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International Water Resources Association (IWRA)
Marrakech, Morocco | 1-5 December 2025

Kingdom of Morocco
Ministry of Equipment and Water

Preliminary Insights into Subterranean Biodiversity and Water Quality in the Draa Basin

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xx/12/2025

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Université Cadi Ayyad
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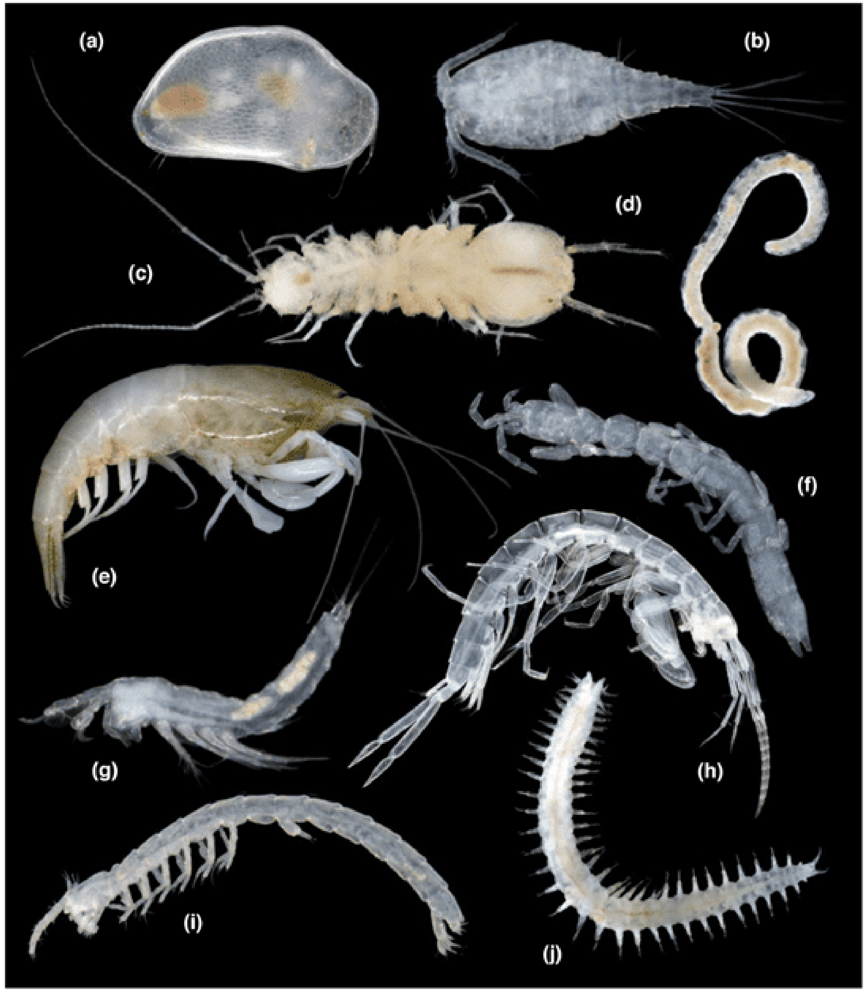
Outline

Introduction

- Groundwater in arid regions is a critical resource for southern Morocco.
- Subject to multiple pressures: agriculture, climate change, over-extraction.
- Knowledge gap: ecological functioning of subterranean fauna remains poorly documented.
- Initial hypothesis: water quality parameters influence the presence and distribution of stygofauna.



Examples of Stygofauna (Stygofaunal diversity and ecological sustainability of coastal groundwater ecosystems in a changing climate: The Australian paradigm, Saccò et al. (2022))

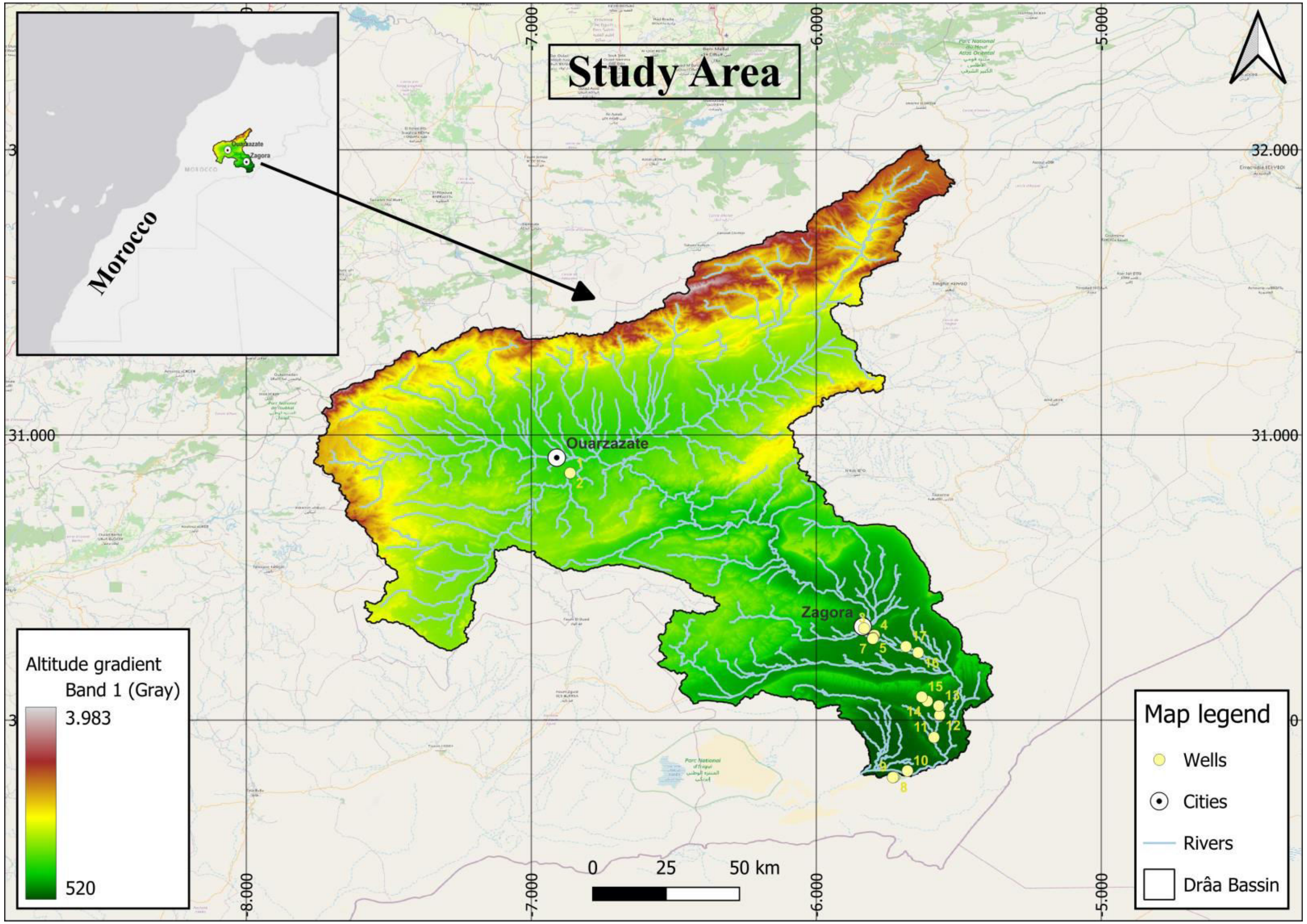
(a) Ostracoda,
(b) Cyclopoida,
(c) Isopoda,
(d) Oligochaeta,
(e) Decapoda,
(f) Isopoda,
(g) Harpacticoida,
(h) Amphipoda,
(i) Syncarida
(j) Polychaeta

Study Objectives

1. Characterize groundwater quality across 17 wells in southern Morocco
2. Assess spatial variability using multivariate analysis
3. Investigate relationship between water chemistry and subterranean fauna presence
4. Identify potential limiting factors for aquatic biodiversity

Sampling → Analysis → Results → Interpretation

Study Area & Sampling Strategy



- Sampling was carried out across 17 wells in the study area during February 2025.

- Map of High and Middle Draa Basin with the sampled wells' locations

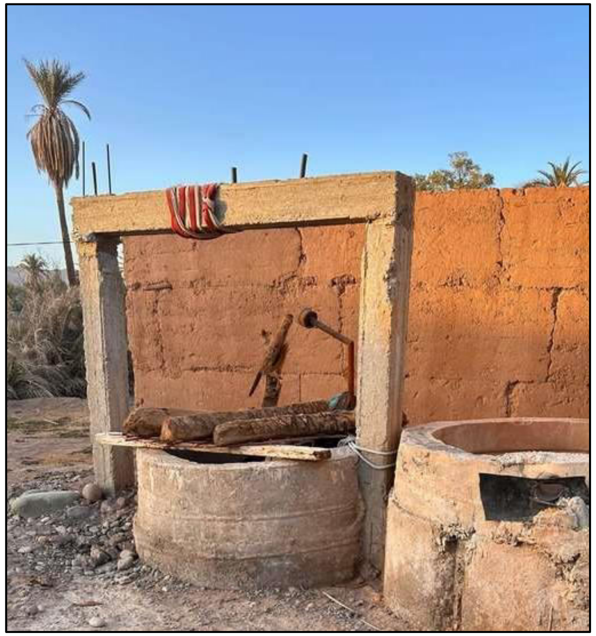
Study Area & Sampling Strategy

- **Well characteristics:**

Wells	Depth (m)	Piezometric level (m)	Diameter (m)	Status	Use
1	12	6	1.8	protected	Agricultural purposes
2	15	7	1.8	protected	Agricultural purposes
3	13	11	1.8	unprotected	Domestic and artisanal use
4	14	13.2	1.8	unprotected	Not used
5	15	13.5	1.8	protected	Agricultural purposes
6	15	6	1.8	protected	Agricultural purposes
7	13	9.5	1.8	protected	Livestock watering and domestic purposes
8	22	18	1.8	protected	Agricultural purposes
9	Borehole		1.8	protected	Agricultural purposes
10	20	15	1.8	unprotected	Agricultural purposes
11	14	12	1.8	protected	Livestock watering and domestic purposes
12	19	10	2.5	unprotected	Agricultural purposes
13	28	14	1.8	unprotected	Livestock watering and domestic purposes
14	30	15	1.8	unprotected	Livestock watering and domestic purposes
15	29	10	2	unprotected	Agricultural purposes
16	Borehole		2	protected	Agricultural purposes
17	12	5.5	1.7	unprotected	Livestock watering and domestic purposes

Study Area & Sampling Strategy

- **Examples of sampled wells:**

Methodology – Water Quality Assessment

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In Situ Parameters

- pH
- Electrical Conductivity (EC, µS/cm)
- Total Dissolved Solids (TDS, mg/L)
- Salinity (PSU)
- Temperature (T, °C)

Hanna multiparameter used for in situ measurements

Methodology – Water Quality Assessment

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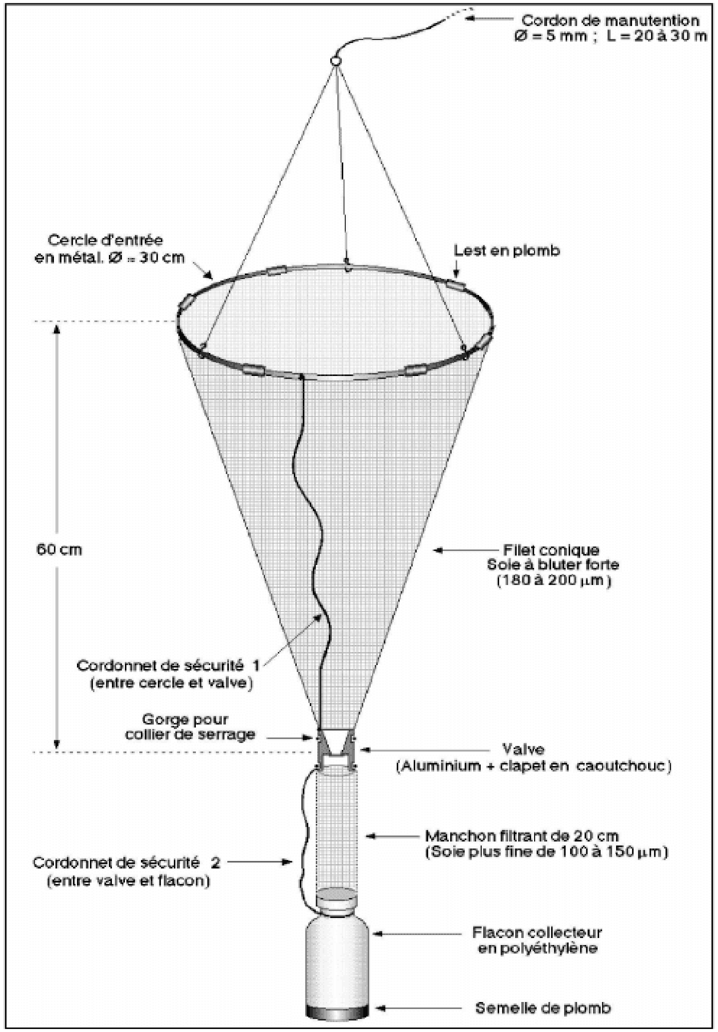
Ex Situ Parameters

- Nitrite (NO_2^-, mg/L)
- Orthophosphate (PO_4^{3-}, mg/L)
- Sulfate (SO_4^{2-}, mg/L)
- Chemical Oxygen Demand (DCO, mg/L)
- Total Hardness (TH, mg/L)
- Calcium (Ca^{2+}, mg/L)
- Magnesium (Mg^{2+}, mg/L)
- Total Alkalinity (TAC, mg/L)

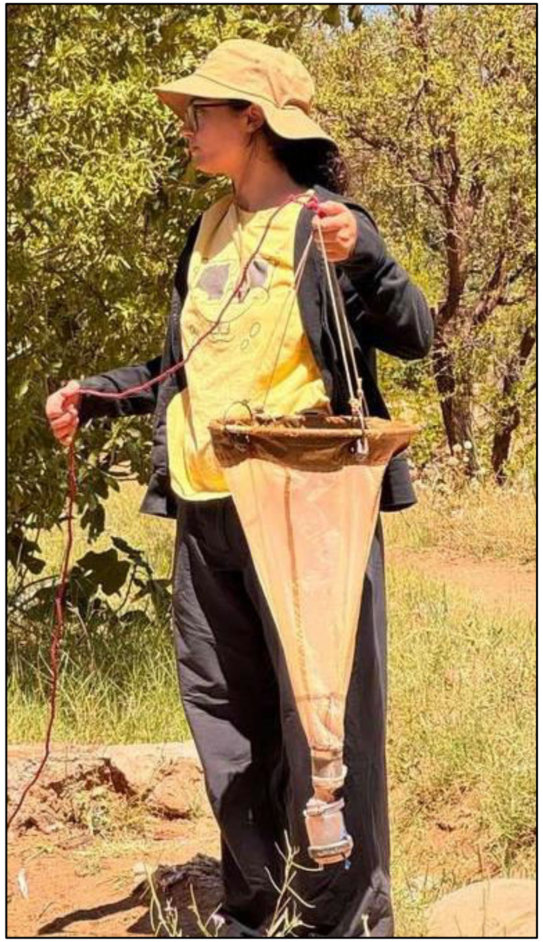
Laboratory analysis of groundwater samples

Methodology - Biological Sampling

Biological Sampling was conducted using a phreatobiological net, allowing the collection of groundwater fauna by filtering water through a fine mesh designed to retain small subterranean organisms.



Phreatobiological net (Boutin et Boulanouar, 1983)



Phreatobiological Net in Use

Analytical Approach

Statistical Methods:

- Principal Component Analysis (PCA): Identify dominant factors controlling water quality variability
- Cluster Analysis: Group wells with similar physico-chemical characteristics
- Descriptive statistics: Range, mean, standard deviation for all parameters

Software Used: STATISTICA

Results - Water Quality Parameters

- **Descriptive Statistics:**

Variable	Minimum	Maximum	Mean	Std. deviation	WHO/Moroccan Standards
NO_2^- (mg/L)	0.030	0.820	0.211	0.176	0.5 mg/l
PO_4^{3-} (mg/L)	0.000	0.290	0.053	0.078	10 mg/L
SO_4^{2-} (mg/L)	9.360	82.680	30.374	19.234	250 mg/L
DCO (mg/L)	5.440	694.270	203.154	220.113	10 mg/L
TH (mg/L)	350.000	1852.400	1006.424	577.492	500 mg/L
Ca^{2+} (mg/L)	16.000	648.000	197.261	182.622	200 mg/l
Mg^{2+} (mg/L)	303.200	1527.120	809.162	435.911	150 mg/l
pH	6.730	8.620	7.704	0.568	6.5 - 8.5
EC (µS/cm)	876.000	12990.000	4778.941	4118.827	2700 µS/cm
TDS (mg/L)	438.000	6497.000	2389.588	2060.215	1500 mg/L
Salinity (PSU)	0.430	7.470	2.626	2.381	2 PSU
T (°C)	18.480	26.340	23.904	2.120	----
TAC (mg/L)	117.140	458.810	296.072	92.669	600 mg/l

Results - PCA to Identify Key Factors Influencing Groundwater Quality

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- **PCA Overview**

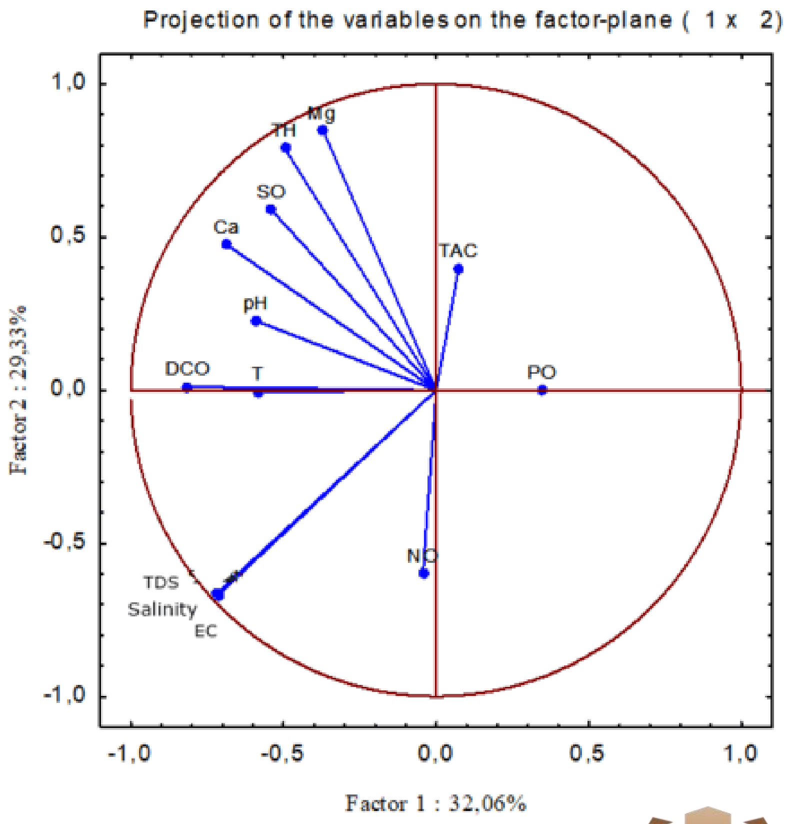
First two axes explain ~61% of total variance
(Factor 1 = 32%, Factor 2 = 29%)
Variables cluster according to distinct physico-chemical processes

- **Factor 1: Mineralization Gradient**

Strong contributions from EC, TDS, Salinity
Represents overall ionic strength / mineral load
PO_4^{3-} positioned opposite → higher in less mineralized waters

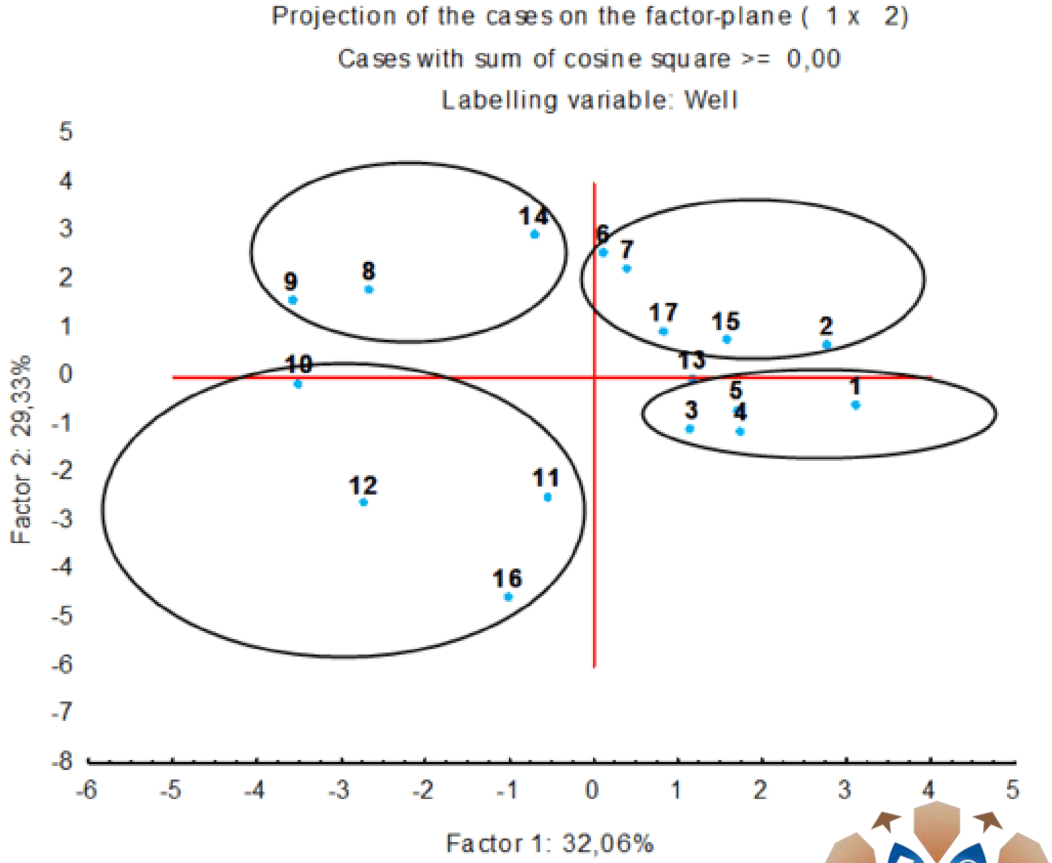
- **Factor 2: Hardness vs. Nitrite**

Driven by TH, Ca^{2+}, Mg^{2+}, SO_4^{2-} (hardness ions)
NO_2^- shows opposite trend → marker of pollution inputs
Contrasts geological mineralization with anthropogenic influence



Results - PCA to Identify Key Factors Influencing Groundwater Quality

- **Cluster A (Wells 8-9-14)**→ Moderate mineralization, high hardness, low pollution.
- **Cluster B (Wells 2-6-7-15-17)**→ Intermediate chemistry, transitional between hardness and mineralization.
- **Cluster C (Wells 1-3-4-5-13)**→ Most mineralized wells, strongest ionic load.
- **Cluster D (Wells 10–11–12–16)**→ Low mineralization, located toward nitrite influence → potential pollution signature.



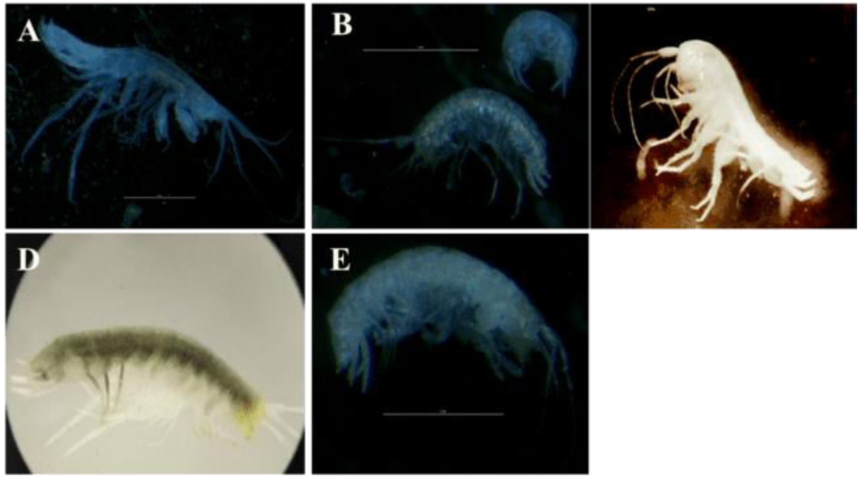
Results - Biological Survey

- Stygofauna sampling was conducted in all 17 wells during the field campaign using a phreatobiological net.
- Collected samples were transported to the natural history museum's laboratory for detailed examination.
- Sorting wes performed using a stereo microscope.
- Despite field sampling and laboratory sorting, no groundwater fauna were detected in any of the samples.

Discussion - Why No Fauna?

- Previous records of subterranean fauna in the region (Boudellah, 2021) indicate that the aquifer system is capable of supporting biodiversity. These findings provide an important reference point for interpreting our results.

Isopoda



Amphipoda

Examples of stygofauna documented in the Fezouata region, Draa Basin (Boudellah, 2021)

Discussion - Why No Fauna?

- Hypotheses
  - Chemical stressors reduce active fauna
  - Fauna mortality / displacement after floods
  - Post-flood ecosystem recovery stage
  - Sampling timing / seasonality effects
  - Fauna present but low-density

Study Limitations & Future Directions

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1. Limitations

- **Possible post-flood disturbance**

Floods in September 2024 may have temporarily altered groundwater fauna through sediment flushing, displacement, or chemical instability.

- **Sampling timing**

February 2025 sampling may have captured the system during a post-disturbance recovery phase, potentially reducing fauna detectability.

- **Fauna may be present but undetected**

Some groundwater organisms are low-density or inhabit microhabitats not fully sampled with standard methods.

- **Limited seasonal coverage**

Only one sampling window → cannot separate seasonal patterns from disturbance or natural variability.

Study Limitations & Future Directions

2. Future Directions

- **Repeat sampling in the same period next year**

To confirm whether absence of fauna was linked to timing, flood aftermath, or true ecological conditions.

- **Additional seasonal resampling**

One pre-rainy and one post-rainy campaign to evaluate seasonal and post-flood dynamics

- **Expanded methodology**

Measure DO, redox, turbidity

- **Use finer mesh sampling to detect low-abundance taxa**
- **Comparative PCA and ecological assessment:**

Re-run PCA after resampling to identify temporal shifts in water quality and potential fauna recovery.

Conclusion

- Groundwater quality shows high spatial heterogeneity, with distinct physico-chemical clusters linked to different environmental pressures.

- No stygofauna detected in any of the 17 wells, suggesting either:
  - ✓ Environmental conditions may exceed biological tolerance thresholds, or
  - ✓ Biogeographic/methodological factors may limit detection.

- Water-quality issues identified: elevated salinity and nutrient contamination in several wells require management attention.

- The absence of fauna is itself an important ecological result, highlighting the vulnerability of groundwater ecosystems in arid regions.

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Thank you!

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