro-basins of the La Piedrera creek. Figure **3** shows the geomorphology of the site and the digital terrain elevation model obtained using UVA system (Escalante, 2016).

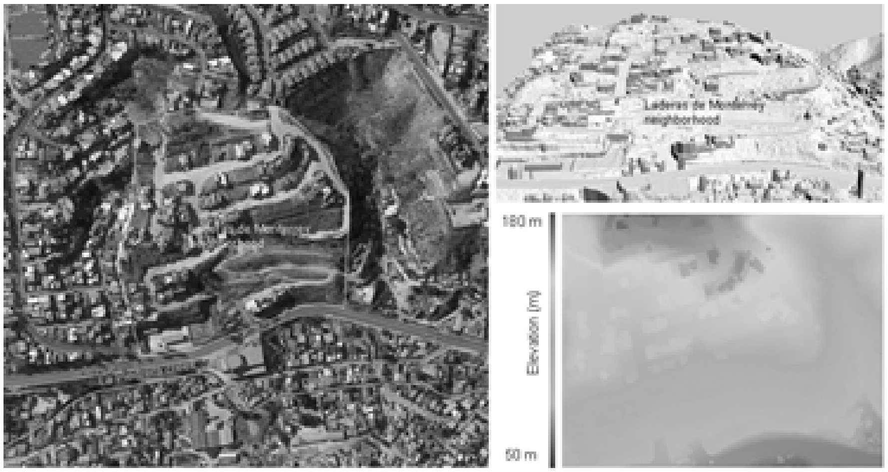

Figure 3. Topography and geomorphology of the study area.
Source: authors.

Geology and geotechnics

At the base of the hillside, there is the typical lithology of the Otay Geological Formation, made up of medium-grained and light-gray color tobaceous sandstones; while in the upper part of the outcrop, the lithology is that of the San Diego Geological Formation, which is characterized by clayey sands with intercalations of boulders, gravel, and thin layers of clay. Recent geotechnical and geophysical studies indicate the presence of significant amounts of soft, low-strength materials, products of the collapse and removal of the natural terrain due to the landslide in 2010 and as a result of the deterioration of the surface soils and fillings due to weathering (Figure **4**).

Table 2 shows the geotechnical parameters of the terrain, obtained with field and laboratory tests.

Seismic activity

In the study area, as in the entire city of Tijuana, the tectonic framework is characterized by the faults that cross the peninsular mountain ranges whose activity directly affects the urban area (Hungr, 1997; Cruz-Castillo, 2002). Studies carried out indicate that one of the triggers for the 2010 landslide was the 7.2 magnitude earthquake that occurred on April 4 of that year (a month earlier), with its epicenter in the Mexicali Valley, 159 km from Tijuana (Oliva *et al*., 2014).

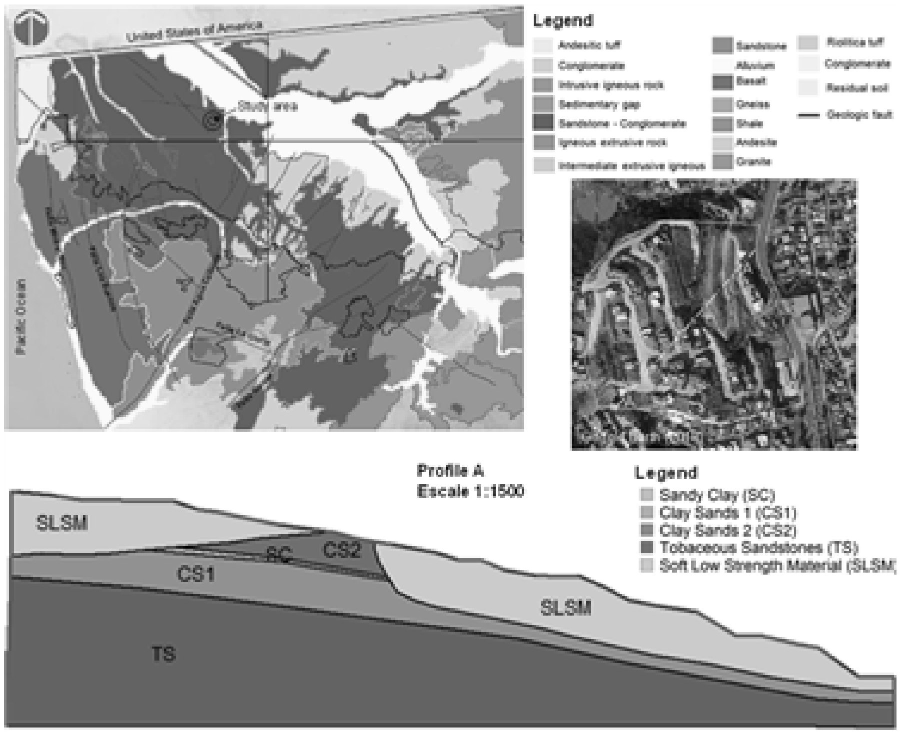

Figure 4. General stratigraphy of the study area.

Source: authors.

Table 2. Properties of the predominant soils in the study area.

Soil type (ID)	**Geotechnical parameters**		
	Volumetric weight (KN/m^3)	**Friction angle (degree)**	**Cohesion (KPa)**
Sandy Clay (SC)	18.00 – 19.50	10 – 15	25 – 30
Clay Sands 1 (CS1)	18.00 – 19.50	15 – 20	22 – 24
Clay Sands 2 (CS2)	18.50 – 20.00	32 – 38	7 – 12
Tobaceous Sandstones (TS)	19.00 – 22.00	30 – 35	60 – 100
Soft Low Strength Material (SLSM)	18.50 – 21.00	5 – 10	15 – 20

Source: authors.

Hydrology and hydrogeology

The rains in the region are scarce and there are no permanent flows of surface water. However, small flows of underground water were detected by employing onshore geotechnical investigation surveys and geophysical exploration. The flows originate in the upper part of the hillside and roughly follow the path of the bed of an old creek that was filled during the construction of the neighborhood.

Procedure to assess risk

The probability of landslides size was not considered in the calculation of the risk because there is no detailed inventory of landslides that occurred in the area where the neighborhood is located. However, records of landslides that occurred in nearby sites, as well as the topographic, geomorphological, geological, and hydrological studies carried out, provide sufficient data and geotechnical parameters to assess the risk using deterministic methods based on slope stability models. The general scheme of the methodology used is presented in Figure **5**.

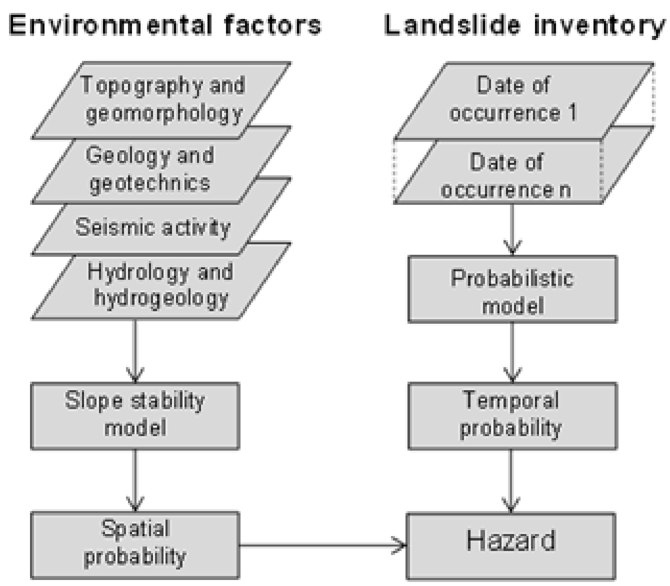

Figure 5. Scheme of the methodology used.

Source: authors.

Spatial probability

The spatial probability was analyzed from the concept of susceptibility to landslides and was calculated using slope stability analysis methods, through which potential landslide surfaces and their corresponding factors of safety were obtained. The stability analyses were carried out in four profiles of the study area (Figure 6), which were selected considering the geometry of the terrain surface, the presence of groundwater flows and anomalies in the subsoil, as well as the geotechnical and structural pathologies associated with processes of terrain instability.

Figure 6. Profiles used for slope stability analysis.
Source: authors.

The relationships used to estimate the spatial probability from the depth of the potential slip surface and its corresponding factor of safety (F.S) are presented in Table 3.

Table 3. Landslides spatial probability.

Parameters from slope stability analysis	**Landslides spatial probability, P (S)**			
Depth of potential slip surface	Superficial	Shallow	Deep	Very deep
	<1.5 m	1.5 ~5.0 m	5.0 ~12.5 m	12.5 ~20,0 m
	P (S) = 0.25	P (S) = 0.50	P (S) = 0.75	P (S) = 1
F.S.	Slope collapse	Critical stability	Moderate stability	Stable slope
	F.S ≤ 1	F.S = 1 ~1.2	F.S = 1.2 ~1.5	F.S >1.5
	P (S) = 1	P (S) = 0.75	P (S) = 0.25	P (S) = 0

Source: modified from Cuanalo *et al.*, 2007.

Temporal probability

Temporal probability was estimated considering that the failures in the slopes are independent random events in time. The Poisson model was adopted (Crovelli, 2000; Sheng *et al.*, 2020) which is expressed mathematically by equation (2).

$$P(N_L) = 1 - e^{-\frac{T}{RI}}, \quad RI = \frac{t}{N} \tag{2}$$

In the equation, T is the return period, RI is the historical mean recurrence interval, t is the time interval of the landslide database, and N is the number of landslides recorded. In our case study, a database of landslides that occurred in an area of approximately 3.0 km^2 was used, which has geomorphological, geological, geotechnical, and hydrological conditions similar to those existing in the Laderas de Monterrey neighborhood (Figure 7). According to database records, 10 landslides have occurred in this area in the last 20 years. Consequentlym landslides can be predicted at a rate of 0.5 per year and a mean recurrence interval (RI) of 2 years.

Figure 7. Record of landslides that occurred in sites with similar conditions to the study area.
Source: authors.

Hazard assessment

The landslide hazard in the profiles of Figure 6 was evaluated based on spatial and temporal probabilities, using equation (3)

$$H = P(S) \cdot P(N_L) \tag{3}$$

RESULTS

This section presents the results obtained in the case study when applying the procedure proposed in the Figure **5**.

Landslide spatial probability assessment

Based on the results of the studies and available data, the geological-geotechnical models were elaborated to determine the susceptibility of the land to landslides in the selected profiles (Figure **8**).

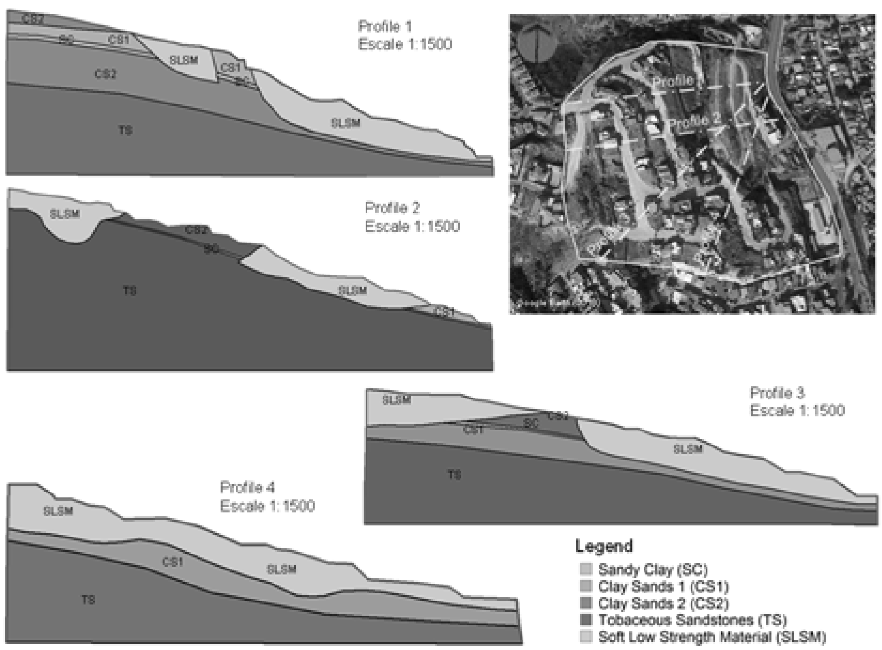

Figure 8. Geological-geotechnical models of the profiles used in slope stability analysis.
Source: authors.

Stability analyzes were performed using methods based on limit equilibrium, enabling the identification of the potential landslide surfaces along with their corresponding factors of safety (Table 4). The effect of seismicity activity on instability was accounted for by integrating the analysis the seismic accelerations of the ground, as outlined in the complementary technical standards of the state of Baja California (NTC, 2017), as well as their amplification by site effect (Acosta-Chang *et al*., 2009). Also, in the static condition, a 50 % saturation of the land was considered to evaluate the influence of the small underground water flows detected in the study area.

Table 4. Minimum factor of safety.

Profile	Factor of safety	
	Static conditions (without seismic acceleration)	Seismic conditions (with seismic acceleration)
1	1,00	0,62
2	1,00	0,36
3	1,36	0,41
4	1,56	0,46

Source: authors.

Figure **9** shows the potential slip surfaces obtained in the most unfavorable scenarios using different limit equilibrium methods (SLOPE/W, 2012). Likewise, Table 5 shows the spatial landslides probability obtained through slope stability analysis.

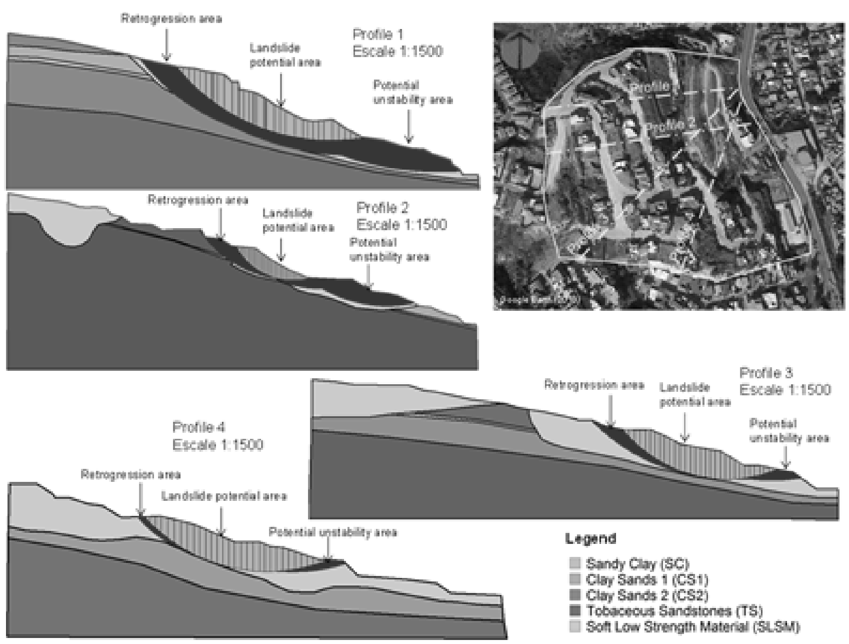

Figure 9. Areas of potential landslides and possible instabilities up and down slopes.

Source: authors.

Considering the pathologies and evidence of geotechnical instability existing in the study area and based on spatial probability values, landslide susceptibility was ordered into five classes: very low (0.00 – 0.20), low (0.20 – 0.40), moderate (0.40 – 0.60), high (0.60 – 0.80), and very high (0.80 – 1.00).

Table 5. Landslides spatial probability in the study area.

Static conditions (without seismic acceleration)			
Profile	Factor of safety	Depth of the landslide potential surface (m)	Spatial probability (according to Table 3)
1	1,00	21,00	0,875
2	1,00	15,00	0,875
3	1,36	17,00	0,625
4	1,56	14,00	0,250
Seismic conditions (with seismic acceleration)			
Profile	Factor of safety	Depth of the landslide potential surface (m)	Spatial probability (according to Table 3)
1	0,62	22,00	1,00
2	0,36	16,00	1,00
3	0,41	20,00	1,00
4	0,46	15,00	1,00

Source: authors.

Landslide temporal probability estimation

The landslides temporal probability occurrence in the study area was estimated using equation (2), for return periods (T) of 5, 10, 15, and 20 years, considering a mean recurrence interval (RI) of 2 years (Figure **10**).

We have assumed that pass events serve as indicators of potential future occurrences. Therefore, utilizing the graph presented in Figure **10**, it becomes possible to project the behavior of landslides in the studied area over the next 20 years.

Landslide hazard assessment

From the spatial and temporal probabilities, the landslides hazard in the study area was assessed, using equation (3). Table 6 and Figure **11** show the results.

The landslide hazard was divided into five classes, based on susceptibility and the temporal probability of occurrence in the study area: very low (0.00 - 0.15), low (0.15 - 0.30), moderate (0.30 - 0.45), high (0.45 - 0.60), and very high (0.60 – 0.75).

Under static conditions (without ground acceleration), the landslide hazard in profiles 1, 2, and 3 for return periods of 5, 10, 15, and 20 years is greater than 0.50, thus falling in the high and very high categories (Figure **11**). In a return period equal to the mean recurrence interval that characterizes the area where the neighborhood is located ($T = RI = 2$), the hazard in profiles 1 and 2 is 0.55 (high), in profile 3 it is 0.39 (moderate) and in profile 4 it is 0.15 (low). In seismic

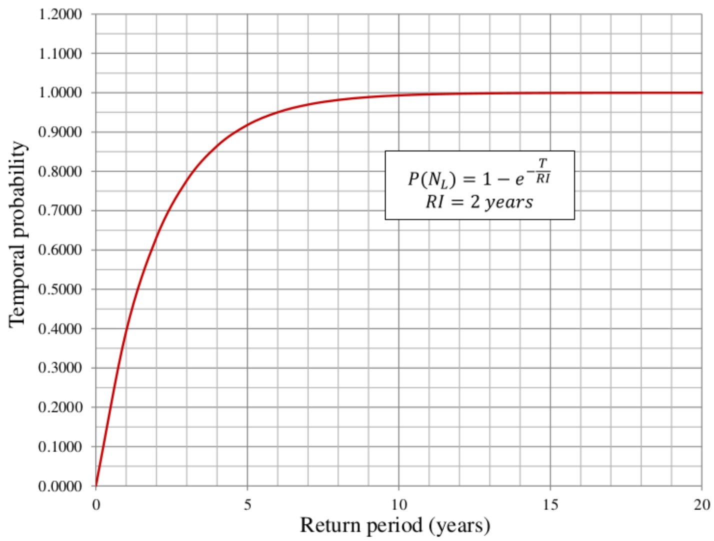

Figure 10. Landslides temporal probability in the study area.

Source: authors.

Table 6. Results of the quantitative assessment of the landslides hazard.

Static conditions (without seismic acceleration)									
Profile	Spatial probability	Temporal probability				Hazard			
		T= 5	T= 10	T= 15	T= 20	T= 5	T= 10	T= 15	T= 20
1	0,8750	0,9179	0,9933	0,9994	1,0000	0,8032	0,8691	0,8745	0,8750
2	0,8750					0,8032	0,8691	0,8745	0,8750
3	0,6250					0,5737	0,6208	0,6246	0,6250
4	0,2500					0,2295	0,2483	0,2499	0,2500
Seismic conditions (with seismic acceleration)									
Profile	**Spatial probability**	**Temporal probability**				**Hazard**			
		T= 5	**T= 10**	**T= 15**	**T= 20**	**T= 5**	**T= 10**	**T= 15**	**T= 20**
1	1,0000	0,9179	0,9933	0,9994	1,0000	0,9179	0,9933	0,9994	1,0000
2	1,0000					0,9179	0,9933	0,9994	1,0000
3	1,0000					0,9179	0,9933	0,9994	1,0000
4	1,0000					0,9179	0,9933	0,9994	1,0000

Source: authors.

conditions, with ground accelerations close to 0.30g, the hazard is very high throughout the study area for any return period. In these cases, large landslides will surely occur.

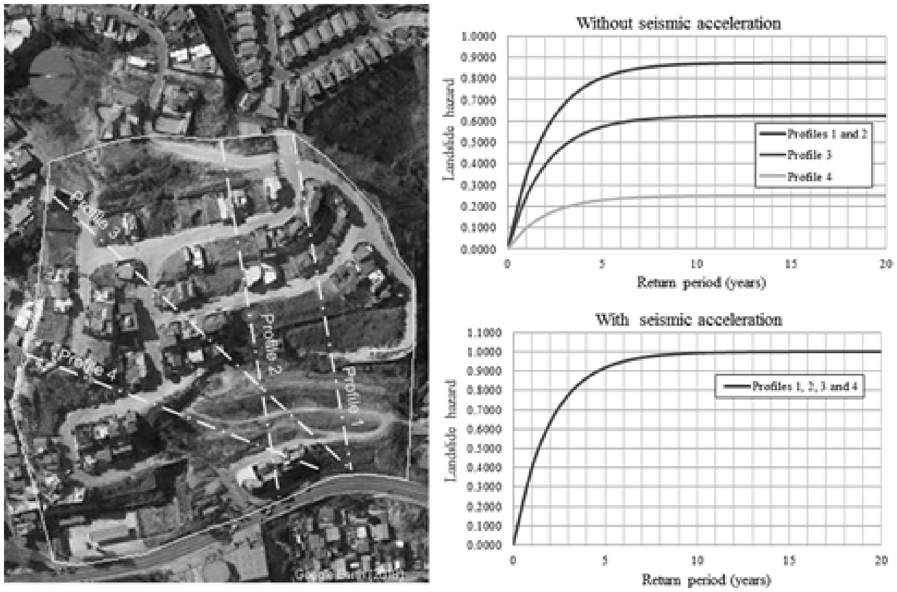

Figure 11. Landslide hazard for return periods of 5, 10, 15, and 20 years.
Source: authors.

CONCLUSIONS

The quantitative assessment of the landslides hazard in the "Laderas de Monterrey" neighborhood was carried out based on existing information on the physical environment of the studied area, as well as on the records of landslides that occurred in sites with similar characteristics, using deterministic and probabilistic methods. The use of models based on the analysis of the slope stability allowed for an assessment of its susceptibility to landslides considering different scenarios. Moreover, it helped to demonstrate that the seismicity of the region, the topography, and the geotechnical properties of the soils are the factors with the greatest influence on the terrain instability. Particularly, the underground flows and the humidity produced by the infiltration of water through cracks and fractures in the studied area considerably reduce the strength of the materials and cause strain and displacement in the terrain. This deterioration process occurs in so-called soft, low-strength materials (SLSM) found in the areas of greatest instability and with the highest potential for landslides (Figure **9**). On the other hand, the occurrence of landslides with an average recurrence interval of two years in a close environment confirms the high probability of occurrence of these phenomena in the studied area. Consequently, we find that for return periods of 5, 10, 15, and 20 years, the existing susceptibility and the temporal probability indicate a high hazard of occurrence of landslides in more than

50 % of the study area under static conditions (without seismic acceleration); while in seismic conditions, with accelerations around 0.30g, the hazard is very high within the study area. The results obtained are an important step in analyzing and evaluating the risk that landslides represent for structures, infrastructures and people exposed to the impact of these phenomena. They are also a valuable tool for making informed decisions related to risk management and the establishment of regulations on land use.

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INVESTIGACIÓN

Alzheimer's disease and its association with dietary aluminum: a review

Enfermedad de Alzheimer y su relación con el aluminio consumido a través de los alimentos: una revisión

Katherine Gutiérrez-Álzate[1], Diofanor Acevedo-Correa[2], Jefferson Jose Urzola Ortega[3], Lorenzo Fuentes-Berrio[4] y Luis Alfonso Beltrán-Cotta[5]

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Abstract

Context: Alzheimer is a neurodegenerative disease that not only occurs in the adult population. Some cases have also occurred in younger people. This has led to research relating to the ingestion of aluminum (considered a precursor to this disease) including its sources, which in many cases comes from food consumption.

Objective: To conduct a literature review to provide an overview of Alzheimer's disease and its relationship to dietary aluminum.

Methodology: A literature review was carried out using the Scopus databases Science Direct, SpringerLink, Scielo, ResearchGate, Web of Science, and Google Scholar. In addition, information was obtained from websites.

Results: Studies were found which associated aluminum intake in various forms with the onset of Alzheimer's disease. Other studies demonstrated the presence of aluminum residue in various prepared foods through direct or indirect migration from utensils, water, or additives used in their preparation.

Conclusions: It was identified that some foods can be a high source of aluminum intake due to leaching, direct absorption from the soil, or through the addition of this element via additives or colorants. This has raised awareness because of the link between this metal and Alzheimer's disease.

Keywords: contaminated food, dementia, health, heavy metal, migration, water.

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Resumen

Contexto: El Alzheimer es una enfermedad neurodegenerativa que no solo se presenta en población adulta, sino que algunos casos también se han presentado en personas de menor edad. Esto ha llevado a que se realicen investigaciones relacionando la ingesta de aluminio (el cual es considerado un precursor de esta enfermedad) y su fuente de ingesta, que en muchos casos es provenientes del consumo de alimentos.
Objetivo: Establecer mediante una revisión literaria una visión general de la enfermedad de Alzheimer y su relación con el aluminio consumido a través de la ingesta de alimentos.
Metodología: Se realizó una revisión de literatura, usando como herramientas las bases de datos Scopus, Science Direct, SpringerLink, Scielo, ResearchGate, Web of Science e Google schoolar. Además, se contó con información proveniente de sitios web.
Resultados: Se encontraron investigaciones donde se asocia la ingesta de aluminio en diferentes formas con la aparición de Alzheimer. Asimismo, se hallaron estudios en los cuales se demostraron la presencia de residuos de aluminio en distintos alimentos preparados, por la migración directa o indirecta de utensilios, agua o aditivos utilizados en su preparación.
Conclusiones: Se pudo identificar que algunos alimentos pueden ser una alta fuente de ingesta de aluminio debida a la lixiviación, a la absorción directa del suelo o por la adición de este elemento a través de aditivos o colorantes. Esto ha generado conciencia debido a la relación existente entre este metal y la enfermedad de Alzheimer.

Palabras clave: alimentos contaminados, demencia, salud, metal pesado, migración, agua.

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INTRODUCTION

Dementia is a disease which is a common and progressive neurological disorder primarily associated with older people (Kjaergaard *et al.*, 2021). The prevalence and reporting of this disease varies according to the region of the world; countries with the best health care systems typically report a higher number of people suffering from this disease. According to data reported by the World Health Organization (WHO) in 2019, the highest registration of people with dementia occurred in the Pacific region (20.1 million reported cases), followed by Europe (14.1 million), the Americas (10.3 million), South-East Asia (6.5 million), the Eastern Mediterranean (2.3 million), and Africa (1.9 million) (WHO, 2021). The low registration of dementia cases in Africa may be associated with the poor healthcare systems in the majority of African countries. Currently, few countries give the necessary priority to dementia patients to access diagnostic and post-diagnostic services. This, coupled with low education, low socio-economic status, depression, social isolation, physical inactivity, smoking, hypertension, obesity, and diabetes, results in the under-recording of dementia cases (Mukadam *et al.*, 2019).

Alzheimer's is considered the most common neurodegenerative disease. Its main characteristics are gradual memory loss and impairment of cognitive functions, including attention span, language, and visuospatial skills (Ballard *et al.*, 2016; Martinez *et al.*, 2019). According to the American Alzheimer's Association (2023), between 2000 and 2017, the number of reported deaths from Alzheimer's disease (AD) compared to the number of deaths from stroke, heart disease, and prostate cancer increased by 145 %. In 2019, AD was the sixth leading cause of death in the United States and the fifth leading cause of death among Americans aged 65 and older, according to official death certificates. However, between 2020 and 2021, it was the seventh leading cause of death due to deaths from SARS-CoV-2. Currently, approximately 6.7 million people have AD; this number may increase to 7.2 million in the United States by 2025, while it is expected that there will be 115 million people with AD worldwide by the year 2050.

AD is not a disease that only affects older individuals, as there have been cases where this disease begins in individuals with an average age of 50 years. In these cases, it is unknown whether there was a genetic predisposition. Studies which included cases of this type have found that the affected subjects have been exposed occupationally (Exley *et al.*, 2014; Mirza *et al.*, 2016) or environmentally (Exley and Esiri, 2006) to high levels of aluminum for prolonged periods. These results have allowed researchers to identify the link between exposure to this element with the onset of AD (Exley, 2017).

Aluminum is one of the most abundant chemical elements in nature, being a metal with proinflammatory, pathological, and genotoxic characteristics which is especially harmful to the homeostatic performance of brain cells, particularly as concerns normal genetic and cytoplasmic functioning. This metal migrates to humans through the consumption of water, contaminated food, and/or processed foods that contain alumimum which is frequently used in packaging and preservatives and/or colorants, the latter being the most bioavailable form absorbed by the intestine. The consumption of food contaminated with aluminum can gradually lead to memory loss. It should be noted that the maximum tolerable level of aluminum exposure is 1 mg aluminum/kg body weight/week (Crisponi *et al.*, 2013; Bondy, 2016; Matías-Cervantes *et* *al.*, 2018).

Considering the relationship between aluminum and AD, studies have been developed such as those conducted by Matias-Cervantes *et al.* (2018), Mera *et al.* (2016), Arcila and Peralta (2016) and Ekong *et al.* (2017), evidencing that treated water could be contaminated with aluminum, this being one of the main routes of intake. This has led to new research on the use of vegetable coagulants obtained from seeds (moringa, jatropha curcas, nirmali), peels, rinds, and skins (banana, watermelon, beans, cassava, papaya, okra), fruit waste, and other natural sources to reduce the use of traditional aluminum-based coagulants (alum, sodium aluminate, aluminum chloride, polyaluminum chloride, polyaluminum chlorosulfate, and polyaluminum sulfate) due to their associated health hazards (Teh *et al.*, 2016; Owodunni & Ismail, 2021). Therefore, the purpose of this research was to conduct a literature review to provide an overview of Alzheimer's disease and its relationship to dietary aluminum.

Methodology

This article is based on a literature review exploring the relationship between aluminum from food or the food industry and AD, which was conducted by searching for publications available in the databases Scopus, Science Direct, SpringerLink, Scielo, ResearchGate, Web of Science, and Google scholar. In addition, information was obtained from websites. The books, articles, and other research sources consulted for this review were all published between 2003 and 2023. For the above, keywords and boolean operators were used (Table 1).

Table 1. Terms and Boolean operators used for literary review

KEYWORDS	BOOLEAN OPERATORS
"Alzheimer's disease", "Alzheimer", "Alzheimer's" "Alzheimer's diseases", "Alzheimer disease", "Alzheimer's disease"	OR
"Aluminum", "Migration of aluminum", "exposure to aluminum", "aluminum ingestion", "aluminum in additives", "aluminum in water", "aluminum in plants", "Aluminum foil", "aluminum lixiviation"	AND/OR
"Food", "Food packaging", "food packaging materials"	AND/OR

Sources: Authors

Background

Research on AD began when Dr. Alois Alzheimer discovered histological alterations in the brain of a 51-year-old woman in the late 1880s. In 1906, Dr. Alzheimer, during a lecture in Tubingen (Germany), presented his first observations on the symptoms and pathology of this disease (Hippius and Neundörfer, 2003; Lopera, 2004). In 1907, Dr. Alzheimer formally established the existence of a new disease, which was initially considered a strange form of presenile dementia characterized by behavioral disorders, depression, psychotic symptoms, and cognitive impairment. At the time, these symptoms were considered strange because the main origin of dementia was believed to be the "hardening of the arteries". In 1910, Emil Kraepelin assigned the name .Alzheimer's disease"to this pathology, a disease which was a significant burden for patients, their caregivers, and the community at large (Hippius & Neundörfer, 2003). Subsequent advances in neuropathology allowed AD to be considered a type of presenile dementia distinct from senile dementia. This hypothesis prevailed until the 1960s, and for the next 20 years, AD remained the dominant and prototypical form of dementia, centered on prominent memory disturbances. However, the term dementia has gradually fallen out of use when referring to major neurocognitive disorder and the heterogeneity of the syndrome at the phenotypic and molecular levels has once again been recognized (Assal, 2019).

Diagnosis of Alzheimer's disease

A definitive diagnosis of AD should include multiple types of progressive cognitive impairments leading to dementia with post-mortem neuropathologic confirmation, as well as a clinical history of memory impairment. Recently, the importance of the use of biomarkers that aid in the in vivo diagnosis of AD has been accepted. Among these markers, one can find the main cerebrospinal fluid (CSF) biomarkers of AD, namely are amyloid-beta ($A\beta42$), which shows the cortical deposition of amyloid, total tau (t-tau), which reflects the intensity of neurodegeneration, and phosphorylated tau (p-tau), which correlates with pathological neurofibrillary changes. Magnetic resonance imaging (MRI) and fluorodeoxyglucose (FDG) positron emission tomography (PET) techniques have also been implemented to discard intracranial causes (meningioma, subdural hematoma) and have been complemented by the notion that the demonstration of regional atrophy in the medial temporal region can provide positive diagnostic information (Scheltens *et al.*, 2016).

MRI remains the modality of choice for the assessment of cerebral vascular changes, such as white matter hyperintensities, lacunae, and microbleeds, which have gained increasing attention because these are frequent secondary effects in antiamyloid trials. Meanwhile, FDG PET estimates the density and distribution of aggregated tau neurofibrillary tangles in cognitively impaired adults being evaluated for AD. Precise interpretation of FDG with PET in patients with dementia is not based on the presence or absence of a single region of hypometabolism, but should take into account the pattern of hypometabolism throughout the cortex (Scheltens *et al.*, 2016; Barthel, 2020). However, further standardization is required to have universal clinical use of biomarkers (McKhann *et al.*, 2011; Barthel, 2020). Likewise, although age is one of the primary factors associated with AD, there is a wealth of research which currently points to neurodegeneration, inflammation, atrophy, and other elements of concern as chronic circumstances that may favor the manifestation of dementia as well as the development of lesions in the structures of the medial temporal lobe, hippocampus, and entorhinal cortex. These lesions are characteristic of the anatomopathological alterations typical of AD due to Aβ protein plaques outside neurons and Tau protein neurofibrillary tangles inside neurons, physiological characteristics of a patient which usher the progression of the disease (Stephan *et al.*, 2012).

General information on aluminum

Aluminum is the third most abundant chemical element in the earth's crust, making up 7.5 % of its composition. Despite its prevalence, it has no biological function in human or animal organisms. However, its low density and ability to self-passivate cause it to be widely used in industries (Stephan *et al.*, 2012; Stahl *et al.*, 2017). According to the European Aluminum Foil Association, aluminum has been used commercially for more than a century.

Due to its abundant availability and characteristics, since the late 19th century, it has increasingly shaped the modern lifestyle and has become necessary for space exploration, electricity transmission, the construction of modern buildings, and the manufacturing of aircrafts, automobiles, vessels, and currently, high-quality packaging of various types for the food industry, to which it is especially suited given its low cost and high levels of conductivity which enable effective temperature regulation (Casaburi *et al.*, 2019).

Therefore, the production of primary aluminum has increased significantly in recent years, reaching a worldwide production level of 68,461 thousand metric tons in 2022, with China being the largest producer at 40,430 thousand metric tons (International-Aluminum, 2023). However, alloying additives and recycled aluminum, which are excluded from the processing of primary aluminum, are used in the production of secondary aluminum, a process which can be repeated almost indefinitely, which cuts costs and multiplies environmental benefits. Aluminum figures are thus expected to increase considerably due to advances in aluminum alloy metallurgy (Brough & Jouhara, 2020).

Sources and behavior of aluminum in food

The migration of aluminum into food impacts the health of consumers, bringing as consequences neurological diseases involving inflammatory neural degeneration, behavioral deterioration, and cognitive impairment (Barthel, 2020). In addition, its accumulation in the central nervous system (CNS) over time can lead to irreversible brain cell damage and functional decline resulting in cognitive, memory, and behavioral deficits. Consequently, researchers have analyzed the aluminum content of the temporal lobe neocortex, finding a range of 1.9 - 16.8 ug aluminum/gm tissue in autopsies performed on patients whose cause of death was AD (McLachlan *et al.*, 2018).

One of the causes of aluminum accumulation in the human body is the consumption of foods which contain this element, either from primary or secondary sources. Primary aluminum in food is generated by the natural migration of aluminum from the earth's crust (where this element is present) to food. This phenomenon occurs primarily in plants. Plants absorb nutrients from the soil that are used for nutrition, development, and growth. Aluminum can be found in fresh vegetables, with values between 2 and 10 mg/kg, depending on the type of soil (alkaline or acidic) where it is harvested, the concentration of aluminum present in the soil, the water used for irrigation, and the type of vegetable, leafy vegetables having the highest values, followed by bulb, stem, flower, pod, root, and tuber vegetables. In fruits, on the other hand, concentrations are lower (mean value of aluminum 1.3 mg/kg) (Liang *et al.*, 2019; Daouk *et al.*, 2020).

Estimates suggest that 40-50 % of cultivable soils worldwide are acidic (pH <5.0). Here, aluminum is present in a cationic form (being highly soluble) which allows plants to easily obtain a higher concentration (Rahman *et al.*, 2018). However, cereal plants are among the plants with the lowest aluminum accumulation. Levels of aluminum in cereal plants are also highly variable between countries or even regions of the same country, as shown in Table 2, which outlines the presence of this metal not only in grains but also in other parts of plants (leaves and shoots) and cereal-based products.

Soil geochemistry not only affects plants and plant products through aluminum migration but also alters water quality. This contamination causes water quality to decrease to levels prejudicial to biota in waterways affected by the easy discharge of aluminum due to the high solubility of this contaminant in more acidic conditions such as those in acidic soil and rain (acid rain) (Hu *et al.*, 2017; Toivonen *et al.*, 2020). Therefore, the above-mentioned phenomena may be factors in the increased levels of aluminum in some plants, as is the case of tea plants (Camellia sinensis) which are produced in acid soils with a pH range of 3.5 - 5.6 (De Silva *et al.*, 2016; Hu *et al.*, 2017). Research has reported aluminum concentrations in tea leaves between 1836.77 and 487.57 mg/kg (Peng *et al.*, 2018; de Silva *et al.*, 2016; Li *et al.*, 2015), which has generated research to address the management and control of aluminum levels in soils and crops. Reducing these levels could help counteract the concentrations present in water systems.

Besides coming from areas with acidic rocks and soils, this metal can also be found in nature, in lake water, either as untreated water or as water treated with Al salts or with electrocoagulation/electroflotation. The latter is a recognized decontamination method for water treatment

Table 2. Aluminum concentration (mg/kg) in some grains, parts of plants, or cereal products

Reference	Plant, food, or product	Aluminum concentrations (mg/Kg)	Country
Chen *et al.* (2008)	Rice, soybean, and corn leaves	< 500	China
	Rice sprouts	< 200	
Bratakos *et al.* (2012)	Cereals and cereal products	7.10	Greece
Chen *et al.* (2017)	Wheat	18.6	China
	Wheat	11	
	Soybeans	8.8	
Liang *et al.* (2019)	Corn	6.2	China
	Millet	2.7	
	Rice	2.1	
	Soybeans	89	
	Rye	50	
	Rice	30	
Squadrone *et al.* (2021)	Oats	28	Italy
	Triticale	21	
	Barley	20	
	Wheat	17	
	Corn	2.9	

in which aluminum electrodes can be used wherever the release of aluminum metal molecules may occur to decontaminate the water containing dyes (Garcia *et al.*, 2016). Moreover, these electrodes are used to remove heavy metals such as chromium present in water (Villabona-Ortíz *et al.*, 2021). Salts are also inappropriately used as coagulants in drinking water treatment to reduce organic matter, color, turbidity, and microorganism levels. In this way, aluminum is transported via the liquid until it reaches residences where it is sometimes consumed directly from the tap. This water could contain a higher aluminum content after purification with aluminum salts since this compound increases the percentage of dissolved polyaluminum species (Al Zubaidy *et al.*, 2011; D'Haese *et al.*, 2019).

This can cause a risk to human health, especially when aluminum is present in high concentrations (≥ 0.1 mg/L aluminum) as it becomes a catalyst for AD and dementia (FAO/WHO, 2007; Matías-Cervantes *et al.*, 2018). Similarly, water treatment affects the aquatic ecosystem by generating contamination with non-essential oligoelements, mainly aluminum, which is transferred through the trophic chain to crustaceans and especially fish. The latter has been held to be amongst the most susceptible aquatic organisms to the accumulation of metals. Consequently, these marine species become vectors of metal contamination for humans which can cause health risks when levels of toxic elements are very high (Trevizani *et al.*, 2019; Dos Santos *et al.*, 2023). Therefore, research has focused on finding natural alternatives to reduce the use of aluminum salts as flocculants in drinking water purification (Ekong *et al.*, 2017; Chao *et al.*, 2020).

Another way in which humans can be exposed to aluminum is through the ingestion of aluminum through food contaminated during processing, packaging, and/or storage. This is secondary source of aluminum associated with the lixiviation of this element from kitchen equipment and utensils (pots, cutlery, trays, knives, frying pans, grills, etc.) that are manufactured with the material. Aluminum is widely used in the industry for the production of these utensils mainly because it is an easily obtainable material with good malleability, thermal conductivity, ease of clean up, and durability (Odularu *et al.*, 2013; Stahl *et al.*, 2018). Despite these industrial benefits, aluminum can easily leach into food due to factors such as the type of aluminum utensils used, exposure time, cooking temperature, salinity, pH, fat content, and food composition in general (Al Zubaidy *et al.*, 2011; Bassioni *et al.*, 2012). Another secondary factor of aluminum exposure is the use of aluminum foil in food preparation and culinary practices. Aluminum foil has been widely used to wrap heat-sensitive foods (mainly seafood and meat products) before cooking, which can generate a high concentration of aluminum in the product after heating.

Table 3 shows studies that have evaluated the leaching of aluminum from aluminum foil into various foods. It shows that the amount of leaching can increase depending on the characteristics of the food, pH, whether it is marinated (wines, citric acid, tomato juice, apple cider vinegar), acidity, or whether it contains spices or additives. Here, acidic solutions and spices, along with increased temperature and cooking time, contributed to increased leaching of the aluminum exposure area. Weidenhamer *et al.* (2016) studied the release of aluminum from cookware materials in 10 developing countries (Bangladesh, Guatemala, India, Indonesia, Ivory Coast, Kenya, Nepal, Philippines, Tanzania, and Vietnam), finding that there was an average aluminum exposure for all cookware studied of 125 mg per serving, six times higher than the provisional tolerable weekly intake for a 70-kg adult (20 mg/day). These authors made preliminary evaluations of three possible methods to reduce metal leaching in the cookware tested (boiling or near-boiling water, addition of curcumin, and fluoropolymer coating), where the fluoropolymer coating reduced up to 98 % of the aluminum level in the final extraction.

Table 3. Leaching of aluminum from food through food preparation and storage.

References	Material	Conditions	Food	Aluminum concentration (mg/kg)
Mol and Ulusoy (2020)	Wrapped in aluminum foil thickness of 12 µm. Opaque part (inner part) was in contact with the product.	Baking on the grill or griddle (200 °C for 20 min). No salt, spices, oil or metal equipment were used during preparation.	Sea bass (Dicentrarchus labrax Linnaeu)	3.8 (Baked with skin/shell) 4.9 (Baked without skin/shell)
			Mussels (Mytilus galloprovincialis Lamarck)	289 (Baked with skin/shell) 252 (Baked without skin/shell)
			Shrimps (Parapenaeus longirostris Lucas)	45.7 (Baked with skin/shell) 58.9 (Baked without skin/shell)
Fermo *et al* (2020)	Wrapped in aluminum foil thickness of 20 µm	Baking in oven (180 °C for 1 h) Seasoning and not seasoning	Chicken	40 (Seasoning)
			Beef	40 (Seasoning)
			Fish	42 (Not seasoning)
Ejovwokoghene and Philipa (2020)	Wrapped in aluminum foil	Oven drying	Barbeque catfish	0,007
Inan-Eroglu *et al.* (2019)	Wrapped in aluminum foil	Baking in oven (150 °C for 40 min and at 200 °C for 20 min) marinated	Salmon	1,228 (150 °C for 40 min)
			Haddoc	0,999 (150 °C for 40 min)
Dordevic *et al.* (2019)	Degree of aluminum leakage from aluminum foil	Baking in oven (220 °C for 40 min) marinated and not marinated	Atlantic salmon	41,86
			Mackerel Scomber,	49,34
			Duck breasts,	117,26
			Cheese Hermelín,	4,46
			Tomato,	7,78
			Paprika,	1,32
			Carlsbad dumplings,	1,88
			Pork roast,	15,87
			Pork neck,	4,91
			Chicken breasts,	5,25
			Chicken thighs	3,6
Hafez *et al.* (2018)	Aluminum cup, aluminum foil cup and silicon cup	Baking in oven (180 °C for 25 min) storage for 20 days	Orange cake	15,47
			Milk cake	12,02
			Control cake	9,02
Ertl, and Goessler (2018)	Wrapped in aluminum foil	Baking in oven (180 °C for 45 min)	Beef	0,27
			Fishfilet	0,18
			Onion	0,51
			Pork	0,28
			Poulard	0,083

			Potato without peel	0,30
			Potato with peel	1,1
Jabeen *et al.* (2016).	Wrapped in aluminum foil	Different food solutions	Chicken	209.52 (yogurt + lemon Juice)
			Beef	292.25 (tomato juice + citric acid + salt)
Al Juhaiman (2015)	Wrapped in aluminum foil thickness of 40 µm	Baking in oven (180 °C for 20, 40, 60 min and 160 °C, 180 °C, 220 °C for 60 minutes) with additives	Chicken	59.20 (60 min.) 154.04 (220 °C)
			Cow stakes	85.34 (60 min.) 111.51(220 °C)
			Fish	132.01 (60 min.) 91.23(220 °C)

Likewise, trays or containers can be found in the market, which are made of aluminum sheets with thicknesses greater than those used to make paper; these are mainly designed for solid and/or semi-solid products. Therefore, this material has attracted much interest in the industry as it is an excellent barrier against gases, light, moisture, odors, flavors, and microorganisms and has properties of impermeability, resistance to freezing, inertness, especially perfect dead fold characteristics, and recyclability (Sarkar & Aparna, 2020). However, it can pose risks to human health due to the migration that occurs when the material comes into contact with food and is exposed to heat. This can lead to corrosion and erosion of the container, allowing aluminum to leach into the food and then follow the digestive and circulatory tract, and finally, it is stored in the tissues, including the brain; similar process happens with aluminum containers, traces of this metal are extracted from the walls of the container, it passes to the liquid phase and followed by the product, presenting itself in low pH sauces and fruit juices (Bejarano & Suárez, 2015; Deng *et al.*, 2021).

Aluminum can also be found as a secondary source of food additives. These are substances that are intentionally added to food for a technological purpose in the manufacture, preparation, processing, treatment, packaging, wrapping, transport, or preservation of the food, so the use of Al-containing additives can affect the total concentration in the final product (Yokel, 2016; FAO/WHO, 2021). In the additives market, aluminum can be found as an ingredient in several of these compounds, such as sodium aluminum sulfate (sodium aluminum duplex sulfate, E521, INS 521), potassium aluminum sulfate (potassium alum, E522, INS 522), ammonium aluminum sulfate (ammonium alum, E523, INS 523), potassium aluminum sulfate (potassium alum, E522, INS 522), ammonium aluminum sulfate (ammonium alum, E523, INS 523), sodium aluminum phosphate (aluminum salt and phosphoric acid salt, E541i, INS 541i), sodium aluminosilicate (sodium aluminum silicate, E554, INS 554), calcium aluminum silicate (E556, INS 556), and aluminum silicate (E559, INS 559). These additives are technically used in processed products and water as synthetic stabilizers, coagulants, and leavening agents to control the rate of CO_2 gas generation, emulsifiers, and acidity regulators (Ogimoto *et al.*, 2016; FAO/WHO, 2021). Among the above-mentioned additives are included fermenting agents, demolding agents, anti-caking agents, and protectants such as aluminum and sodium silicate in cake mixes and dry products, gelatins, wheat flour, and wheat-based foods (including fried dough sticks, fried dough cakes, steamed bread, noodles, cakes, and pastries, etc.). These are the foods with the highest levels of aluminum and potassium dodecahydrate due to the use of aluminum and potassium sulfate dodecahydrate, fried dough cakes, steamed bread, noodles, cakes, and pastries, etc.) are the foods with the highest levels of aluminum due to the use of aluminum potassium sulfate dodecahydrate (alum) in the preparation of these types of products (Ning *et al.*, 2016; Wang *et al.*, 2022). Due to the health risks posed by aluminum, some countries, such as China, have conducted several studies (Guo *et al.*, 2015; Chen *et al.*, 2017; Ding *et al.*, 2021) on the use of additives containing this metal to provide scientific information to the government so that it can better control the limits of aluminum residues in food additives.

In the food industry, aluminum is also used as a colorant (E173), known as Çl pigment metal", which presents a silver-gray hue or tiny sheets used to decorate bakery and confectionery products (Silva *et al.*, 2022). It is also used in the extraction process of some colorants such as carmine (carminic acid E120), which is obtained naturally from cochineal when it is subjected to a heat treatment and pH 5 in combination with aluminum, citric acid, and calcium salts (Gebhardt *et al.*, 2020). This colorant is commonly used in the production of meat products (smoked fish, crustacean paste, fish paste, pre-cooked crustaceans), dairy products (yogurts, ice creams, fresh flavored cheeses, cured cheeses, edible cheese rinds), among others (candies, sweets, candies, chewing gum, desserts, cakes, pastries, candies, jams, vitamins, pharmaceutical tablets, and medicinal capsules), due to the tonality (purple to red) that it imparts in the product mainly used (Silva *et al.*, 2021). Another colorant extensively used to improve the appearance of soft drinks, dairy products, candies, and confectionery, are anthocyanins (E163) which can be obtained from vegetables and edible fruits, such as blueberries, strawberries, raspberries, blackberries, currants, and grapes. In this colorant can be found aluminum particles product of the extraction of this compound (Gebhardt *et al.*, 2020; Silva *et al.*, 2022). Also, aluminum in the form of aluminum oxide is used to improve the technological properties of titanium dioxide or "CI white pigment 6", a colorant that is used in confectionery products, decorations, dairy products and analogs, surimi and similar products, salmon substitutes, seasonings, condiments, mustard, sauces, broths, soups, among others (Ropers *et al.*, 2017; Silva *et al.*, 2022).

In general, the use of aluminum-containing additives is gaining increasing significance due to the technological benefits they offer in terms of their visual impact on food. Sometimes these additives enhance the food's color, making it much more attractive than its natural hue. Additionally, some additives like sodium aluminum silicate, calcium aluminum silicate, and aluminum silicate, serve as anti-caking agents in dry powdered products and generate greater solubility at the time of preparation (FAO/WHO, 2021). Sodium aluminum phosphate is also used to emulsify and improve product quality, melt cheese, thicken juices and sauces, and for pickling vegetables, and is found in fruit confectionery, meat binders, dough reinforcers, stabilizers, buffers, neutralizers, texturizers, and curing agents (Ogimoto *et al.*, 2016). Likewise, the additives aluminum sodium sulfate, aluminum potassium sulfate, and aluminum ammonium sulfate are used to regulate acidity in order to reduce the growth of organisms both in water and in foods, mainly of vegetable origin, resulting in them being used as preservatives. Therefore, these additives function in ways that both appeal to consumers and, at the same time, lead to better results for the industry due to the profitability of these foods on the market. Thus, in some countries, attempts to ban the use of additives which contain aluminum have not been successful, which has led to the regulation of the use of each additive based on the concentration of aluminum it contains. This includes stipulations that products must be labeled with the type of additive used according to the specifications established by the Codex alimentarium (Ropers *et al.*, 2017; FAO/WHO, 2021).

Adverse effects of aluminum on human health

According to WHO, the tolerable daily intake (TDI) of aluminum for humans should be 1 mg/kg body weight/day (FAO/WHO, 2007). Exposure at these levels is not a problem since the human body can excrete small amounts of this metal very efficiently. Unfortunately, a large part of the population is exposed to and ingests more than their bodies can excrete. As a result, the effects that this metal can produce on tissue function can be significant, starting with the reduction of human brain cell growth, proportional to the amount of concentrated aluminum (Diamond, 2008; Bassioni *et al.*, 2012). The above has spurred a surge in research on the relationship between the accumulation of aluminum in the human body and the risk of multiple neurological pathologies. Some studies, cited in Table 4, were carried out to determine the levels of aluminum present in patients diagnosed with neurological pathologies such as autism spectrum disorder, the precise origins of which are unknown. Mold *et al.* (2018) performed the first study which examined the aluminum content in the brain tissue of people diagnosed with autism. The results showed a high presence of aluminum in the extracellular and intracellular tissue, suggesting that aluminum may be related to the etiology of this disorder. Likewise, aluminum has been associated with breast cancer due to the accumulation of traces from the use of cosmetic products such as deodorants that may contain aluminum salts. In the cases studied, women and the elderly were found to be the most susceptible to the accumulation of metals in their bodies as a result of the use of some medications, environmental exposure, water intake, and foods with high concentrations of additives such as those mentioned in this study. Therefore, it is important to give consumers the information necessary to make informed decisions about the type of products consumed and the type of utensils used for their preparation. This is especially important for pregnant women, since this metal may from an early age, and research has even established that aluminum may be related to congenital malformations of the central nervous system (Troisi *et al.*, 2019).

Also in the studies mentioned in Table 4, AD is one of the most studied pathologies because of the relationship aluminum has with the neurotoxin associated with the disorder. The research indicates that the abnormal aluminum concentrations found in elderly patients, as well as in young patients with AD, can cause an excess of inflammatory activity in the brain, which is a factor that accelerates the rate of brain aging, in turn inevitably increasing the incidence of age-related neurological diseases (Bondy, 2016).

According to Exley (2017), AD is considered an acute response to chronic aluminum intoxication, with aluminum acting as a catalyst in the early onset of the disease because of the way the brain responds to this aluminum load. This metal is accumulated in the body in the frontal cortex and hippocampal regions of the brain, generating neurotoxic activities in the central nervous system which lead to decreased enzymatic activities, increased oxidative stress, and aggregation of proteins such as beta-amyloid (Aβ), all of which contribute to the generation of senile plaques where a series of processes can lead to neurodegeneration and cell death (Kabir *et al.*, 2020).

Research on aluminum from cookware and aluminum foil

One of the sources of aluminum contamination in food is cooking equipment such as pots and pans, among others, which, when subjected to high temperatures (>100 ºC), undergo a leaching process, causing the food to absorb traces of aluminum which are subsequently ingested by the consumer. In 2010, Luján studied the aluminum ingestion that occurs when boiling water and cooking food in pots made with aluminum. The results found that aluminum was present in the water and food (vegetable soup) after 30 minutes of heating at concentrations of 220 μg/L for the water and 400 µg/L for the soup. In another study, Cisneros *et al.* (2019) found a range between 2.33 and 5.12 mg/kg of aluminum in rice cooked in 6 containers from different brands, which exceeds the limits set out in European regulations of 1 mg/kg.

Another source of contamination by this element is aluminum foil, which is widely used to wrap food for cooking or reheating, either in the oven or using pots or pans. To address this concern, Ertl and Goessler (2018) evaluated the aluminum content in foods that were coated with aluminum foil and baked at 5 min at 180 °C. Notably, the results revealed a 12-fold increase of aluminum in cow (from 0.021 to 0.27 mg/kg), a 5-fold increase in onion (from 0.088 to 0.51 mg/kg), and a 4-fold increase in pork (from 0.055 to 0.28 mg/kg), after the baking process. These findings provide clear evidence of the metal leaching into the food after being subjected to a thermal process. In this same research, it was found that high temperatures are not the only cause of aluminum leaching into foods. After 3 days of refrigeration at 7 ºC, foods such as salmon, ham, lemon, and orange increased their aluminum content 16 times (from 0.13 to 2.2 mg/kg), 32 times (from 0.11 to 3.6 mg/kg), 163 times (from 0.032 to 5.2 mg/kg), and 200 times (from 0.034 to 6.9 mg/kg) respectively.

Likewise, Ejovwokoghenea and Philipa (2020) investigated the risk of aluminum consumption through the ingestion of barbecued catfish that was wrapped in aluminum foil for protection during cooking. These researchers found that the fish went from 0.039 mg/kg (raw) to 0.047 mg/kg after the cooking process, which indicated the rate of leaching of 18.65 % aluminum into the fish. However, consuming this food in small quantities, prepared as described here, does not pose a danger, as the aluminum content remains below the amount allowed by the norms (1 mg/kg).

Table 4. Research on the relationship between aluminum and human health risks

Reference	Purpose	Population	Results
Bocca *et al.* (2015)	Determination of neurotoxic metals in cases of Amyotrophic Lateral Sclerosis (ALS).	34 ALS patients (62 ± 10 years old) and 30 controls (65 ± 11 years old).	The results indicated that, Aluminum concentrations were higher in blood (p = 0.045) in ALS subjects with respect to controls (8.04 μg/L vs. 6.68 μg/L).
Virk *et al.* (2015)	occupational exposure to aluminum and risk of AD.	1056 individuals from 3 retrospective case-control studies.	Occupational aluminum exposure was not associated with AD (odds ratio, 1.00; 95 % confidence interval, 0.59 to 1.68).
Zioła- Frankowska *et al.* 2015	Evaluate the aluminum concentrations between the femoral head and neck, and whether these concentrations may pose a risk to human health.	96 patients operated on for total hip replacement (THR), not diagnosed with dementia-related diseases, nor with AD and renal disease.	The highest aluminum concentrations in the femoral neck were found in patients aged 41 - 50 years (4,443 μg/g), and in the femoral head at ages 51 - 60 years (2,478 μg/g), some cases aluminum concentrations in older patients were higher than in the younger group
Wang *et al.* (2016)	Meta-analysis to investigate whether chronic aluminum exposure is associated with an increased risk of AD.	10567 individuals from 8 cohort and case-control studies.	Chronic exposure to aluminum was found to be associated with AD with a probability of more than 71 % (OR: 1.71, 95 % confidence interval (CI), 1.35-2.18).

Linhart *et al.* (2017)	Breast cancer risk associated with the use of cosmetic products containing aluminum salts in the armpits.	460 women, 210 were breast cancer cases and 250 were healthy controls.	Median (interquartile) aluminum concentrations were significantly higher ($p = 0.001$) in cases than in controls (5.8, 2.3–12.9 versus 3.8, 2.5–5.8 nmol/g). In ten breast cancer patients, aluminum concentrations over 60 nmol/g up to 367 nmol/g dry weight (15-115 nmol/g wet weight) were observed.
Choi *et al*. (2018)	Association between serum aluminum level and amnestic mild cognitive impairment (aMCI) or AD.	136 patients with aMCI and 191 patients with AD.	Blood aluminum levels were 11.09 μg/L (95 % CI: 10.20, 12.06) in the aMIC group and 11.16μg/L (95 % CI: 10.04, 12.39) in AD patients, indicating that blood aluminum level was positively associated with the risk of aMIC and AD.
McLachlan *et al.* (2018)	Aluminum content of the temporal lobe neocortex in the brains of human neurological and neurodegenerative disease ever undertaken.	511 high quality human brain samples from 18 diverse neurological and neurodegenerative disorders, including 2 groups of age-matched controls.	There is a statistically significant trend for aluminum to be increased only in AD to a mean of ∼8.08-fold over these controls (N=186; range 1.9-16.8 ug aluminum/gm tissue); Down's syndrome (DS) to a mean of ∼4.53-fold over age and gender-matched controls (N=24; 2.0-7.1 ug aluminum/gm tissue) and dialysis dementia syndrome (DDS) to a mean of ∼3.69-fold over age and gender-matched controls (N=27; range 1.2-6.2 ug aluminum/gm tissue).

Mold *et al*. (2018)	Measured aluminum in brain tissue in autism and identified the location of aluminum in these tissues.	5 individuals with Autism Diagnostic Interview-Revised ASD, 4 males and 1 female, aged 15–50 years old.	The aluminum content of all tissues ranged from 0.01 (the limit of quantitation) to 22.11 μg/g dry wt, with a mean for each lobe of 3.82(5.42), 2.30(2.00), 2.79(4.05), 3.82(5.17) and 8.74 (11.59) μg/g dry weight.
Bichu *et al*. (2019)	Association between use of aluminum utensils for cooking and occurrence of Chronic Aluminum Toxicity (CAT) in Patients on Maintenance Hemodialysis (MHD).	31 patients on MHD for more than one year were included, 10 cases and 21 controls.	The relative risk of having CAT in Patients on Maintenance Hemodialysis (MHD) because of use of aluminum utensils compared to not using was 28.46 (1.81 to 445.3) and the odd's ratio estimated was 120 (5.45 to 2642).
Troisi *et al*. (2019)	Between specific congenital defects and maternal exposure to heavy metals.	111 patients with a diagnosis of fetal anomalies and 90 were control.	Serum aluminum concentration was significantly higher in mothers with a fetus affected by a congenital CNS defect (0.14 ± 4.72) compared to serum samples from mothers with a normally-developed fetus (-5.03 ± 1.27).
Wen *et al*. (2019)	Associations between the multiple metals in plasma and the risk of ischemic stroke.	2554 participants: 1277 newly diagnosed IS patients and 1277 control subjects.	Positive associations with ischemic stroke risk were observed for aluminum, where a concentration of 10.49 (95 % CI: 7.38, 14.90) was found in the single-metal model and 4.23 (95 % CI: 2.63, 6.79; p -trend <0.001) with the multi-metal model.

Adani *et al.* (2020)	Environmental risk factors in the etiology of early onset dementia (EOD), taking into account its different clinical types.	112 participants (58 patients with EOD and 54 controls)	Aluminum exposure was associated with an increased risk of frontotemporal dementia (FTD) (OR 4.1, 95 % CI 0.5-34.5), but not for AD. Thus, most of the investigated cases presented positive associations between EOD and occupational exposure to aluminum, pesticides, and other chemicals (dyes, paints or thinners.

On the other hand, the presence of aluminum can also be caused by migration from the food packaging. Iscuissati *et al.* (2021) evaluated the migration of aluminum to coffee prepared by a high-pressure machine with metal seals (Nespresso® Essenza Mini machine). It was found that using the machines to prepare the beverages contributes to increase the aluminum content by approximately 13 % (459 μg/L) compared to a conventional filtration coffee preparation process (408 μg/L). Concerns are also expressed about the reuse of ground coffee, since the increase in aluminum content is approximately 3.5 times higher in this after its preparation, and therefore this recycling strategy should be discarded.

For this reason, Stahl *et al.* (2018) investigated human exposure to aluminum and food contact materials. The study found regional differences that led to variations in the global consumption of aluminum. For the adult population, the average exposure to this metal was between 0.2 and 1.5 mg/kg body weight/week. On the other hand, children and adolescents, who have a lower body weight, were found to have a higher aluminum concentration (between 0.7 and 2.3 mg/kg body weight/week). These results show values between 14 and 105 mg of aluminum/week for an adult weighing 70 kg while the values for a child weighing 30 kg were 21 to 69 mg aluminum/week. These values indicate that a portion of the human population can consume enough aluminum through their usual diet to reach the tolerable weekly intake.

Between 2015 and 2016, Takanashi *et al.* (2018) conducted a survey in Japan on the aluminum content in flour-based products and confectionery with baking powder. Aluminum was found in 33.33 % of the evaluated products (corresponding to 41 out of 123 samples), at levels between 0.01 (limit of quantification) and 0.40 mg/g. The presence of this metal in confectionery products was reduced compared to previous studies. However, the presence of aluminum was high in Japanese confectionery and flour-based foods. Consuming one serving of 4 of the 41 samples analyzed would result in an aluminum intake that exceeds the recommended levels for young children, whose average weight was 16 kg.

To study the toxic risk of aluminum intake, Hardisson *et al.* (2017) collected and compared data on the concentrations of this metal across various types of foods, aiming to estimate the total dietary intake. The most predominant analytical techniques for aluminum determination were inductively coupled plasma atomic mass spectrometry and atomic emission spectroscopy (ICP-OES and ICP-AES). The highest aluminum levels were found in vegetables (16.8 mg/kg), fish and shellfish (11.9 mg/kg), and roots and tubers (9.60 mg/kg). Among the foods that contributed most to the tolerable weekly intake of this metal were fruits (18.2 % for adults and 29.4 % for children) and vegetables (32.5 % for adults and children). As a result, it could be concluded that the dietary intake of aluminum may pose a health risk due to the accumulation of this metal in the brain caused by long-term intake.

Plant extracts to fight Alzheimer's disease

Considering the need of reducing the effects generated by aluminum on the nervous system, researchers have been driven to explore the potential of the Moringa oleifera plant. Ekong *et al.* (2017) studied the neuroprotective effects of moringa leaf extract on aluminum-induced temporal cortical degeneration in rats and concluded that it protects against aluminum-induced neurotoxicity of the temporal cortex of rats.

Previous research has confirmed that yerba mate (*Ilex paraguariensis*) has an antioxidant potential that could help reduce the risk of developing neurodegenerative diseases, such as AD; antioxidants can mitigate the oxidative stress that causes and/or contributes to the development or progression of AD. Bortoli *et al.* (2018) evaluated the potential of *I. paraguariensis* in the etiology of AD using *Caenorhabditis elegans* strains. The study explored the concentration of aluminum and antioxidants in the plant's leaf extract. It was determined that the metal content impacts the Acetylcholinesterase (AChE) activity. Consequently, acute and chronic exposure to both the element and leaf extract of *I. paraguariensis* demonstrated notable similarity to wild-type worms. In addition, it was observed that the results in both transgenic strains exposed long-term to leaf extract and aluminum concentrations showed an increase in AChE activity.

Similarly, Elufioye *et al.* (2019) found that extracts from the leaves of *Macrosphyra longistyla* have high antioxidant and anticholinesterase activities. According to the results found, extracts from this plant can potentially be used in the treatment of neurodegenerative diseases such as AD. Similarly, Oboh *et al.* (2021) found that extracts from the leaves of *Heinsia crinita* and *Pterocarpus soyauxii*, owing to their anticholinesterase, antioxidant and metal chelating properties, can reduce the presence of aluminum in the body. Researches have shown that the use of extracts from natural sources (mainly plants like the aforementioned) can be an alternative against AD, due to the multiple benefits they offer.

CONCLUSIONS

The results of the research in this area provide important information to consider that AD is a degenerative disease and may be related to the accumulation of aluminum in the brain. This metal is accumulated in the human body mainly through the ingestion of foods contaminated with aluminum; being a heavy metal, it is often found in the soil and is therefore easily present in fruits and vegetables, as well as in water. In addition, the use of containers or kitchen utensils made of aluminum becomes a source of contamination of products since the migration process of this metal is accelerated when exposed to heat in contact with food. In the last few years, the population has become increasingly aware of the health risks caused by the ingestion and accumulation of this metal in the human organism. The concern generated by the consumption of aluminum through food matrices and its consequences on the health of consumers has led researchers, industry, and consumers to develop and use alternatives for kitchen utensils, packaging, food additives, and water treatment with materials that do not contain this metal, with the purpose of mitigating the risks of aluminum consumption and its relationship with AD.

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REVISIÓN

Water quality indices (WQI) and contamination indices (WPI) a bibliographic review

Índices de calidad y contaminación del agua: una revisión bibliográfica

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Abstract

Context: surface water sources are the fundamental resource in any activity or development process as an axis of interest for their use. However, anthropogenic activities have deteriorated bodies of water, considerably altering their properties, physicochemical and microbiological characteristics, which are the fundamental indicators of contamination levels in the dynamics of water bodies. At an individual level, they only represent an idea of their concentration in the analyzed samples. Therefore, to assess the quality of the bed, these variables must be integrated through Quality Indicators and Contamination Indicators (WQI and WPI) in lotic, lentic, and underground systems.
Methodoly: a bibliographic review was carried out in the Sciencedirect database and digital platform, using the phrase "water quality index and pollution index" as search criteria. This search pattern was applied to the keywords of the articles consulted. The most relevant documents of the last 10 years were selected, with which the review was performed.
Results: the most common way to characterize water involves determining its physicochemical parameters and analyzing them against national or international maximum permissible values. This process transforms Water Quality Indices and Pollution Indices into useful methods with a simple and practical applications, helping to identify problems related to the concentration levels that vary in lotic, lentic, and underground bodies. This research presents the most frequently used WQIand WPI based on the bibliographic review, revealing that the countries where more research has been conducted are China, India, Brazil, Nigeria, and Indonesia.
Conclusions: the water quality indices and contamination index have been repeatedly implemented in recent years in various countries around the world with the aim of evaluating the quality of both surface (rivers, lakes, seas) and

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groundwater (water streams). Similarly, new indices have been developed from some existing WQI.

Keywords: surface water, groundwater, Pollution Index (WPI), Water Quality Index (WQI), physicochemical parameters.

Resumen

Contexto: las fuentes de agua superficiales son el recurso fundamental en toda actividad o proceso de desarrollo, pues su eje representa un interés de interés. No obstante, las actividades antropogénicas han generado un deterioro de los cuerpos de agua, alterando considerablemente sus propiedades, las características fisicoquímicas y microbiológica, las cuales son los indicadores fundamentales de los niveles de contaminación en la dinámica de los cuerpos hídricos. A nivel individual, estos cuerpos hídiricos solo presentan una idea de su concentración en las muestras analizadas, por lo que para tener una evaluación de la calidad del lecho se debe integrar estas variables a través de Indicadores de Calidad e Indicadores de contaminación (ICA e ICO) en sistemas loticos, lenticos y subterráneos.
Metodología: se realizó una revisión bibliográfica en la base de datos y plataforma digital Sciencedirect, utilizando como criterio de búsqueda la frase "water quality index and pollution index". Este patrón de búsqueda se aplicó a las palabras claves de los artículos consultados. Se seleccionaron los documentos más relevantes de los últimos 10 años, con los cuales se procedió a realizar la revisión.
Resultados: la forma más común de caracterizar el agua es a través de determinar sus parámetros fisicoquímicos y analizarlos con valores los máximos que son permitidos nacional e internacionalmente. Así pues, los Índices de Calidad del Agua y los Índices de Contaminación se convierten en métodos útiles, pues tienen un uso simple y práctico que ayuda a identificar problema relacionado con los niveles de concentración que varían en los cuerpos loticos, lenticos y subterráneos. En esta investigación, se presentan los ICA e ICO más usados en la revisión bibliográfica y se establece que los países donde más investigación se realizaron es China, India, Brasil, Nigeria e Indonesia.
Conclusiones: los índices de calidad del agua y el índice de contaminación se han implementado de manera reiterativa en los últimos años en varios países del mundo con el objetivo de evaluar la calidad de cuerpos de agua tanto superficial (ríos, lagos, mares) como subterráneas. De igual manera, se han desarrollado nuevos índices a partir de algunos ICA existentes.

Palabras clave: agua superficial, agua subterránea, Índice de contaminación (ICO), Índice de Calidad del Agua (ICA), parámetros fisicoquímicos

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INTRODUCTION

The sources of water can be mainly take the form of rivers, lakes, rainwater, groundwater, among others. The quality of these fluids is of vital importance for the sustainable development of communities, serving several fundamental purposes such as drinking, bathing, and domestic tasks (Das *et al.*, 2021; Sunitha *et al.*, 2022; Hasan *et al.*, 2019). In addition, water plays a vital role in different sectors of the economy such as livestock, industrial activities, forestry, agriculture, hydroelectric generation, fishing, and other recreational activities. However, these anthropogenic activities release pollutants that have generated an impact on the quality of surface and groundwater bodies that affect their potential uses, causing problems for the environment and human health (Zhao, Kuo, & Chen, 2021; Dimri, Daverey, Kumar, & Sharma, 2021; Oñate & Cortéz, 2020; Effendi, 2016).

Human life has evolved around water. It is an essential resource for the populations, as they rely on this fluid to sustain different socioeconomic activities both in urban and rural centers (Barbulescu *et al.*, 2021; Dash & Kalamdhad, 2021; Torres *et al.*, 2009). Yet, these human activities have a detrimental impact on water quality due to population growth resulting from the urbanization and industrialization associated with them. This decline in quality is, in turn, exacerbated by the excessive use of chemical products in daily activities such as discharging domestic wastewater and solid waste. As a result, the quality of aquatic ecosystems and their ecosystem services is impacted. Their condition is decisive and variable in time and space and can be associated with the concentration of different pollutants in the route and dynamics of the source. Because of this, the global community strives to keep apprised of the current state of these ecosystems, recommending a monitoring system that facilitates the observation of their conditions as an early warning to protect the quality of the rivers (Moyano *et al.*, 2021; Ben Brahim *et al.*, 2021; Granitto *et al.*, 2021; Diaz *et al.*, 2020; Ustaoğlu *et al.*, 2020; Sahoo *et al.*, 2015)

Water quality is of vital importance for people and the aquatic biota upon which they rely for sustenance. The most effective method to assess water quality and ecological status of a body of water is by quantifying its physicochemical parameters (Ustaoğlu *et al.*, 2020). In this context, the WQI is presented as a method that allows to easily evaluate the changes presented in a body of water that alter its quality. The index is based on a mathematical equation that incorporates information from various physical, chemical, and microbiological parameters. This enables the analysis of complex variables and facilitates the generation of an assessment that accurately reflects the current state of the quality of the body of water, allowing in turn to understand the environmental problems associated with the various alterations of the fluid. Consequently, this index becomes a highly valuable tool for environmental authorities to manage and plan the usage of surface water resources. This is evidenced by its global application since the 1960s. The criteria for calculating the WQI can be divided into four steps: (a) selection of important parameters, (b) estimation of sub-index values (generally with the use of binding requirements), (c) calculation of weights for selected parameters, (d) final determination of the ACI by adding weighted sub-index values (Pandit *et al.*, 2022; Uddin *et al.*, 2021; Nayak *et al.*, 2021; Wątor & Zdechlik, 2021).

On the other hand, when assessing water for human consumption, color and odor are fundamental aspects. However, they are not always reliable indicators, as these qualities do not guarantee water's suitability for consumption. Invisible chemical contaminants and pathogenic organisms may be present despite favorable color and odor (Egbueri *et al.*, 2020). Likewise, the Pollution Indices (WPIWPI) are introduced as tools for assessing water quality, applicable to various types of water bodies. They contribute to the control and supervision of water pollution (Sharma *et al.*, 2021; Effendi *et al.*, 2015).

In this context, this bibliographical review serves the purpose of a documentary analysis on water quality indices and contamination indices from the last 10 years. It involves searching, synthesizing, classifying, and comparing previous publications available on the virtual scientific platform Sciencedirect.

Materials and methods

To gather information for this article, the Sciencedirect database was consulted. This platform is one of the largest digital repositories for medical, scientific, and technical research, encompassing twenty-four important scientific disciplines. It stands as the main peer-reviewed literature reviewed platform by Elsevier. This database provides access to approximately 18 million articles and chapters, 2,650 peer-reviewed journals, 42,000 e-books, 362,000 cross-subject pages, 500 journals, and 1.4 million open access articles (Sciencedirect, 2021). The bibliographical review used as search criteria keywords with the following combinations: 'water quality index' and 'pollution index', establishing 'and' as a logical connector. In this way, 55,849 articles related to the search theme were identified from 2008 to 2021. This bibliographical search was based on the foundations recommended by Vera (2016), using mainly (a) secondary sources, (b) a database search strategy with key descriptors, (c) a selection criteria where the title, the authors, the year of publication, and the abstract presented in the Mendeley bibliographic manager were taken into account. In the process of writing of this article, a synthesis, analysis, and comparison of the pertinent articles from the review were conducted, taking into account available evidence, relevant aspects or themes, as well as convergent and divergent critical discussions from various research investigations (Guirao *et al.*, 2008).

Historical analysis of references associated with WQI and WPI

Figure **1** shows a compilation of the selected articles obtained from the Sciendirect platform, illustrating the utilization of WQI and WPI indices over a specified timeframe as indicators to evaluate both underground and surface water bodies. Notably, of the fifty selected articles, more than thirty were published between 2020 and 2021.

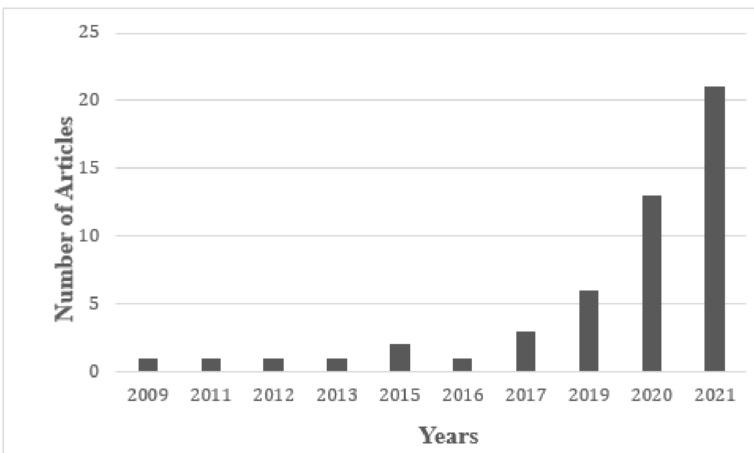

Figure 1. Articles published in the period between 2009 and 2021

Indicators of contamination in water bodies involve analyzing global and/or local maximum permissible values to evaluate the quality of the fluid. The results of these analysis can establish correlations or relationships between water quality and the polluting sources that are determinant for consumptive and non-consumptive uses related to the concentrations of the physicochemical characteristics found in the water samples (Ustaoğlu & Tepe, 2019). In this sense, by employing these indices to assess water quality, it can be predicted possible transformations that the lotic ecosystem may undergo if the multiple measurements of the variables or environmental parameters condensed in the calculation of a dimensionless variable (WQI).

Likewise, these measurements serve as foundational data for environmental authorities and the general public, enabling informed decisions that promote the sustainability of the natural resource (Hasan *et al*., 2020; Pesce & Wunderlin, 2000; Unda et al., 2020).

In 1965, Horton developed the first water quality index. Subsequently, the National Sanitation Foundation (NSF) introduced a similar ICA based on the opinion of 142 experts. This index is also known as WQINSF by its English abbreviation. Although numerous WQI have been formulated and implemented around the world, today there is no a generally accepted methodology to create an index (Dutra *et al*., 2019; Noori *et al*., 2019; Unda *et al*., 2020).

WQI are used in numerous countries worldwide, with a notable concentration of research related to them in China, India, Brazil, Nigeria, and Indonesia. As a result, WQI are presented in the bibliographic review.

National Sanitation Foundation (NSF) water quality index

The WQI-NFS, known by its English acronym, was developed in 1965 by Brown. It stems from the modified version of Horton's model and was created using the Delphi method. This index holds global prominence and is extensively utilized, particularly within the Indian subcontinent, for assessing surface water quality. Its creation involved a rigorous procedure of the selected parameters, scale definitions, and weight assignments. It is calculated through the application of different parameter quality qualification curves. The WQI-NFS is considered an integral index and universally applicable for categorizing surface water bodies in relation to their quality. This index incorporates nine parameters to evaluate water quality: Temperature, Total Solids, Turbidity, pH, Dissolved Oxygen, Fecal Coliforms, Biological Oxygen Demand (BOD), Total Nitrates, and Phosphates. Each of these parameters has a weight corresponding to its importance and impact on its development as shown in Table 1; The rating of this WQI varies from 0 to 100, presenting a rating scale of five categories: excellent (90-100), good (70-89), medium (50-69), bad (25-49), very bad (0-24) (Uddin, *et al*., 2021; Nayak *et al*., 2021; Razaie *et al*., 2020; Noori *et al*., 2019; Gupta & Gupta, 2021). The WQI-NFS is defined as follows according to (Brown *et al*., 1970).

$$\text{WQI} = \sum_{i=1}^{n} w_i q_i \tag{1}$$

Where:

WQI : The water quality index, a number between 0 and 100

q_i : quality of the i-th parameter (Table 1)

w_i : Unit weight of the i-th parameter

Table 1. Weights corresponding to each parameter of the NSFWQI

Parameters	Weight
Temperature	0,10
Dissolved Oxygen (DO)	0,17
Biological Oxygen Demand (BOD)	0,10
Turbidity	0,08
Total Solids	0,08
Match	0,10
Nitrates	0,10
Fecal Coliforms	0,15
pH	0,12
Total = $\sum$ =	1

The WQI-NSF is extensively used worldwide. Despite this, the absence of vitally important parameters such as cyanobacteria, algae, total organic carbon, presents it as an inadequate index to evaluate surface water treatment (Dutra *et al.*, 2019).

Canadian water quality index

The WQI-CCME is an index formulated by the Canadian Council of Ministers of the Environment. It is originated from the WQI of the Ministry of Environment, Lands, and Parks of British Columbia in 1997, with the objective of being used by several agencies in many countries. This WQI offers a flexible index model adaptive to specific site and treatment conditions associated with drinking water assessment. It offers the flexibility to assign values to different combinations of specific parameters. In this regard, the score for the evaluation fluctuates between 0 and 100 with five quality categories: bad (0-44), marginal (45-64), regular (65-79), good (80-94) and excellent (95-100) (Dao *et al.*, 2020; Yu *et al.*, 2020; Abdel-Satar *et al.*, 2017; Hurley *et al.*, 2012). Its greatest strength lies in its capability to incorporate toxic contaminants such as hydrocarbons, pesticides, or heavy metals, aligning with environmental quality guidelines and with current management as an objective (Gikas, *et al.*, 2020).

The calculation for the index in the WQI-CCME method is obtained as shown below:

$$\text{WQI-CCME} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \quad (2)$$

Where: $F_1 =$ (Scope) is the number of parameters that do not comply with the water quality variables:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right) \cdot 100 \quad (3)$$

F_2 = **(Frequency) is the number of times the objectives are not met:**

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right) \tag{4}$$

F_3 = (Amplitude) is the difference between the non-conforming measurements and the corresponding guidelines, this is calculated in three steps.

$$F_3 = \frac{nse}{0.01\ nse + 0.01} \tag{5}$$

$$nse = \frac{\sum \text{excursión}}{\text{Total number of tests}} \tag{6}$$

$$\text{excursión} = \frac{\text{Failed test}}{\text{Standard value}} - 1 \tag{7}$$

From this index, new WQI have been developed such as the modified water quality index, which was developed by Shankar and Raman (2020). This index emerged due to the deficiencies that its creators recognized in the existing indices. The modification of the index was applied to the groundwater in the drinking water sources of the Bommanahalli Area in Bangalore. The main modification it presented was assigning suitable weighting factors for the critical input parameters. Likewise, Ma *et al.*, (2020) incorporated it to evaluate the water quality of the aquaculture area of the southern coast of Dalian, China, covering four main farming areas in forty sampling points. This WQI was used to identify the water quality classes and thus be able to assess spatial and temporal alterations in the sampling area.

Cetesb water quality index

The CETESB index, adapted from the WQI of the NFS by the Environmental Company of the State of São Paulo, was developed with the objective of evaluating the quality of raw water for its use as public supply. To this end, it was taken into account nine parameters with their respective weights (Table 2) that represent the most frequent pollution indicators generated by domestic residual discharges. It should be noted that one of the disadvantages it presents are the limitations related to the limited analysis of parameters such as toxic substances, among these are heavy metals, pesticides, organic compounds are found. Likewise, substances that limit the organoleptic properties of water are excluded (National Water Agency [ANA], 2017; Medeiros *et al.*, 2017).

The calculation of the WQI-CETESB is carried out according to the following formula using the weighted product of the nine parameters (ANA, 2017):

$$\text{ICA-CETESB} = \prod_{i=1}^{n} q_i^{w_i} \tag{8}$$

Where: ICA-CETESB = Water quality index. A number on the scale of 0 to 100

q_i = quality of the ith parameter. A number on the scale 0 to 100, obtained from the respective quality curves, based on its concentration or measure.

w_i = weight assigned to each water quality parameter established by the specialist's judgment, that is, a number on the 0 to 1 scale, such that:

$$\sum_{i=1}^{n} w_i = 1 \tag{9}$$

Table 2. Parameters and weights of the WQI-CETESB

Parameters & Weight
Dissolved oxygen & 0,17
Total Coliforms (Thermotolerant) & 0,15
Hydrogen Potential (pH) & 0,12
Biochemical Oxygen Demand (BOD) & 0,10
Temperature & 0,10
Total Nitrogen & 0,10
Total Phosphorus & 0,10
Turbidity & 0,08
Total Waste & 0,08

Source: National Water Agency [ANA], 2017

Water quality index for public supply in the vale do rio pardo region (WQI-VRP)

The index was developed with the objective of providing a tool to assess water quality for public supply in the Vale do Rio Pardo region, Brazil. This development involved using the databases from the Regional Health Coordinations located in the municipality of Santa Cruz do Sul. For its calculation, the WQI-NFS was taken as a reference, forming a weighted product representing the water quality associated with each parameter under evaluation. Within the weighted product, the weights of importance of the variables are generated (Table 3), assigning a dimensionless value from 0 to 1, which is then multiplied. In order to accomplish this, the arithmetic weight approach is used to assign weighted values (Gad et al., 2021; Torres *et al.*, 2009)

The calculation of the WQI-VRP is carried out according to the following formula:

$$\text{WQI-VRP} = \prod_{i=1}^{n} q_i^{w_i} \tag{10}$$

Where:
q_i : relative quality of the i^{th} parameter
w_i : relative weight of the i^{th} parameter
i : order number of the parameter (1-7).
For the calculation, a step is required where each parameter is transformed to a scale from 0 to 100, with 100 being the highest quality.

Table 3. Parameters and weights of the WQI-VRP

Variables	WQI-VRP weights
Total Coliforms	0.19
E. coli	0.17
Free Residual Chlorine	0.08
Color	0.15
turbidity	0.14
Fluoride	0.12
pH	0.15
Total	1

Source: Klamt *et al.*, 2021

POLLUTION INDICES (WPI)

The WPI serves as a simple and easy method for managing water quality, playing a crucial role in evaluating fluid contamination. In this sense, they have the potential to establish solid arguments and indicators for environmental authorities to promote and implement policies and programs in relation to this renewable natural resource (Effendi *et al.*, 2015; Suriadikusumah *et al.*, 2021).

Hossain & Patra (2020) introduce a contamination index that employs an integrated approach, treating all input parameters as a single value for classifying water quality. This interdependence among these parameters plays a pivotal role in determining water quality. Even minor alterations to the input variables lead to changes in the indicator, with measurement variations directly related to the allowable limits for the groundwater parameters regulated in India's regulations for drinking water and quality guidelines outlined by the World Health Organization (WHO).

19 parameters were used: pH, electrical conductivity, total dissolved solids, Na+, K+, Mg2+, Ca 2+, F -, HCO3 -, Cl -, NO3 -, SO4 2-, and trace elements, namely Zn 2+, Cd 2+, Pb 2+, Cu 2+, Ni 2+, Co 2+, and total Fe (Fe 2+ + Fe 3+). The applications of the indicator have been

numerous due to the wide range of data it processes in its calculations. As a result, the index yields a general representation of the state of the quality of the water body.

However, the WPI can add more variables given the flexibility of n number of parameters within four types of qualifications: (a) excellent quality water (0-0.5), (b) good quality water (0.5-0.75), (c) moderately polluted water (0.75-1), (d) highly polluted water (>1). To calculate this ICO, the following equation is used:

$$\text{WPI} = \frac{1}{n}\sum_{i=1}^{n} PL_i \tag{11}$$

Where:

$$PL_i = 1 + \left(\frac{Ci - Si}{Si}\right) \tag{12}$$

C_i = Observed concentration of the ith parameter.

S_i = Standard limit or maximum allowable limit for the respective parameter.

PL_i = Standardized value of a particular parameter.

If the pH is < 7, the following equation is recommended, with 6.5 being the minimum acceptable value:

$$PL_i = \left(\frac{Ci - 7}{Si_a - 7}\right) \tag{13}$$

If the pH is >7, the following equation is recommended, with 8.5 being the maximum acceptable value:

$$PL_i = \left(\frac{Ci - 7}{Si_b - 7}\right) \tag{14}$$

Organic pollution index

The organic pollution index is a comprehensive tool that includes many components of water quality. It explains the multivariate effects of parameters such as COD, Dissolved Inorganic Nitrogen, Dissolved Inorganic Phosphorus, and Dissolved Oxygen, resulting in a dimensionless index that allows for an evaluation of aquatic environments through comparison with standard values and the combination of various contaminants with the same property. It is used in coastal and estuarine waters due to its significant advantage in evaluating the level of organic contamination (Liu *et al.*, 2011).

To determine this index, the following equation is presented:

$$\text{WPI} = \frac{\text{DQO}}{\text{DQO}_S} + \frac{\text{NID}}{\text{NID}_S} + \frac{\text{PID}}{\text{PID}_S} + \frac{\text{OD}}{\text{OD}_S} \tag{15}$$

Where:
BOD = Chemical Oxygen Demand.

NID = Dissolved Inorganic Nitrogen.
PID = Dissolved Inorganic Phosphorus.
DO = Dissolved Oxygen.
CODs, NIDs, PIDs, ODs = are the standard concentrations defined in the regulations.

This index presents 5 types of classification: excellent quality water (if WPI < 0), good quality water (0-1), water starting to become contaminated (1-2), slightly contaminated water (2-3), moderately polluted water (3-4), and highly polluted water (WPI >4).

Liu *et al.* (2011) used this index comprehensively to assess the water quality of the Bohai Sea. From their experiences, they affirm that this WPI can be used to reasonably quantify the level of temporal and spatial pollution in coastal waters.

Heavy metal contamination index (HPI)

Heavy metals cause significant pollution in aquatic environments, raising global concerns. This is due to the toxicity and lethal impact these metals impose on aquatic organisms. In response to this issue, the Heavy Metal Pollution Index (HPI) has been developed. It aims to evaluate the compound influence of individual heavy metals that contaminate and deteriorate water quality. The index takes into consideration the aggregation of trace elements, including highly toxic metals and metalloids like nickel, mercury, iron, arsenic, among others (Karaouzas *et al.*, 2021; Wątor & Zdechlik, 2021; Khadija *et al.*, 2021).

This index is based on the weighted arithmetic quality mean method and is calculated as follows:

$$\text{HPI} = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i-1}^{n} W_i} \tag{16}$$

Where:
W_i = unitary weight of the i-th heavy metal.
Q_i= subscript for the i-th heavy metal, it is calculated like this:

$$Q_i = \sum_{i=1}^{N} \frac{|M_i - I_i|}{S_I - I_i} \tag{17}$$

M_i = Examined value of the ith heavy metal.
I_i and S_i = standard and ideal values for drinking water for heavy metals.
n = number of heavy metals.

Values less than 100 mean low heavy metal contamination, values of 100 suggest probable contamination with harmful consequences for health, and values greater than 100 indicate that the water is not suitable for consumption.

Convergent and divergent criteria of background references and associated with the study of WQI and WPI

The WPI and WQIhave found diverse uses since their inception, serving as tools that facilitates the effective management of one or several underground and/or surface water sources, In general terms, the results of their calculation can specify the suitability of the natural element's use (Rana & Ganduly, 2020; Pandit *et al.*, 2022). In fact, they allow researchers and environmental agencies to present an accurate report of quality of a given water body. The combined effects of several quality parameters facilitates the identification of weighted variables with the greatest impact on the alteration. In other words, it could measure how suitable is the studied water for use (Rahman *et al.*, 2021; Gayer *et al.*, 2021).

Countries across Asia, Europe, and America have reported a recent surge in the study of water quality using the aforementioned indices. The emergence of new methodologies suggests that their utilization is likely to exhibit an upward trend in the timeline (Dash & Kalamdhad, 2021), such as Klam, *et al.*, (2021) who developed an ICA-VRP for supply in the Vale do Rio Pardo region (Brazil), using the database of the 13 regional health coordination offices of the municipality of Santa Cruz do Sul. This index is calculated in a similar way to the WQI-NFS, taking as reference 7 parameters: free residual chlorine, turbidity, apparent color, pH, fluoride, total coliforms and Escherichia coli. The aforementioned corroborates what was reported by Barbulescu *et al.* (2021) and Hasan *et al.* (2020). This tool could help in guidelines associated with the development of policies and actions established by the competent authorities, in favor of mitigating the impact on the fluid. Likewise, (Kumar *et al.*, 2019) developed an index to measure the toxicity of heavy metals in water based on median lethality dose (MLD) values, demonstrating their maximum toxicity.

However, one of the main problems reported by Uddin *et al.* (2021) creates uncertainty in the use of WQI. This stems from the way results are described upon concluding the use of such models, since they hide the real nature of water quality. This discrepancy is attributed to potentially inappropriate sub-indexing or incorrect weighting, which fail to accurately represent the dynamics of these parameters in this type of complex systems.

Moreover, other authors such as Nayak *et al.* (2020) explored the dynamism of lotic systems in India and reported high levels of content of BOD5 and Total Solids (TS). The significant presence of these specific parameters suggest that the use of the WQI-NFS may yield inconclusive outcomes. This is because its values of the parameter based on the observed value do not agree with the pollutant loads (BOD5 and ST) of the studied rivers.

On the other hand, issues arising from the use of WPI are related to the concentrations of heavy metals. By only taking into account the traces of metals at the individual level, forgetting the synergistic impacts of different parameters and variables associated with metals, the real state of the contamination is not always detected. In addition to this, a divergence in the results can occur when using these indices in the same place due to the diversification of the results, thus leading to a degree of variability in the conclusions of the study. Despite the fact that there are different contamination indices, a model has not yet been put forward that allows the evaluation of the environmental-chemical state of a body of water at an international level (Liu *et al.*, 2011).

Other aspects that differ in these methods were presented by Kumar, *et al.*, (2019) when they analyzed the groundwater quality and potential sources of trace metal contamination of the Saharanpur district (India), using the contamination index (Cd) and the HPI. In the results, they demonstrate that the analysis and mathematical models are not sufficient to represent the categories of water contamination, reporting more accurate results when the index method was used for the evaluation of water quality. The contamination index is thus shown to be a tool that can provide a better mechanism to show the health of a body of water. When the contamination indices reported by Karaouzas, *et al.*, (2021) were compared, they stated that there is a conceptual convergence in the Contamination Index (CI) and HEI methods. This is due to the integration of the maximum admissible and upper admissible concentration of heavy metals. Conversely, when using the HPI method, an arbitrary classification between 0 and 1 is considered the maximum admissible concentration of metals.

CONCLUSIONS

Frequently used trends were identified for the WQI-NFS and WQI-CCME quality indices and for the HPI contamination index. The water quality indices have been used repeatedly in recent years in several countries around the world with the objective of evaluating the quality of bodies of water, both surface (rivers, lakes, seas) and underground. In the same way, new indices have been developed from some existing WQI in an effort to improve deficiencies that appear in the indices, allowing us to evaluate water bodies in a better way. This, in turn, will help to support environmental authorities so that they may best manage water resources.

The discussion of the references allows us to conclude that there are convergences and divergences in the use of contamination and quality indices in the different studies, limiting their use in relation to the dynamics of the fluid to be studied and the limiting weights of each of them. methods.

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Wątor, K., & Zdechlik, R. (2021). Application of water quality indices to the assessment of the effect of geothermal water discharge on river water quality – case study from the Podhale region (Southern Poland). *Ecological Indicators*, *121*. https://doi.org/10.1016/j.ecolind.2020.107098

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Zhao, E., Kuo, Y., & Chen, N. (2021). Assessment of water quality under various environmental features using a site-specific weighting water quality index. *Science of The Total Environment*, *783*. https://doi.org/10.1016/j.scitotenv.2021.146868

Instrucciones para los autores

https://revistas.udistrital.edu.co/index.php/Tecnura/about/submissions

CONTENIDO

ALCANCE Y POLÍTICA EDITORIAL DE LA REVISTA

La revista Tecnura es una publicación institucional de la Facultad Tecnológica de la Universidad Francisco José de Caldas, de carácter científico-tecnológico con periodicidad trimestral, que se publica los meses de enero, abril, julio y octubre. Su primer número apareció en el segundo semestre del año 1997 y hasta la fecha ha mantenido su regularidad.

Las áreas temáticas de interés de la revista Tecnura están enfocadas a todos los campos de la ingeniería, como la electrónica, telecomunicaciones, electricidad, sistemas, industrial, mecánica, catastral, civil, ambiental, entre otras. Sin embargo, no se restringe únicamente a estas, también tienen cabida los temas de educación y salud, siempre y cuando estén relacionados con la ingeniería. La revista publica únicamente artículos de investigación científica y tecnológica, de reflexión y de revisión. En consecuencia, durante la fase de evaluación editorial inicial se rechazarán los artículos cortos y reportes de caso.

La revista Tecnura está dirigida a docentes, investigadores, estudiantes y profesionales interesados en la actualización permanente de sus conocimientos y el seguimiento de los procesos de investigación científico-tecnológica, en el campo de las ingenierías. Tiene como misión divulgar resultados de proyectos de investigación realizados en el área de las ingenierías, a través de la publicación de artículos originales e inéditos, realizados por académicos y profesionales pertenecientes a instituciones nacionales o extranjeras del orden público o privado. Los artículos presentados deben ser trabajos inéditos escritos en español o inglés; sin embargo, tendrán preferencia los artículos que muestren conceptos innovadores de gran interés, que traten sobre asuntos relacionados con el objetivo y cobertura temática de la revista.

Tecnura es una publicación de carácter académico indexada en los Índices Regionales Scielo Colombia (Colombia) y Redalyc (México), además de las siguientes bases bibliográficas: INSPEC del

Institution of Engineering and Technology (Inglaterra), Fuente Académica Premier de EBSCO (Estados Unidos), CABI (Inglaterra), Index Corpernicus (Polonia), Informe Académico de Gale Cengage Learning (México), Periódica de la Universidad Nacional Autónoma de México (México), Oceanet (España) y Dialnet de la Universidad de la Rioja (España). También hace parte de los siguientes directorios: Sistema Regional de Información en Línea para Revistas Científicas de América Latina, el Caribe, España y Portugal Latindex (México), Índice Bibliográfico Actualidad Iberoamericana (Chile), e-Revistas (España), DOAJ (Suecia), Ulrich de Proquest (Estados Unidos).

Tecnura es una revista arbitrada mediante un proceso de revisión entre pares de doble ciego. La periodicidad de la conformación de sus comités Científico y Editorial está sujeta a la publicación de artículos en revistas indexadas internacionalmente por parte de sus respectivos miembros.

La Universidad Distrital Francisco José de Caldas, sus directivas, el Editor, el Comité Editorial y Científico no son responsables por la opinión y criterios expresados en el contenido de los artículos y estos se publican bajo la exclusiva responsabilidad de los autores y no necesariamente reflejan el pensamiento del Comité Editorial.

Además de la versión impresa, la revista Tecnura tiene también una versión digital disponible en su página web: `http://revistas.udistrital.edu.co/ojs/index.php/Tecnura`

TIPOS DE ARTÍCULOS ACEPTADOS

De acuerdo con la clasificación del Índice Nacional de Publicaciones Científicas y Tecnológicas

(Publindex-Colciencias), la revista Tecnura recibe postulaciones de artículos inéditos de los siguientes tipos:

Artículos de investigación científica y tecnológica: documento que presenta, de manera detallada, los resultados originales de proyectos de investigación. La estructura generalmente utilizada contiene cuatro apartes importantes: introducción, metodología, resultados y conclusiones.

Artículo de revisión: documento resultado de una investigación donde se analizan, sistematizan e integran los resultados de las investigaciones publicadas o no publicadas, sobre un campo en ciencia o tecnología, con el fin de dar cuenta de los avances y las tendencias de desarrollo. Se caracteriza por presentar una cuidadosa revisión bibliográfica de al menos 50 referencias.

FORMATO DEL ARTÍCULO

Del lenguaje y estilo apropiado para la redacción de artículos

- Deben emplearse estructuras de oraciones simples, evitando las que sean demasiado largas o complejas.
- El vocabulario empleado debe ser básico y común. Los términos técnicos deben explicarse bre-

vemente; asimismo, el significado de las siglas debe presentarse la primera vez que estas aparecen en el texto.

- Los autores son responsables de que su trabajo sea conducido de una manera profesional y ética.

De la extensión de los documentos

Los artículos no deben tener una extensión de más de 25 páginas en tamaño carta y a doble espacio, con márgenes simétricas de 3 cm. Solo en el caso de los artículos de revisión las 25 páginas no inclu- yen las referencias bibliográficas.

Del formato de presentación

Los artículos presentados deben ser trabajos inédi- tos escritos en español o inglés y deben digitarse en Microsoft Word (2003 en adelante), cumplien- do con las siguientes indicaciones:

Letra *Times New Román* de 12 puntos (a excep- ción de que se requiera lo contrario para algunos apartados).

- Una columna a doble espacio.
- Todas las márgenes de 3 cm.
- Los párrafos se justifican, y no debe haber espacio entre los consecutivos.
- No incluir saltos de página o finales de sección.
- Si se desea resaltar palabras o frases del texto, no usar letra negrita sino letra cursiva.
- Los decimales se deben señalar con coma (,) y no con un punto.
- Los millares y millones se deben señalar con un espacio fino.
- Evitar las notas de pie de página.
- Se debe utilizar nomenclatura arábiga hasta el tercer nivel únicamente.

De la estructura del documento

Los trabajos deben tener la siguiente estructura y cumplir con los siguientes requisitos:

Composición de un artículo

Todos los artículos remitidos para su evaluación y posible publicación por parte de la revista Tecnura deben tener por lo menos los siguientes componentes:

- Título en español e inglés.
- Información de los autores.
- Resumen en español e inglés.
- Palabras clave en español e inglés.
- Introducción.
- Conclusiones.
- Trabajo futuro (opcional).
- Agradecimientos (opcional).
- Referencias bibliográficas.

Si el artículo es de investigación científica y tecnológica deben tener, además de lo anterior, los siguientes componentes:

- Metodología.
- Resultados.
- Financiamiento.

Título

ítulo El título del artículo deberá ser corto o dividido en título y subtítulo, atractivo para el lector potencial y escrito en mayúscula sostenida. Este debe aparecer centrado entre las márgenes, escrito con letra *Times New Roman*, en negrita, tamaño de fuente 18. El título del artículo debe ir en español e inglés separado por un espacio doble. Máximo 20 palabras.

Autores

Después del título debe escribirse el (los) nombre(s) completo(s) del (los) autor(es), acompañado de los datos biográficos básicos: título de pregrado, título de posgrado, ocupación o cargo, afiliación institucional (institución donde labora), dependencia, ciudad, país y correo electrónico. La información anterior debe ir inmediatamente debajo del nombre del autor.

Resumen

Debe establecer el objetivo y alcance del trabajo, una descripción clara y concisa de la metodología, los resultados y las conclusiones obtenidas. Máximo 250 palabras.

Palabras clave

Debe escogerse entre tres y diez palabras clave, escritas en español con letra *Times New Roman*, en negrita y cursiva.

Las palabras clave deben estar escritas en orden alfabético y ser de uso estandarizado, para lo cual se sugiere utilizar bases de datos internacionales según el área del conocimiento. Por ejemplo, en el área de Eléctrica y Electrónica se sugiere utilizar el tesauro de la UNESCO que se pueden encontrar en la página: http://databases.unesco.org/thessp.

Abstract

Debe ser una traducción correcta y precisa al idioma inglés del texto que aparece en el resumen en español.

Keywords

Debe ser una traducción correcta y precisa al idioma inglés de la lista de palabras clave en español.

Las *keywords* deben estar escritas en el orden de las palabras clave y ser de uso estandarizado, para lo cual se sugiere utilizar bases de datos in- ternacionales según el área del conocimiento. Por ejemplo, en el área de Eléctrica y Electrónica se sugiere utilizar los Tesauros de la IEEE y/o World Bank que se pueden encontrar en las siguientes páginas respectivamente: http://www.ieee.org/documents/2009Taxonomy_v101.pdf, http://multites.net/mtsql/wb/site/default.asp

Introducción

Debe describir el planteamiento general del trabajo, así como contexto, antecedentes, estado de arte de la temática abordada, objetivo y posible alcance del trabajo.

Metodología

La redacción de este apartado debe permitir a cualquier profesional especializado en el tema replicar la investigación.

Resultados

Explicación e interpretación de los hallazgos. Si es necesario, se puede presentar una discusión breve y enfocada a la interpretación de los resultados.

Conclusiones

Implicación de los resultados y su relación con el objetivo propuesto.

Financiamiento

Mencionar la investigación asociada de la cual se derivó el artículo y la entidad que avaló y financió dicha investigación.

Agradecimientos

Preferiblemente deben ser breves y deben incluir los aportes esenciales para el desarrollo del trabajo.

Ecuaciones

Deben aparecer centradas con respecto al texto principal. Las ecuaciones deben ser referenciadas con números consecutivos (escritos entre paréntesis cerca al margen derecho). Las ecuaciones se citan en el texto principal empleando la palabra ecuación y seguida del número entre paréntesis. Las ecuaciones deben ser elaboradas en un editor de ecuaciones apropiado y compatible con el paquete de software InDesign, por ejemplo, el editor de ecuaciones de Windows.

Tablas

Para el caso de realización de tablas se recomienda que estas no sean insertadas como imágenes, considerando que en este formato no pueden ser modificadas. El encabezado de cada tabla debe incluir la palabra Tabla (en negrita) seguida del número consecutivo correspondiente y de un breve nombre de la tabla. El encabezado debe estar escrito con letra Times New Roman, en cursiva y tamaño de fuente 9.

No se presentan cuadros sino tablas y estas se deben levantar automáticamente desde el procesador de textos. Las tablas deben ir nombradas y referenciadas en el artículo, en estricto orden. Toda tabla debe tener en su parte inferior la fuente de la que fue tomada, o mencionar que es autoría de los autores si es el caso.

Figuras

Todas las figuras o fotografías deben enviarse en formato PNG o TIFF con una resolución mínima de 300 DPI, adaptadas a escala de grises.

El pie o rótulo de cada figura debe incluir la palabra Figura (en negrita) seguida del número consecutivo correspondiente y de una breve descripción del contenido de la figura. El pie de figura debe estar escrito con letra Times New Roman, en cursiva y tamaño de fuente 9. Las figuras deben ir nombradas y referenciadas en el artículo, en estricto orden. Toda figura debe tener también la fuente de la que fue tomada, o mencionar que es autoría de los autores si es el caso.

Símbolos

Los símbolos de las constantes, variables y funciones en letras latinas o griegas –incluidos en las ecuaciones– deben ir en cursiva; los símbolos matemáticos y los números no van en cursiva. Se deben identificar los símbolos inmediatamente después de la ecuación. Se deben utilizar las unidades, dimensiones y símbolos del sistema internacional.

Cuando se empleen siglas o abreviaturas, se debe anotar primero la equivalencia completa, seguida de la sigla o abreviatura correspondiente entre paréntesis y en lo subsecuente se escribe solo la sigla o abreviatura respectiva.

Referencias bibliográficas

El estilo de citación de referencias adoptado por la revista Tecnura es APA sexta edición. Las citas, referencias bibliográficas e infografía se incluyen al final del artículo. Las referencias bibliográficas deben ordenarse alfabéticamente de acuerdo con el primer apellido del primer autor, sin numeración.

Solo deben aparecer las referencias que fueron citadas en el texto principal del trabajo, en las tablas o en las figuras. Es decir, en la lista no deben aparecer otras referencias aunque hayan sido consultadas por los autores para la preparación del trabajo. Sugerimos utilizar herramientas como: *Citas y bibliografía de Microsoft Word* (para APA sexta edición versión 2013 o superior), *Zotero, Mendeley*, entre otras.

El llamado de una referencia bibliográfica se inserta en el texto, en el punto pertinente, bajo ciertas características:

- Si la oración incluye el apellido del autor, solo se debe escribir la fecha dentro de un paréntesis, ejemplo:

  Cuando Vasco (2012), analizó el problema de presentado en . . . .

- Cuando no se incluye el autor en la oración, debe ir entre el paréntesis el apellido y la fecha. La investigación de materiales dio una visión en el área (Martínez, 2012).

- Si el documento u obra tiene más de dos autores, se debe citar la primera vez con todos los apellidos. 1990. (Fernández Morales, Villa Krieg & Caro de Villa, 2008) . . . .

- En las menciones siguientes, solo se debe escribir el primer apellido del autor, seguido de un “et al”. En cuanto al estudio de las aguas, Fernández Morales et al. (2008) encontraron que . . .

- Cuando el documento u obra tiene más de seis autores, se debe utilizar desde la primera mención el “et al”.

A continuación se describen una serie de ejemplos de las referencias más utilizadas, según el estilo de referencias adoptado por la revista Tecnura:

Publicaciones Periódicas:

Forma Básica

Apellidos, A. A., Apellidos, B. B. & Apellidos, C. C. (Fecha). Título del artículo. Título de la publicación, volumen (número), pp. xx-xx. doi: xx.xxxxxxx

Artículo básico

Guevara López, P., Valdez Martínez, J., Agudelo González, J., & Delgado Reyes, G. (2014). Aproximación numérica del modelo epidemiológico SI para la propagación de gusanos informáticos, simulación y análisis de su error. Revista Tecnura, 18(42), 12 -23. doi: http://dx.doi.org/10.14483/udistrital.jour.tecnura.2014.4.a01

Artículo web

Rodríguez Páez, S., Fajardo Jaimes, A., & Páez Rueda, C. (2014). Híbrido rat-race miniaturizado para la banda ISM 2,4 GHZ. Revista Tecnura, 18(42), 38-52. Recuperado de http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/article/view/8059/9675

Libros:

Forma Básica

Apellidos, A. A. (Año). Título. Ciudad: Editorial.

Apellidos, A. A. (Año). Título. Recuperado de http://www.xxxxxx.xxx

Apellidos, A. A. (Año). Título. doi: xx.xxxxxxxx

Apellidos, A. A. (Ed.). (Año). Título. Ciudad: Editorial.

Libro con autor

Goleman, D. (2000). La inteligencia emocional: Por qué es más importante que el cociente intelectual. México: Ediciones B.

Libro con editor

Castillo Ortiz, A. M. (Ed.). (2000). Administración educativa: Técnicas, estrategias y prácticas gerenciales. San Juan: Publicaciones Puertorriqueñas

Libro versión electrónica:

Montero, M. & Sonn, C. C. (Eds.). (2009). Psychology of Liberation: Theory and applications. [Versión de Springer]. doi: 10.1007/ 978-0-387-85784-8

Informe técnico

Forma Básica

Apellidos, A. A. (Año). Título. (Informe Núm. xxx). Ciudad: Editorial

Informe con autores

Weaver, P. L., & Schwagerl, J. J. (2009). U. S. Fish and Wildlife Service refuges and other nearby reserves in Southwestern Puerto Rico. (General Technical Report IITF-40). San Juan: International Institute of Tropical Forestry.

Informe de una agencia del gobierno

Federal Interagency Forum on Child and Family Statistics. America's Children: Key National Indicators of Well-Being, 2009. Washington, DC: U.S. Government Printing Office. Recuperado de http://www.childstats.gov/pubs/index.asp

Tesis

Forma Básica

Apellidos, A. A. (Año). Título. (Tesis inédita de maestría o doctorado). Nombre de la institución, Localización.

Tesis inédita, impresa

Muñoz Castillo, L. (2004). *Determinación del conocimiento sobre inteligencia emocional que poseen los maestros y la importancia que le adscriben al concepto en el aprovechamiento de los estudiantes*. (Tesis inédita de maestría). Universidad Metropolitana, San Juan, PR.

Tesis de base de datos comercial

Santini Rivera, M. (1998). *The effects of various types of verbal feedback on the performance of selected motor development skills of adolescent males with Down syndrome*. (Tesis doctoral). Disponible en la base de datos ProQuest Dissertations and Theses. (AAT 9832765).

Tesis web

Aquino Ríos, A. (2008). *Análisis en el desarrollo de los temas transversales en los currículos de es- pañol, matemáticas, ciencias y estudios sociales del Departamento de Educación.* (Tesis de maestría, Universidad Metropolitana). Recuperado de http://suagm.edu/umet/biblioteca/UMTESIS/Tesis_Educacion/ARAquinoRios1512.pdf

Estándares o patentes

Forma Básica

Apellidos, A. A. Título de la patente. País y número de la patente. Clasificación de la patente, fecha de concesión oficial. Número y fecha de solicitud de la patente, paginación.

Hernández Suárez, C. A., Gómez Saavedra, V. A., & Peña Lote, R. A. Equipo medidor de indicadores de calidad del servicio de energía eléctrica para usuario residencial. Colombia., 655. G4F 10/0, 15 de Marzo 2013. 27 de Octubre 2011, 147

ENVÍO DE ARTÍCULOS

Los autores deben enviar sus artículos a través de la aplicación para tal fin del Open Journal System en formato digital, adjuntando la carta de presentación y el formato de información artículo-autores.

Carta de presentación

El artículo debe ir acompañado de una carta de presentación dirigida al director y editor de la revista, Ing. Cesar Augusto García Ubaque, donde incluya:

- Solicitud expresa de considerar su artículo para publicarlo en la revista Tecnura.
- Título completo del trabajo.
- Nombres completos de todos los autores del trabajo.
- Certificación de la originalidad y el carácter inédito del trabajo.
- Exclusividad de su remisión a la revista Tecnura.
- Confirmación de la autoría con la firma de todos los autores.

Esta carta deberá estar firmada por todos los autores, escanearse y enviarse junto con los demás documentos solicitados.

Formato de información artículo-autores

El artículo además debe ir acompañado de un formato de información sobre el artículo y sus autores, el cual se puede descargar de la página web de la revista Tecnura: http://revistas.udistrital.edu.co/ojs/index.php/Tecnura, en la sección "Formatos y Documentos". Es importante completar todos los campos de información solicitados, algunos de ellos tienen comentarios para aclarar mejor lo que se está solicitando. El formato no debe escanearse.

Artículo

Artículo en formato digital (Word 2003 en adelante) que cumpla con todas las normas de presentación descritas en el capítulo 3, "Formato del artículo", de la presente en las instrucciones a los autores.

PROCEDIMIENTO PARA LA PUBLICACIÓN

El procedimiento que sigue la revista Tecnura para la evaluación y posible publicación de los trabajos enviados por los autores es el siguiente en orden cronológico:

1. Envío del articulo acompañado de la carta de presentación y el formato de información por parte de los autores.
2. Notificación al autor de correspondencia de la recepción del artículo.
3. Verificación del tema del artículo con respecto a las áreas de interés de la revista.

4. Verificación de las normas de presentación por parte del monitor de la revista.
5. Notificación al autor de correspondencia de la evaluación de las normas de presentación.
6. Envío de las correcciones realizadas por los autores con respecto a la evaluación de las normas de presentación
7. Envío del artículo a los árbitros seleccionados.
8. Notificación del inicio del proceso de arbitraje del artículo.
9. Notificación a los autores de la decisión tomada por el Comité Editorial y de las evaluaciones hechas por los árbitros.
10. Envío de las correcciones realizadas por los autores con respecto a las evaluaciones de los árbitros.
11. Estudio de la versión final del artículo y de las evaluaciones de los árbitros por parte del Comité Editorial.
12. Envío por parte de los autores de la carta de cesión de derechos al editor de la revista.
13. Envío de la versión con corrección de estilo y diagramada a los autores.
14. Verificación de errores y aprobación final de la versión con corrección de estilo y diagramada por parte de los autores.
15. Publicación del artículo en el número correspondiente de la revista Tecnura.
16. Notificación a los autores de la publicación del número de interés.
17. Envío de un ejemplar de la revista a cada autor del artículo publicado.

PROCESO DE ARBITRAJE DE ARTÍCULOS

Considerando la periodicidad trimestral de la revista, el Comité Editorial realiza cuatro convocatorias anuales para la recepción de artículos, aproximadamente en los meses de febrero, mayo, agosto y noviembre. Los artículos serán recibidos hasta la fecha máxima establecida en cada convocatoria.

Una vez recibidos los artículos el monitor de la revista realizará una primera evaluación de forma para verificar que cumplan con todos los elementos mencionados en esta guía de instrucciones a los autores. Luego de recibir nuevamente el articulo con las correcciones de forma solicitadas por el monitor de la revista, este será sometido a evaluación por tres pares académicos (paulatinamente se espera incorporar un mayor número de pares externos que participen en el proceso).

Instrucciones para los autores

Cada artículo remitido a la revista Tecnura es revisado por dos pares académicos externos a la institución de los autores, mediante un proceso de "revisión entre pares" (*Peer-review*) de doble-ciego, garantizando el anonimato de los autores y evaluadores; se considera confidencial todo trabajo recibido y así se le exige a sus evaluadores.

Las posibles conclusiones de los resultados de la evaluación por parte de los árbitros son únicamente tres: publicar el artículo sin modificaciones, publicar el artículo con modificaciones o no publicar el artículo.

Posteriormente, el Comité Editorial toma la decisión de publicar o no los artículos, con base en los resultados de las evaluaciones realizadas por los árbitros asignados. En caso de existir contradicciones en las evaluaciones con respecto a la publicación de un artículo, el Comité Editorial enviará el artículo a un tercer árbitro y se inclinará por las dos evaluaciones que tengan el mismo concepto respecto a la publicación del artículo.

En cada convocatoria el autor de correspondencia debe sugerir al menos cuatro posibles evaluadores externos a su institución laboral, los cuales deben ser especialistas en el tema específico del artículo remitido, tener al menos maestría y por lo menos dos deben ser internacionales. Los posibles evaluadores pueden pertenecer a una universidad o industria, pública o privada; de estos se debe proporcionar el nombre completo, su formación académica más alta, su afiliación institucional y su correo electrónico. Estos cuatro potenciales evaluadores serán analizados por el Comité Editorial a fin de ampliar la base de datos de los árbitros de la revista Tecnura.

El Comité Editorial de la revista Tecnura se reserva los derechos de impresión, reproducción total o parcial del artículo, así como el de aceptarlo o rechazarlo. Igualmente, se reserva el derecho de hacer cualquier modificación editorial que estime conveniente; en tal caso el autor recibirá por escrito recomendaciones de los evaluadores. Si las acepta, deberá entregar el artículo con los ajustes sugeridos dentro de las fechas fijadas por la revista para garantizar su publicación dentro del número programado.

CONTACTO

Para cualquier solicitud de información adicional puede comunicarse a través del correo electrónico de la revista Tecnura: tecnura@udistrital.edu.co, tecnura@gmail.com, o por mensajería con el Ing. Cesar Augusto García Ubaque, Director y Editor de la revista Tecnura, a la dirección:

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Sala de Revistas, Bloque 5, Oficina 305.
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Universidad Distrital Francisco José de Caldas
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Teléfono: 571 – 3239300 Extensión: 5003

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Bogotá D.C., Colombia

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Página web:

https://revistas.udistrital.edu.co/ojs/index.php/Tecnura

Instructions for authors

https://revistas.udistrital.edu.co/index.php/Tecnura/about/submissions

CONTENT

- Scope and editorial policy of the journal
- Type of accepted articles
- Article format
- Article submission
- Publication procedure
- Article arbitration
- Contact

Tecnura journal is an institutional publication of the Faculty of Technology from University Francisco José de Caldas. It is a scientific and technological publication with quarterly periodicity, which is published in January, April, July and October. The first issue appeared in the second semester of 1997 and up to now it has maintained its regularity.

The areas of interest of Tecnura journal are focused on all engineering fields such as electronics, telecommunications, electricity, systems, industrial, mechanics, cadastral, civil, environmental, among others. However, it is not restricted to those; it also has room for education and health issues, as long as they are related to engineering. The journal will only publish concerning scientific and technological research, reflection and revision. In consequence, during the initial editorial evaluation, short articles and case reports will be rejected.

Tecnura Journal is addressed for professors, researchers, students and professionals interested in permanent update of their knowledge and follow-up of scientific-technologic processes in the field of engineering. Tecnura Journal has as mission to disseminate results of research projects in the areas of engineering, through the publication of original and unpublished articles, conducted by academics and professionals accredited by public or private national or foreign institutions. Articles submitted to Tecnura journal must be unpublished works written in Spanish or English; nevertheless, preference will be given to articles that show innovative concepts of great interest, related to the objective and scope of the journal.

Tecnura is an academic publication indexed in the Regional Index Scielo Colombia (Colombia) and Redalyc (México); as well as of the following bibliographic databases: INSPEC of the Institution of Engineering and Technology (England), Fuente Académica Premier of EBSCO (United States), CABI (England), Index Copernicus (Poland), Informe Académico of Gale Cengage Learning (México), Periódica from the Universidad Nacional Autónoma de México (México), Oceanet (Spain) and Dialnet from the Universidad de la Rioja (Spain). It is also part of the following directories: Online

Regional Information System for Scientific journals from Latin America, Caribbean, Spain and Portugal Latindex (México), Bibliographic Index Actualidad Iberoamericana (Chile), e-Revistas (Spain) , DOAJ (Sweden) and Ulrich of Proquest (United States).

Tecnura is a journal arbitrated by a revision process among double blind peers. The schedule of the conformation of its scientific and editorial committee is subject to the publication of articles in internationally indexed journals by their members.

District University Francisco José de Caldas, its directors, the editor, the editorial and scientific committee are not responsible for the opinions and the criteria expressed in the content of the articles and they are published under the exclusive responsibility of the authors and do not necessarily reflect the ideas of the editorial committee.

In addition to the printed version, Tecnura journal also has a digital version available in its web page: http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/index

TYPE OF ARTICLES ACCEPTED

According to the classification of the Scientific and Technological Publications National Index (Publindex-Colciencias), Tecnura journal receives nominations of unpublished articles on the following topics:

- **Scientific and technological research articles:** document that presents, in a detailed manner, the original results of research projects. The generally used structure contains four main parts: introduction, methodology, results and conclusions.
- **Reflection articles:** document that presents research results from an analytic, interpretative or critic perspective from the author, dealing with a specific topic and adopting original sources.
- **Review article:** document that results from a research where the results of published or unpublished research on a science or technology field are analyzed, systematized and integrated, in order to state the advances and tendencies in development. It is characterized for presenting a careful bibliographical review of at least 50 references.

ARTICLE FORMAT

About the appropriate language and style for articles writing

- Authors must use simple sentence structures, avoiding those too long or complex.
- The vocabulary used must be basic and common. Technical language must be briefly explained; also, the meaning of the acronyms must be given the first time they appear in the text.
- The authors are responsible for their work to be conducted in a professional and ethic manner.

Instructions for authors

https://revistas.udistrital.edu.co/index.php/Tecnura/about/submissions

About the length of articles

The articles should not exceed 25 pages in letter size and double space, with symmetric margins of 3 cm. Only in the case of review articles, these 25 pages do not include references.

About the presentation format

Submitted articles must be unpublished works written in Spanish or English, and must be typed in Microsoft Word (2003 and beyond), complying with the following indications:

- *Times New Roman* letter, 12 point (except it is required for some sections).
- One column, double-spaced.
- All the margins 3 cm.
- Paragraphs should be justified without spaces between consecutives and without cutting words.
- Do not include page breaks or section finals.
- If you want to emphasize words or phrases from the text, do not use bold letters but italic.
- Decimals should be pointed with comma (,) and not with period (.).
- Thousands and millions should be pointed with a fine space.
- Avoid footnotes.
- Arabic nomenclature must be used only until the third level.

About the article structure

The papers must have the following structure and comply with the following requirements:

Composition of an article

All the articles submitted for evaluation and possible publication by the Tecnura Journal must have at least the following components:

- Title in Spanish and English.
- Information about the authors.
- Abstract in Spanish and English.
- Key words in Spanish and English.
- Introduction.
- Conclusions.

- Future work (optional).
- Acknowledgements (optional).
- Bibliographical references.

If the article is related to scientific and technological research must have, in addition to the above, the following components:

- Methodology.
- Results.
- Financing.

Title

The title of the article must be short or divided in title and subtitle, attractive for the potential reader and written in capital letters. It should appear centered between the margins, written in *Times New Roman* letter, in bold, font size 18. The title of the article has to be in Spanish and English separated by double space. Maximum 20 words.

Authors

After the title the complete name(s) of the author(s) must be written, with their basic biographical data: undergraduate degree, graduate degree, occupation or position, institutional affiliation (institution where they work), dependency, city, country and e-mail. The above information must be immediately below the author's name.

Abstract

The scope and purpose of the work must be established giving a clear and concise description of the methodology, results presented and the conclusions obtained. Maximum of 250 words.

Keywords

Between three and ten keywords must be chosen, written in English with *Times New Roman* letter in bold and italic.

Key words must be written in alphabetic order and must be as standard as possible, for which it is suggested the use of international databases accor- ding to the area of knowledge. For example, in the area of Electrics and Electronics it is suggested to use the IEEE thesaurus and World Bank thesaurus that can be accessed at the following web pages respectively:

`http://www.ieee.org/documents/2009Taxonomy_v101.pdf` http://multites.net/mtsql/wb/site/default.asp

Abstract in Spanish

Translation to the Spanish language of the text that appears in the abstract, it must be correct and precise.

Keywords in Spanish

Translation to the English language of the keywords in Spanish, they must be correct and precise.

´ Keywords must be written in the order of the English version and must be as standard as possible, for which it is suggested the use of international databases according to the area of knowledge. For example, in the area of Electrics and Electronics it is suggested to use the UNESCO thesaurus that can be found at the following web pages:

http://databases.unesco.org/thessp

Introduction

The general idea of the work must be described, its context, backgrounds, state of the art of the topic, objectives and possible scope of the work.

Methodology

The writing of this part must allow any specialized professional in the topic to replicate the research.

Results

Explanation and interpretation of the findings. If necessary, a brief discussion focused on the interpretation of the results can be presented.

Conclusions

Implication of the results and their relation to the proposed objective.

Financing

Mention the associated research from which the article was derived and the entity that endorsed and financed the research.

Acknowledgments

They should preferably be brief and include the essential contributions for the development of the paper.

Equations

Equations must appear centered with respect to the main text. They must be referenced with consecutive numbers (written in parenthesis close to the right margin). Equations are cited in the main text employing the word equation, and followed by the number in parenthesis. Equations must be made in an appropriate equation editor and compatible with "InDesign" software, as for example the equation editor of Windows.

Tables

In the case of implementation of tables, it is recommended that these are not inserted as images, considering that in that format they cannot be modified. The title of each table must include the word table (in italic) followed by the corresponding consecutive number and a brief name of the table. The heading must be written in TNR letter, italic and font size 9.

Charts are not presented but tables and they should be automatically raised from the text processor. Tables should be named and referenced in the article, in strict order. Every table must have at the bottom the source from which it was taken, or to mention self-authorship if it is the case.

Figures

All the figures or pictures have to be sent in JPG or PNG format with a minimum resolution of 300 DPI, adapted to gray scale.

The footnote or name of each figure must include the word figure (in italic) followed by the corresponding consecutive number and a brief description of the content of the figure. The footnote of the figure must be written in Times New Roman letter, italic and font size 9. Figures must be named and referenced in the article, in strict order. Every figure must have at the bottom the source from which it was taken, or to mention self-author-ship if it is the case.

Symbols

The symbols of the constants, variables and functions in Latin or Greek letters –included in the equations- must be in italic; the mathematical symbols and the numbers do not go in italic. The symbols must be identified immediately after the equation. Units, dimensions and symbols of the international system must be used.

When using acronyms or abbreviations, the complete equivalence should be written first, followed by the corresponding acronym or abbreviation in parenthesis and from there it is only written the respective acronym or abbreviation.

Bibliographic references

The adopted reference citation style by Tecnura journal is APA sixth edition. The cites, bibliographic references and infography are included in the last part of the article. The bibliographic references must be alphabetically ordered according to the author's first surname, without numbering.

There should only appear the cited references in the main body of the work, in tables or in figures. It means, in the list there should not appear other references although they have been consulted by the authors for the work preparation. We suggest using tools such as: Cites and bibliography from Microsoft Word (for APA sixth edition version 2013 or superior), Zotero, Mendeley, among others.

The call for a bibliographic reference is inserted in the text, at the pertinent point, under certain characteristics:

- If the sentence includes the author's surname, it should only be written the date into a parenthesis, for instance:
  Cuando Vasco (2012), analizó el problema de presentado en ....
- When the author is not included in the sentence, surname and date must be into a parenthesis.
  La investigación de materiales dio una visión en el área (Martínez, 2012).
- If the document or work has more than two authors, the first cite must include all the surnames.
  1990. (Fernández Morales, Villa Krieg & Caro de Villa, 2008) ....
- In the following mentions, it must only be written the author's first surname, followed by "et al.". En cuanto al estudio de las aguas, Fernández Morales et al. (2008) encontraron que ...
- When the document or work has more than six authors, it must be used from the first mention "et al.".

Next it is described a series of examples of the more used references, according to the reference style adopted by Tecnura journal:

Periodical Publications:

Basic Form

Surnames, A. A., Surnames, B. B. & Surnames, C. C. (Date). Article's title. Title of the publication, volu- me (number), pp. xx-xx. doi: xx.xxxxxxx

Basic article

Guevara López, P., Valdez Martínez, J., Agudelo González, J., & Delgado Reyes, G. (2014). Aproximación numérica del modelo epidemiológico SI para la propagación de gusanos informáticos, simulación y análisis de su error. Revista Tecnura, 18(42), 12 -23. doi:http://dx.doi.org/10.14483/udistrital.jour.tecnura.2014.4.a01

Web article

Rodríguez Páez, S., Fajardo Jaimes, A., & Páez Rueda, C. (2014). Híbrido rat-race miniaturizado para la banda ISM 2,4 GHZ. Revista Tecnura, 18(42), 38-52. Recuperado de http://revistas.

udistrital.edu.co/ojs/index.php/Tecnura/article/view/8059/9675

Books:

Basic Form

Surnames, A. A. (Year). Title. City: Editorial.

Surnames, A. A. (Year). Title. Recovered from http://www.xxxxxx.xxx

Surnames, A. A. (Year). Title. doi: xx.xxxxxxxx

Surnames, A. A. (Ed.). (Year). Title. City: Editorial.

Book with author

Goleman, D. (2000). La inteligencia emocional: Por qué es más importante que el cociente intelectual. México: Ediciones B.

Book with editor:

Castillo Ortiz, A. M. (Ed.). (2000). Administración educativa: Técnicas, estrategias y prácticas gerenciales. San Juan: Publicaciones Puertorriqueñas.

Book elecronic version:

Montero, M. & Sonn, C. C. (Eds.). (2009). Psychology of Liberation: Theory and applications. [Versión de Springer]. doi: 10.1007/ 978-0-387-85784-8

Technical report:

Basic Form

Surnames, A. A. (Year). Title. (Report No. xxx). City: Editorial

Report with authors

Weaver, P. L., & Schwagerl, J. J. (2009). U. S. *Fish and Wildlife Service refuges and other nearby reserves in Southwestern Puerto Rico*. (General Technical Report IITF-40). San Juan: International Institute of Tropical Forestry.

Report from a Government agency

Federal Interagency Forum on Child and Family Statistics. America's Children: Key National Indicators of Well-Being, 2009. Washington, DC: U.S. Government Printing Office. Recuperado de http://www.childstats.gov/pubs/index.asp

Thesis

Basic form

Surnames, A. A. (Year). Title. (Unpublished master or doctorate thesis). Institution name, Location.

Unpublished thesis, printed

Muñoz Castillo, L. (2004). *Determinación del conocimiento sobre inteligencia emocional que poseen los maestros y la importancia que le adscriben al concepto en el aprovechamiento de los estudiantes*. (Tesis inédita de maestría). Universidad Metropolitana, San Juan, PR.

Commercial database thesis

Santini Rivera, M. (1998). *The effects of various types of verbal feedback on the performance of selected motor development skills of adolescent males with Down syndrome*. (Tesis doctoral). Disponible en la base de datos ProQuest Dissertations and Theses. (AAT 9832765).

Web thesis

Aquino Ríos, A. (2008). *Análisis en el desarrollo de los temas transversales en los currículos de español, matemáticas, ciencias y estudios sociales del Departamento de Educación*. (Tesis de maestría, Universidad Metropolitana). Recuperado de http://suagm.edu/umet/biblioteca/UMTESIS/Tesis_Educacion/ARAquinoRios1512.pdf

Standards or patents

Basic form

Surnames, A. A. Title of the patent. Country and number of the patente. Classification of the patent, date of official license. Number and date of patent request, pagination.

Hernández Suárez, C. A., Gómez Saavedra, V. A., & Peña Lote, R. A. Equipo medidor de indicadores de calidad del servicio de energía eléctrica para usuario residencial. Colombia., 655. G4F 10/0, 15 de Marzo 2013. 27 de Octubre 2011, 147

ARTICLE SUBMISSION

Authors must submit their articles through the application Open Journal System in digital format, attaching the cover letter and the article-authors format.

Cover letter

The article must be submitted with a cover letter addressed to the director and editor of the journal, Engineer Cesar Augusto Garcia Ubaque, including:

- Specific request to consider your article to be published in Tecnura journal.
- Full title of the article.
- Full names of all the authors of the paper.

- Certification of the originality and unpublished character of the paper.
- Exclusivity of submission to Tecnura journal.
- Authoring confirmation with signature of all the authors.

This letter must be signed by all the authors, scanned and sent with the remaining requested documents.

Article-authors information format
The article has to be submitted with an information format about the article and its authors which can be downloaded from the web page of Tecnura journal http://revistas.udistrital.edu.co/ojs/index.php/Tecnura/index, in the section "Forms and Documents". It is important to complete all the fields of information requested, some of them have comments to clarify better what is being requested. The format must not be scanned.

Article
Article in digital format (Word 2003 and later editions) that complies with all the presentation rules described in chapter three, "Article structure", of this guide of instructions for authors.

PUBLICATION PROCEDURE
The procedure to be followed by Tecnura journal for the evaluation and possible publication of the papers sent by the authors is the following in chronological order:

1. Delivery of the article with the cover letter and the information format by the authors.
2. Notification to the author about the reception of the article.
3. Verification of the presentation rules by the monitor of the journal.
4. Notification to the author about the evaluation of the presentation rules.
5. Submission of corrections made by the authors related to the evaluation of presentation rules.
6. Submission of the articles to the selected arbitrators.
7. Notification of the beginning of the arbitration process of the article.
8. Notification to the authors about the decision made by the editorial committee, and about the evaluations made by the arbitrators.
9. Delivery of the corrections made by the authors with respect to the evaluations made by the arbitrators.

10. Study of the final version of the article and the evaluations of the arbitrators by the editorial committee.

11. Delivery by the authors of the letter that surrenders right to the editor of the journal.

12. Submission of the version with style corrections and diagramed to the authors.

13. Verification of errors and final approval of the version with style corrections and diagrammed by the authors.

14. Publication of the article in the corresponding number of Tecnura journal.

15. Notification to the authors of the number of interest.

16. Delivery of a copy of the journal to each one of the authors of the published article.

ARTICLE ARBITARION PROCESS

Considering the quarterly periodicity of the journal, the Editorial Committee makes four calls every year for the submission of articles, approximately in the months of February, May, August and November. The articles will be received until the date established in the call.

Once received the articles, the monitor of the journal will make an initial form evaluation to verify the completion of the elements mentioned in this guide of instructions to authors. After receiving again the article with the requested corrections by the journal's monitor, the paper will be submitted to evaluation by three academic peers (through time it is expected to include more external peers to participate in the process).

Each article sent to Tecnura journal is checked by two expert academic peers external to the institution of the authors, by a process of "*Peer-review*" of double blind, guaranteeing the anonymity of authors and evaluators; every paper sent is considered confidential and so it is demanded to evaluators.

Possible conclusions of the result of the evaluation by the judges are only three: publish the article without modifications, publish the article with modifications and not publish the article.

Subsequently, the Editorial Committee takes the decision to publish or not the articles, based on the results of the evaluations made by the assigned arbitrators. In case of contradictions in the evaluations with respect to the publication of an article, the editorial committee will send the article to a third peer and will be inclined for the two evaluations that have the same concept with respect to the publication of the article.

In each call the main author must suggest at least four possible external arbitrators to his work institution evaluators, who must be specialists in the specific topic of the article sent and must have at least Masters level, and at least two must to be international. Potential evaluators can belong to a university or industry, public or private; their complete names must be provided, highest academic formation, institutional affiliation and e-mail. The editorial committee will analyze these four potential evaluators in order to enrich the database of arbitrators of Tecnura journal.

The Editorial Committee of Tecnura journal reserves the right to print, reproduce total or partially the article, as the right to accept or reject it. In the same way, it has the right to make any editorial modification that considers necessary; in this case the author will receive written recommendations from the evaluators. If accepted, authors must deliver the article with the suggested adjustments within the dates given by the journal to guarantee its publication in the programmed number.

CONTACT

For any additional information request, please send an e-mail to Tecnura journal tecnura@udistrital.edu.co, tecnura@gmail.com or by mail to Cesar Augusto Garcia Ubaque, Director and Publisher of Tecnura Journal, to the following address:

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