UNIVERSIDAD COMPLUTENSE MADRID

THE 77TH ANNUAL FEMTEC SCIENTIFIC CONGRESS AND GENERAL ASSEMBLY

Balneology and Cutting-Edge Technologies: Shaping the Road to 2034



Thermal waters of Uruguay,Northern Littoral and their potential use in Health Resort Medicine

Francisco Maraver, Elena Alvareda, Francisco Armijo, Ana Ernst, Sofía Da Rocha, PabloGamazo, Lorena Vela

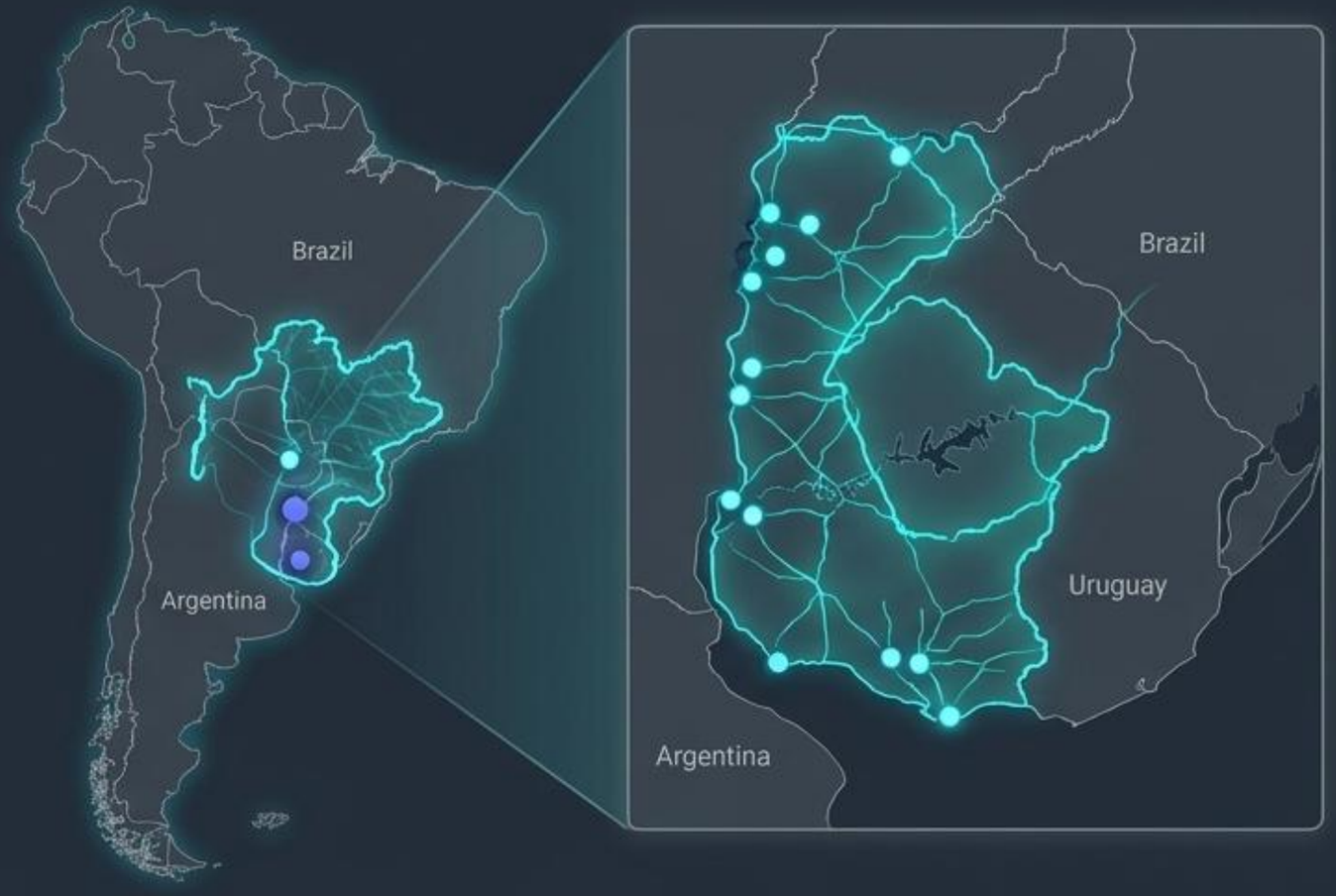
CENUR Litoral Norte

Thermal Water from the Guaraní Aquifer



The Uruguayan Thermal Region: A Historic Resource, Scientifically Mapped

80 years of empirical wellness and tourism usage, now mapped through the first comprehensive and integrated hydrochemical, geospatial, and balneological characterization.



Group 1: Guaraní Aquifer System (GAS)

- Altos del Arapey
- Arapey
- Club Remeros
- Aguas Claras
- Daymán
- Guaviyú

Group 2: Distinct Hydrogeological Setting

- Almirón

UNIVERSIDAD COMPLUTENSE MADRID



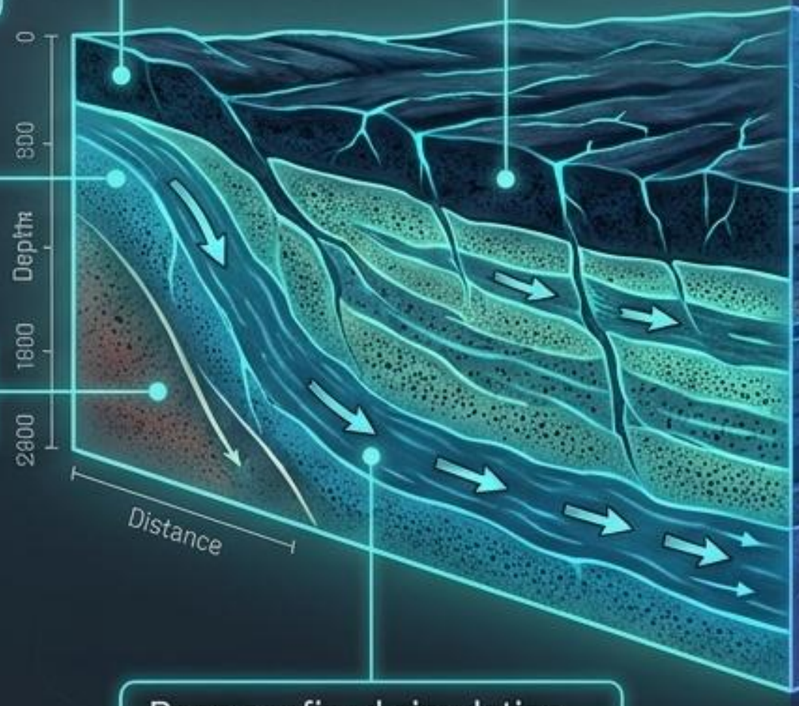




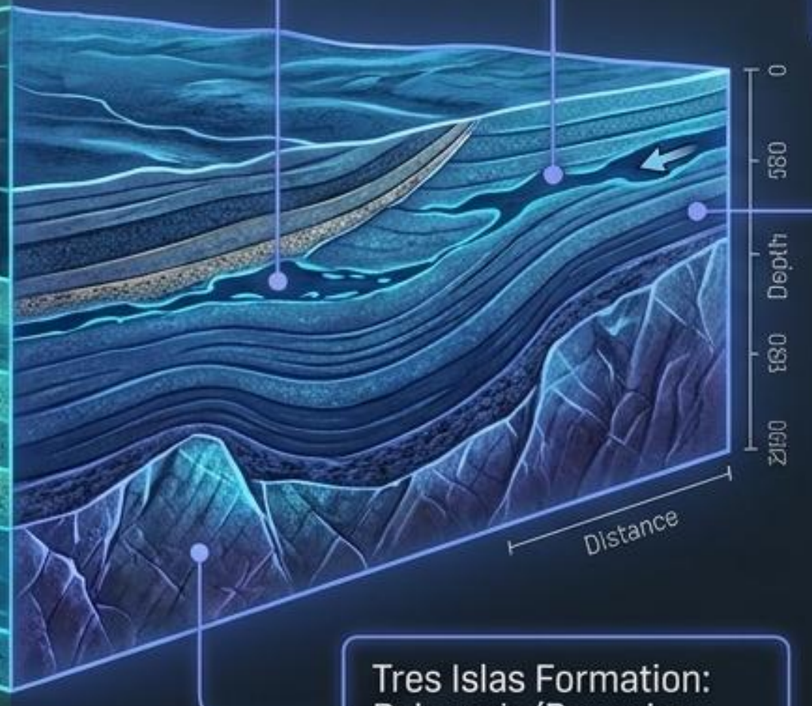


Subterranean Origins: Two Distinct Geological Architectures

Guaraní Aquifer System (GAS)



Almirón system



UNIVERSIDAD COMPLUTENSE MADRID

Physicochemical Baselining: Temperature and Mineralization Divergence

A massive divergence in total dissolved solids and heat dictates fundamentally different therapeutic applications.



Mesothermal to Hyperthermal
(36.0 °C – 44.5 °C)



Hypothermal
(32.0 °C)



Weak to Medium Mineralization
(311.5 – 734.0 mg/L)

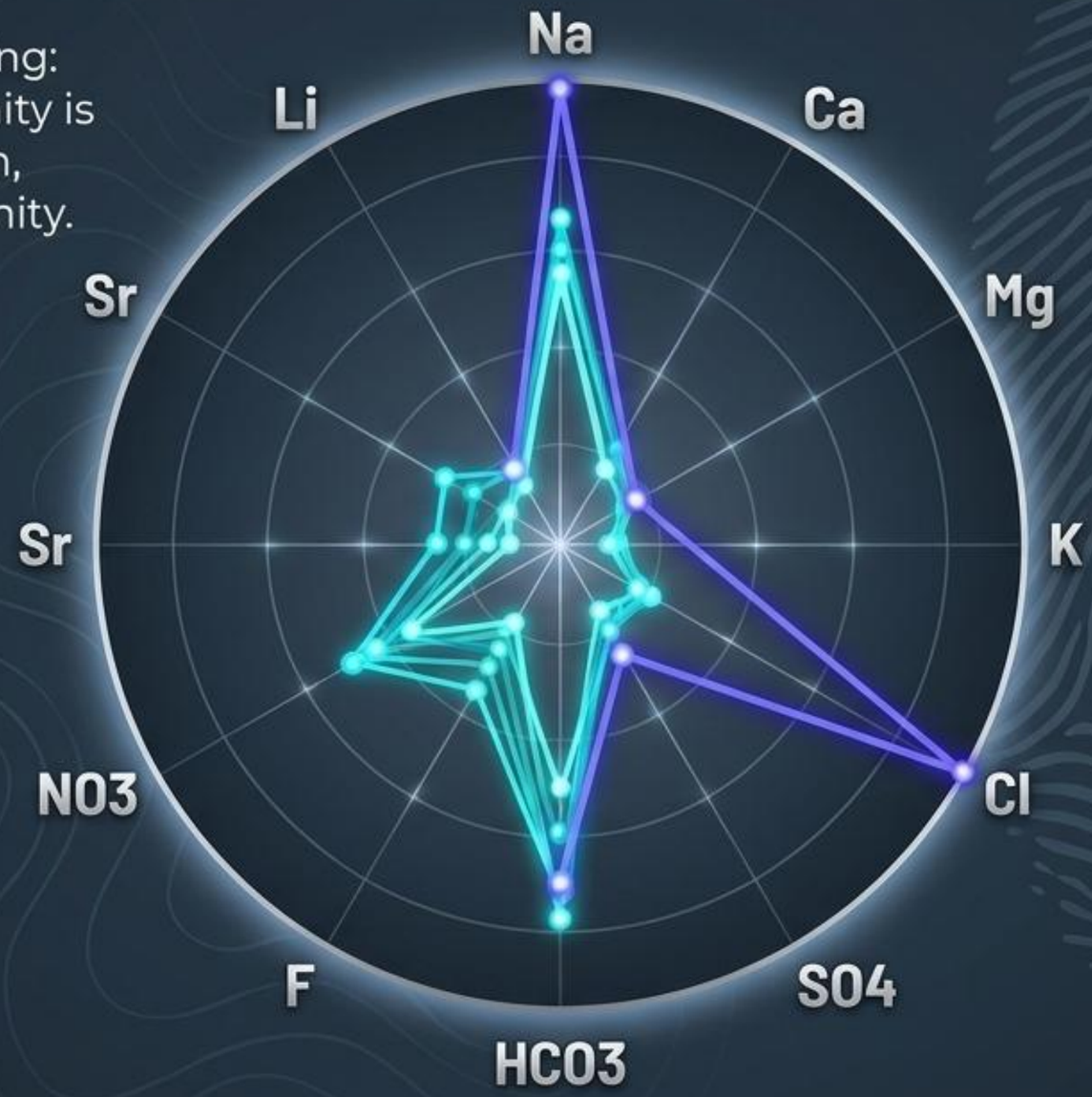


Strong Mineralization
(6,590.0 mg/L)

UNIVERSIDAD COMPLUTENSE MADRID

The Hydrochemical Fingerprint

Normalized Ion Fingerprinting: Proving hydrochemical affinity is dictated by geological origin, not mere geographic proximity.



UNIVERSIDAD COMPLUTENSE MADRID

The Diagnostic Dichotomy

	WMW (Weak/Medium Mineralization)	SMW (Strong Mineralization)
Origin	Guaraní Aquifer System (GAS)	Crystalline Basement / Tres Islas Fm.
Facies	Sodium-Bicarbonate	Chloride-Sodium
Temperature	Mesothermal to Hyperthermal (36-44.5°C)	Hypothermal (32°C)
Mineralization	311–734 mg/L	6,590 mg/L
Primary Indications	Musculoskeletal, Stress, Sleep, Long COVID	Musculoskeletal, Dermatological (Psoriasis)

UNIVERSIDAD COMPLUTENSE MADRID

Thermal Water from the Guaraní Aquifer

water

MDPI

Article

Hydrogeochemical Characterization of Thermal Waters from the Guaraní Aquifer in Uruguay and Their Potential Use in Balneology

Elena Alvareda [1], Lorena Vela [2,3], Francisco Armijo [3], Ana Ernst [4], Sofia Da Rocha [1], Pablo Gamazo [1] and Francisco Maraver [2,3,*]

[1] Departamento del Agua, CENUR LN, Universidad de la República, Salto 50000, Uruguay; alvareda@fq.edu.uy (E.A.); sdarochacarballo@gmail.com (S.D.R.); gamazo@unorte.edu.uy (P.G.)
[2] Professional School of Medical Hydrology, Complutense University of Madrid, Plaza Ramón y Cajal s/n, 28040 Madrid, Spain; marialorenavela@ucm.es
[3] Medical Hydrology Group, Department of Radiology and Rehabilitation, Complutense University of Madrid, Plaza Ramón y Cajal s/n, 28040 Madrid, Spain; farmijoc@ucm.es
[4] Club Remeros Salto, Costanera Norte y Belén, Salto 50000, Uruguay; anaernstar@gmail.com
* Correspondence: fmaraver@ucm.es

Abstract

Thermal groundwater resources constitute valuable health-oriented georesources, particularly when integrated into regional strategies for wellness, balneotherapy, and therapeutic tourism. This study presents the first comprehensive and integrated hydrochemical, geospatial, and balneological characterization of thermal groundwater systems in Uruguay, enabling their classification from a medical hydrology perspective and supporting the assessment of their potential use in balneotherapy. Seven thermal groundwater sources located in northwestern Uruguay were investigated, mainly associated with the Guaraní Aquifer System (GAS), together with the singular Almirón spring, which represents a distinct hydrogeological setting. Field measurements and laboratory analyses were conducted to determine physicochemical parameters, major ions, and gases. Hydrogeochemical facies were identified using Piper and Gibbs diagrams, while multivariate statistical techniques, including Principal Component Analysis (PCA) and hierarchical clustering, were applied to discriminate water types and support their balneological classification. The results indicate that most thermal waters associated with the GAS are characterized by sodium–bicarbonate facies, weak to medium mineralization. Dry residue to 180 °C, (311–734 mg/L), and mesothermal to hyperthermal temperatures (36.3–44.5 °C), reflecting deep confined circulation and prolonged water–rock interaction. By comparison, the Almirón spring exhibits a chloride–sodium facies with strong mineralization. Dry residue to 180 °C, (6590 mg/L) and hypothermal (32 °C), consistent with a distinct hydrogeological origin involving crystalline basement and Devonian sedimentary units and reflecting more evolved geochemical conditions. Based on the obtained results, and by analogy with comparable international hydrothermal profiles, the main balneological indications of these waters include musculoskeletal and rheumatic disorders, dermatological disorders, and other emerging indications such as stress, sleep disorders, obesity, and Long COVID. In conclusion, this study reveals the hydrochemical diversity of Uruguay's thermal groundwater and its possible use in balneology. Future research should focus on controlled clinical and balneological studies to validate specific therapeutic effects.

Keywords: thermal groundwater; balneotherapy; spa therapy; Guaraní Aquifer System; Uruguay

Check for updates

Academic Editor: José Manuel Marques

Received: 26 January 2026
Revised: 12 February 2026
Accepted: 16 February 2026
Published: 24 February 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

Vademécum de aguas minerales termales de Uruguay

Balnea
Num 12
2026

Balnea

Vademécum de aguas minerales termales de Uruguay



Editores:
Francisco Maraver, María Lorena Vela, Elena M. Alvareda

Número 12 (2026) Serie de Monografías

ISBN: 978-84-09-86382-2

Anatomical Mapping: Musculoskeletal & Rheumatic Disorders (MRD)

GAS Path: Weak/Medium Mineralization

Therapeutic Factor: Hyperthermal & Hydrostatic.

Mechanism: Thermoregulation, joint unloading via buoyancy, reduced muscle tone, increased exercise tolerance.

Target: Osteoarthritis, Low back pain, Fibromyalgia. Best integrated into structured aquatic rehabilitation.



Almirón Path: Strong Mineralization

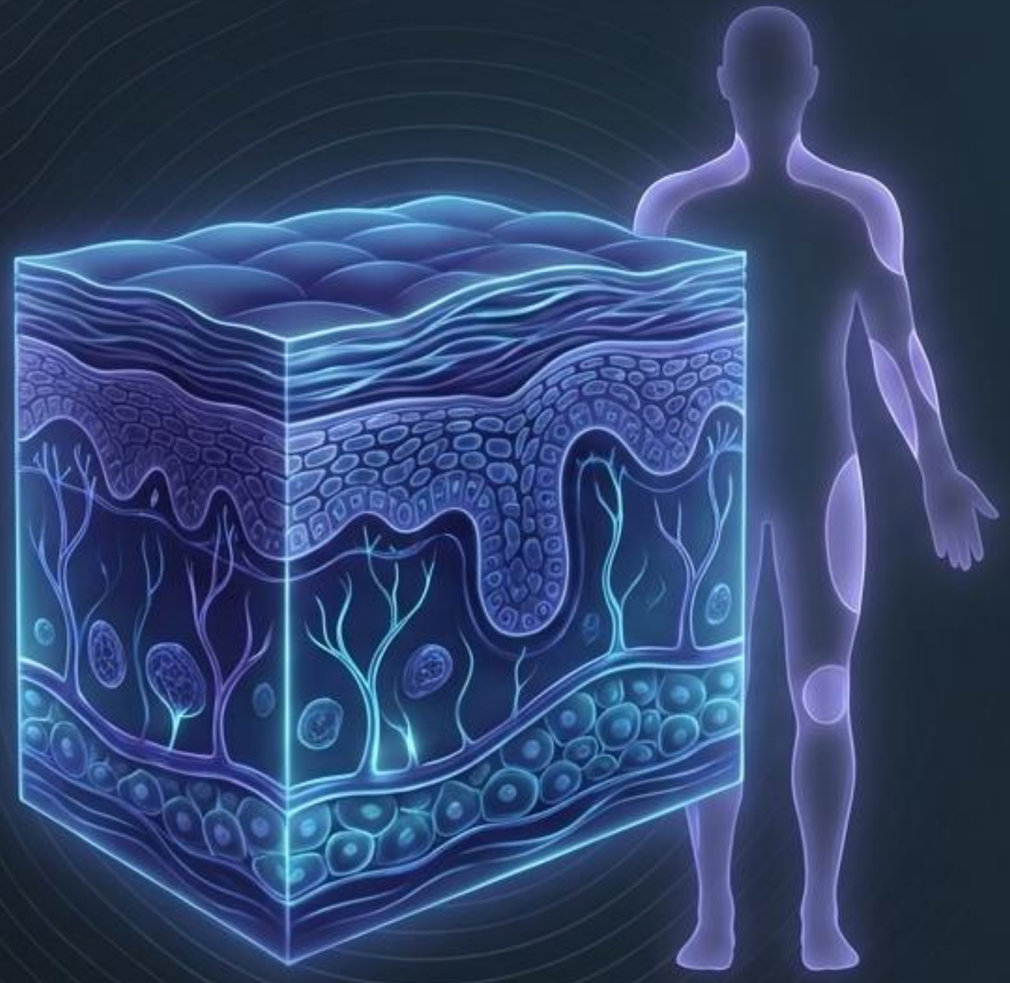
Therapeutic Factor: Salinity & Osmotic.

Mechanism: Mild hormetic stimulus, modulation of immune-neuroendocrine responses, systemic redox balance.

Target: Chronic inflammatory rheumatic conditions with stiffness and low-grade inflammation.

UNIVERSIDAD COMPLUTENSE MADRID

Dermatological Translation: Chloride-Sodium Interventions



The Indication

Plaque psoriasis and chronic inflammatory dermatoses.

The Mechanism

Salinity and ionic composition influence epidermal homeostasis, modulate cutaneous inflammatory pathways, and improve skin barrier desquamation.

Clinical Caution

Due to extreme mineralization (6,590 mg/L), requires strict protocol standardization (duration, frequency, temperature) and barrier integrity assessment.

UNIVERSIDAD COMPLUTENSE MADRID

Emerging Indications: Stress and Sleep Architecture

Stress (HPA Axis Modulation)

Moderate hyperthermia induces transient hypothalamic-pituitary-adrenal (HPA) activation, followed by an adaptive reduction in basal cortisol secretion.

This controlled thermal stimulation improves physiological resilience and dampens the biological markers of chronic stress.



Sleep (Thermoregulation)

Peripheral distal vasodilation from warm immersion accelerates the transition to sleep.

The crucial mechanism is the post-heating core cooling phase, which significantly significantly reduces sleep onset latency and improves total sleep consolidation.

UNIVERSIDAD COMPLUTENSE MADRID

Systemic Rehabilitation: Obesity & Long COVID



Obesity (Behavioral & Mechanical)

Balneotherapy acts as a crucial adherence facilitator. Hydrostatic unloading allows for safe, low-impact aerobic training. The hyperthermal environment serves as a behavioral "kick-start," concentrating high-intensity intervention into a short period to drive lasting lifestyle changes.

Long COVID (Paced Recovery)

Targets core post-viral symptoms of fatigue, pain, and neuromotor deconditioning. Warm-water immersion provides a safe, resistance-adjustable environment for proprioceptive training and paced functional capacity recovery, minimizing the risk of post-exertional symptom worsening.

UNIVERSIDAD COMPLUTENSE MADRID

From Subterranean Origins to Therapeutic Translation



Uruguay's thermal groundwater is no longer just a geological phenomenon or an empirical tradition. Through rigorous hydrochemical fingerprinting, the Guaraní and Almirón aquifers are now defined as distinct, evidence-based therapeutic instruments ready for the future of medical hydrology.

UNIVERSIDAD COMPLUTENSE MADRID

48th ISMH WORLD CONGRESS
СВЕТСКИ КОНГРЕС БАЛНЕОКЛИМАТОЛОГА
BANJA KOVILJAČA, SERBIA
MAY 13-16 2026

Gracias por su atención

