Laboratory of Modelling in Hydraulic and Environment (LMHE)

Ecole Nationale d'Ingénieurs de Tunis

Hydrological and Hydrochemical Process of the Sebkha Oum El Khialette, South East of Tunisia

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BGR

Outlines

- I Context
- II Purposes
- III Study area: Sebkha Oum El Khialette
- IV Conceptual Model of the sebkha
- V Hydrochemical characteristics and brine evolution paths
- VI Conclusion

Context

- Brines in sedimentary basins are related to evaporites.

- Evaporites: sediment deposited from natural waters that have been concentrated as a result of evaporation (Ingebritsen et al., 1998) in semi arid to arid area.

- Their deposit is mined for salt which

Constitutes economically important minerals like: gypsum, halite, natron, mirabilite and other.

- The genesis of these deposits is controlled by many aspects such us:

- ✓ Hydrological condition,
- ✓ The sedimentological framework,
- ✓ Chemistry and mineralogy of brine.

Purposes

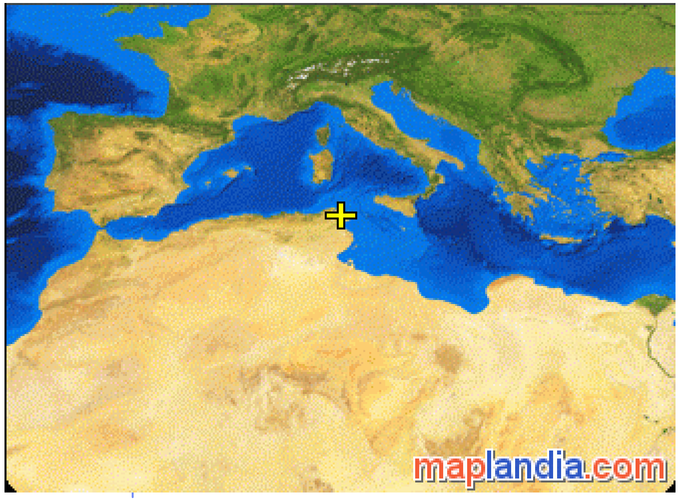
- To understand the hydrological and hydrochemical processes of the sebkha.
- Solute Mass balance is developed:

  - ✓ To follow the concentration of brines through time
  - ✓ To define the role of water outflow (evaporation) and water inflow (rain).

- Modelling by PHREEQC using data base PITZER during evaporation

To characterize the geochemical evolution of brine and salt minerals

Study area: Sebkha of Oum Lekhialette



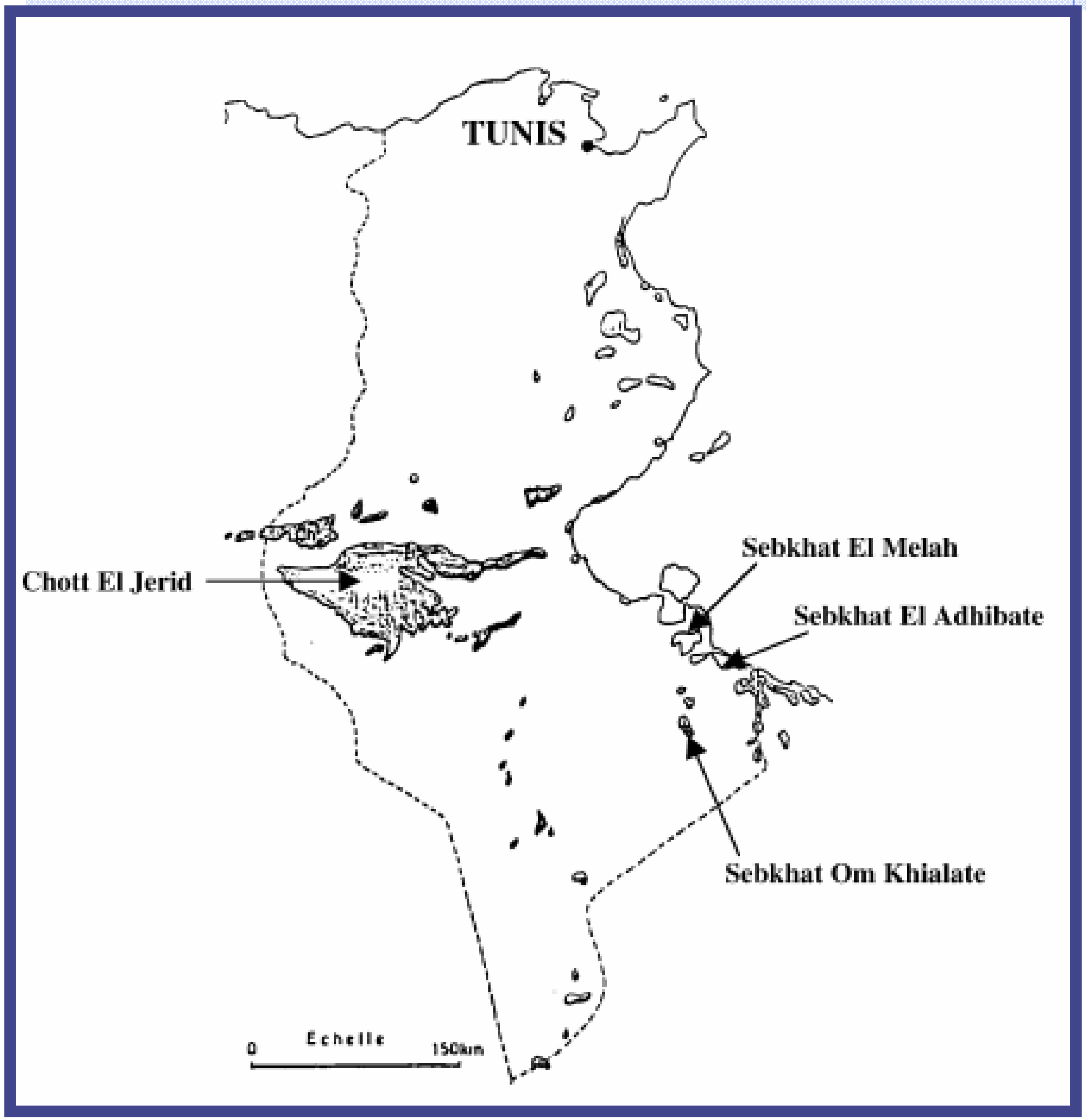
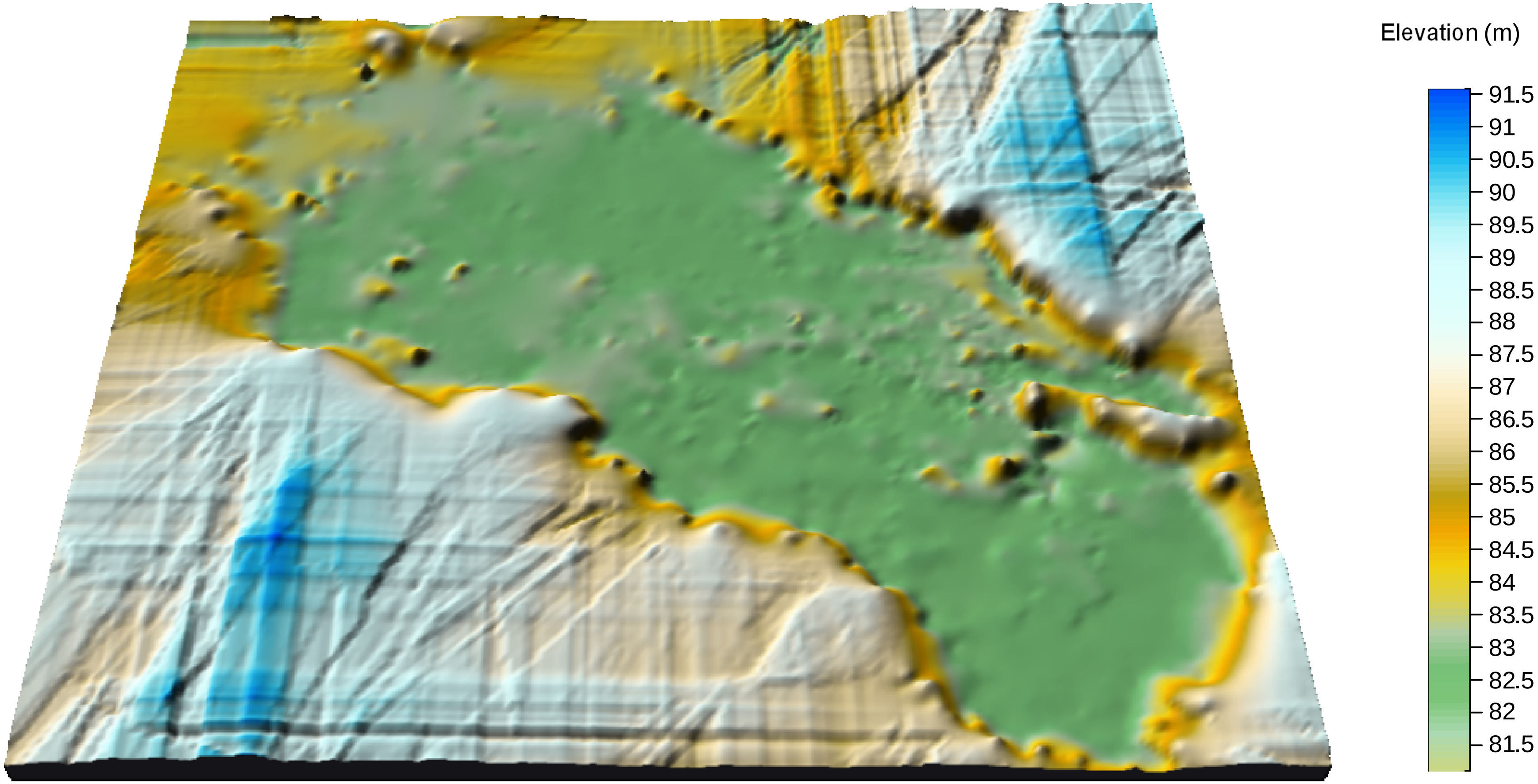


Fig.1: Map of the study zone: Sebkha Om Khialate

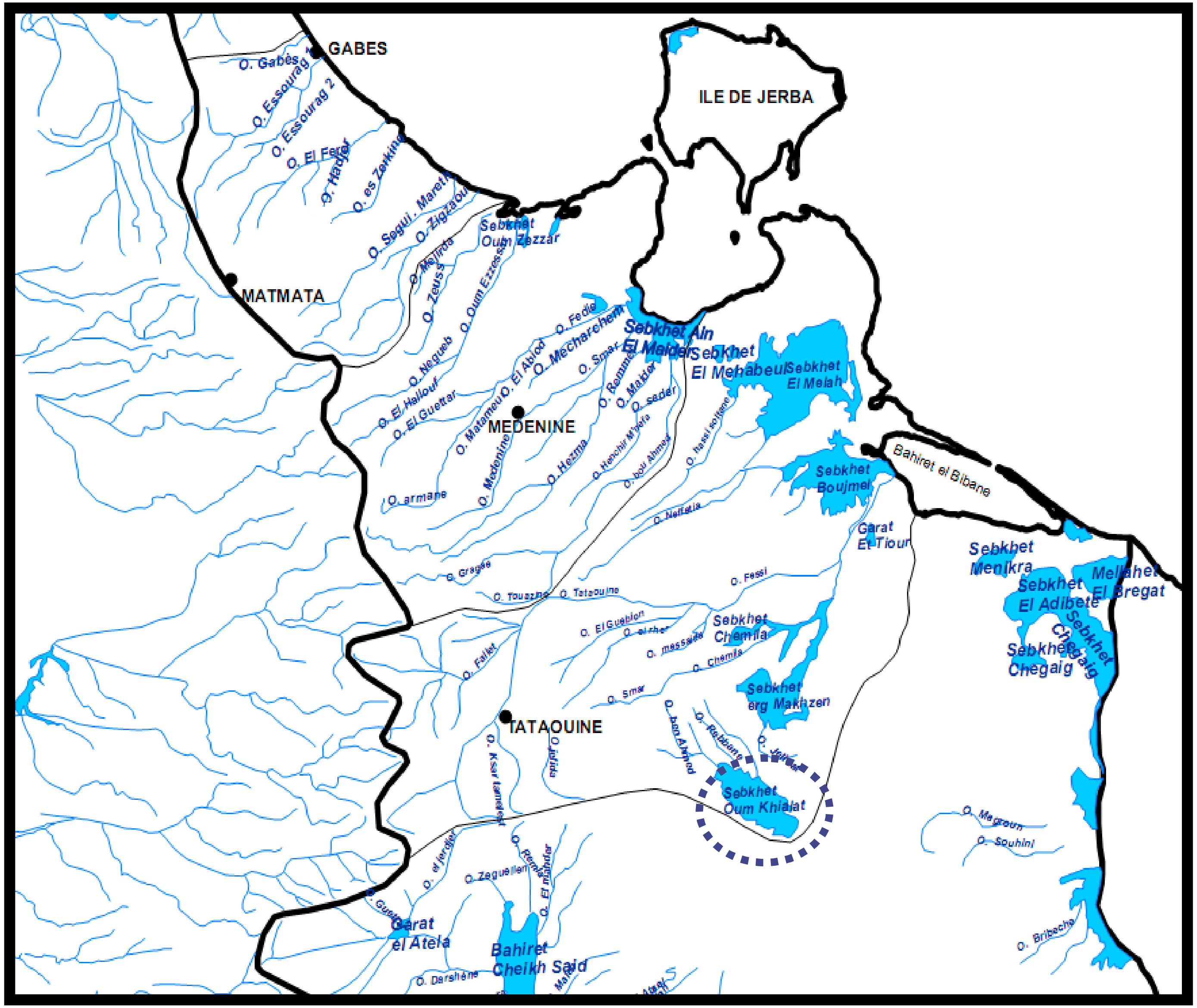
S= 52 Km²



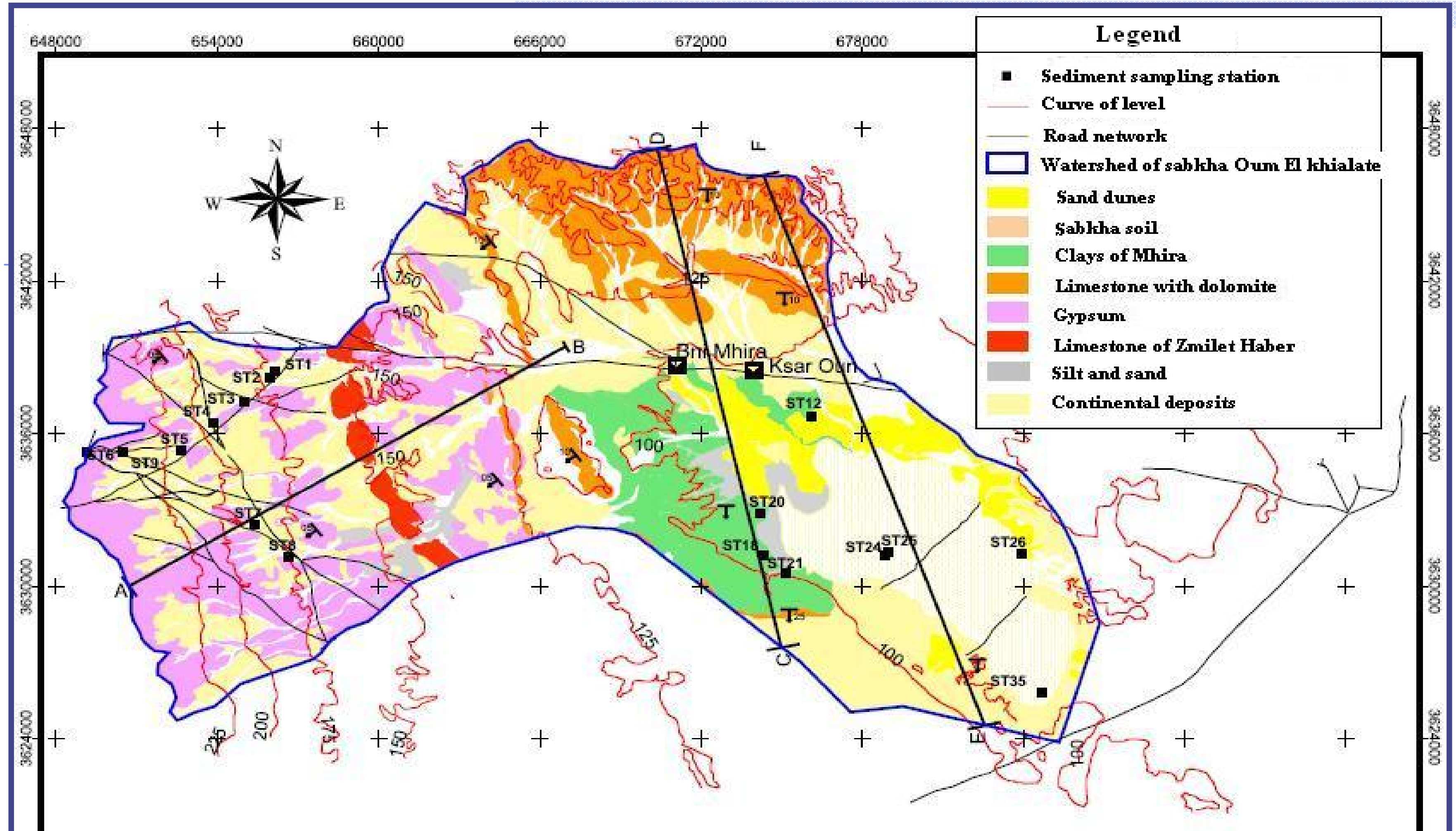
Sebkha Oum El Khialette (South East of Tunisia) (Eco[ressource], 2007)

P=104 mm/ year
ETP= 1100mm/ year

Surface runoff=
400 000 m³/year
600 000 m³/year



Map of hydrographical network

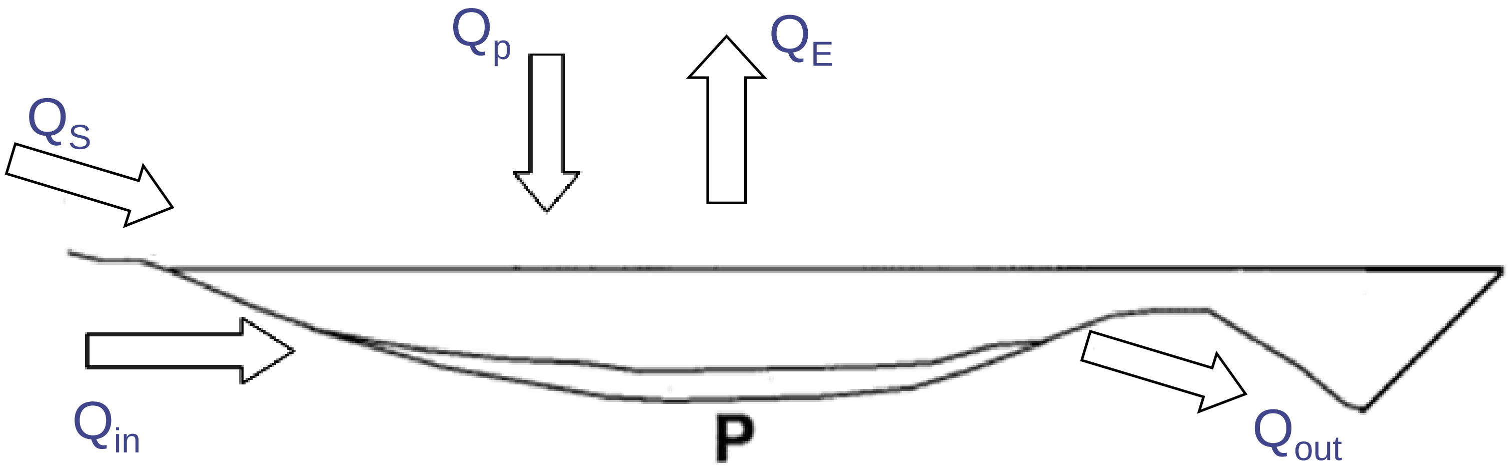


*Geological map of sabkha Oum El Khialette (Eco*ressources, 2007)

Formations	**Mineralogy composition**
Dune deposits	Quartz, gypsum, dolomite, illite and kaolinite
Quaternary encrusting	Gypsum, Quartz, calcite
clay of Mhira	illite and Kaolinite, quartz, gypsum, halite, feldspars
Mestaoua evaporitic	Gypsum, dolomite, quartz

Conceptual model of the sebkha

Conceptual model of input and output flows in hydrologically system



Q_p: average rainfall, Q_S: surface runoff (continental water inflow: river); Qin: inflow; Q_{out}: outflow to aquifers; Q_E: evaporation out-flow; P: precipitated minerals.

Component of the water and solute budget of the sabkha (S=52 km²)

Budget component flux	Volume water flux (m^3/year)	Total solute (g/l)
Lateral flux in	18562.0896	1.5
Lateral flux on	5581.872	133
Evaporation	674239.68	0
Rainfall	661309.92	<2

Water mass balance

$$Q_{in} + Q_p + Q_s - (Qev + Q_{out}) = \frac{dV(t)}{dt}$$

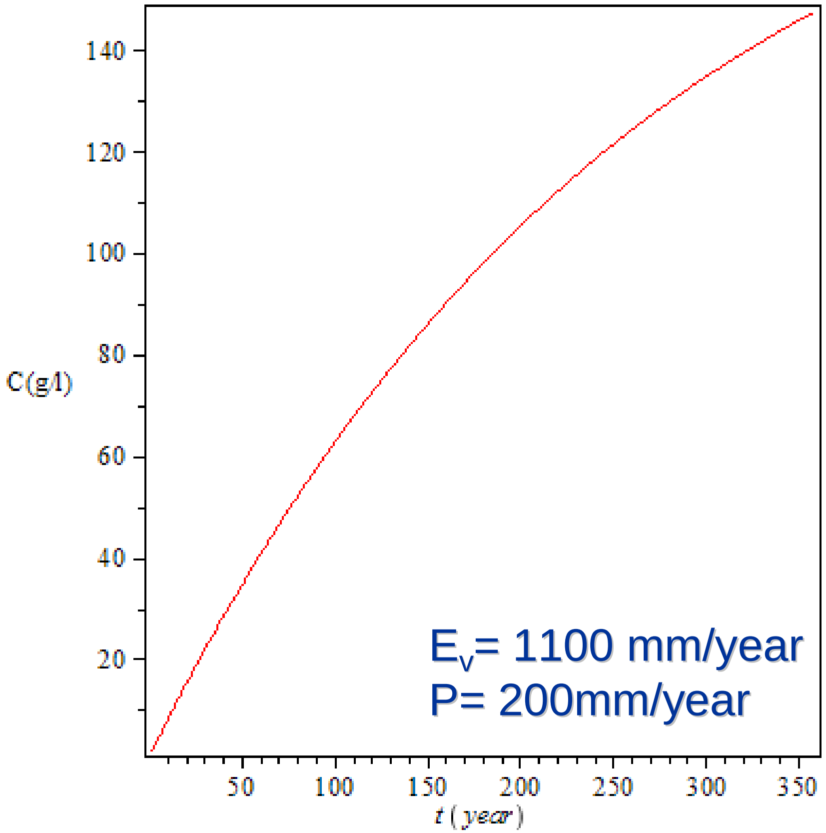
Where:
V: volume of the system (m^3) : V= S*e*Ө (S: area of the study area=52 km^2,
e: thickness= 6.71m, Ө: porosity=0.4).
Q_p is average rainfall (L^3/T), Q_{out} is average outflow (L^3/T), Q_{in} is average inflow (L^3/T), and Q_{ev} is evaporation rate (L^3/T)

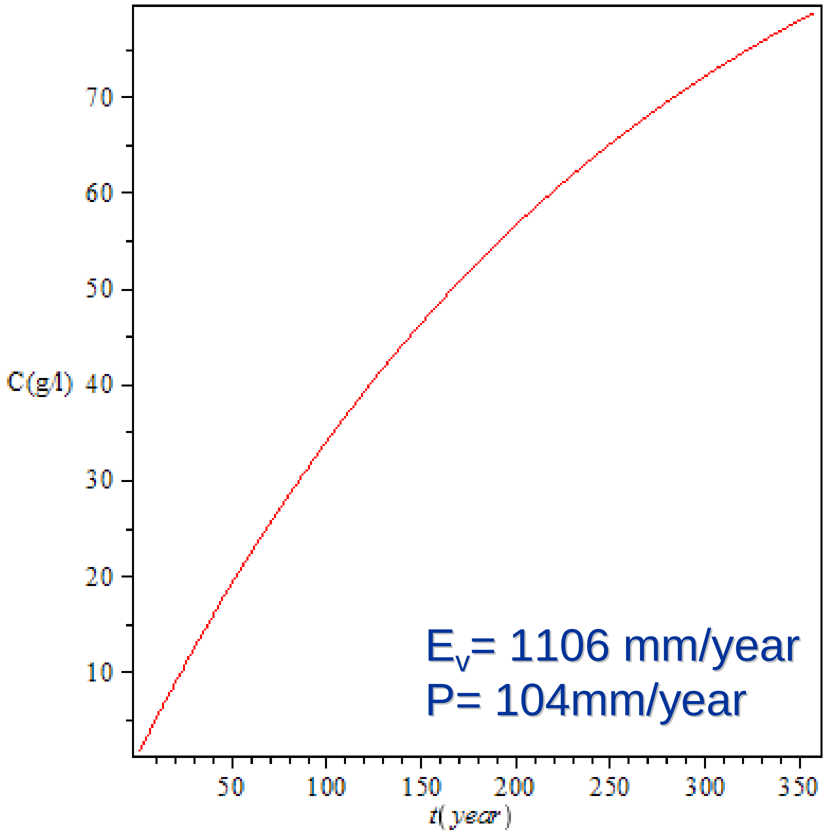
Solute mass balance

$$\frac{d}{dt} C(t)V = Q_p C_p + Q_s C_s + Q_{in} C_{in} - Q_{out} C\ (t) + P$$

C_p: is average solute concentration in the rain (M/L^3), C: is average solute concentration in outflow (M/L^3), C_{in}: is average solute concentration in inflow (M/L^3), C_s: is average solute concentration in the runoff (M/L^3), P: Mineral precipitation

$$\frac{C(t)}{C_{in}} = \frac{Q_{in} + Q_p}{Q_{out}} - \left(\frac{Q_{in} + Q_p}{Q_{out}} e^{\frac{-Q_{out}\ Q_e}{Q_{in}\ V} t} + e^{\frac{-Q_{out}\ Q_e}{Q_{in}\ V} t}\right)$$





Evolution of brines for various climatic conditions

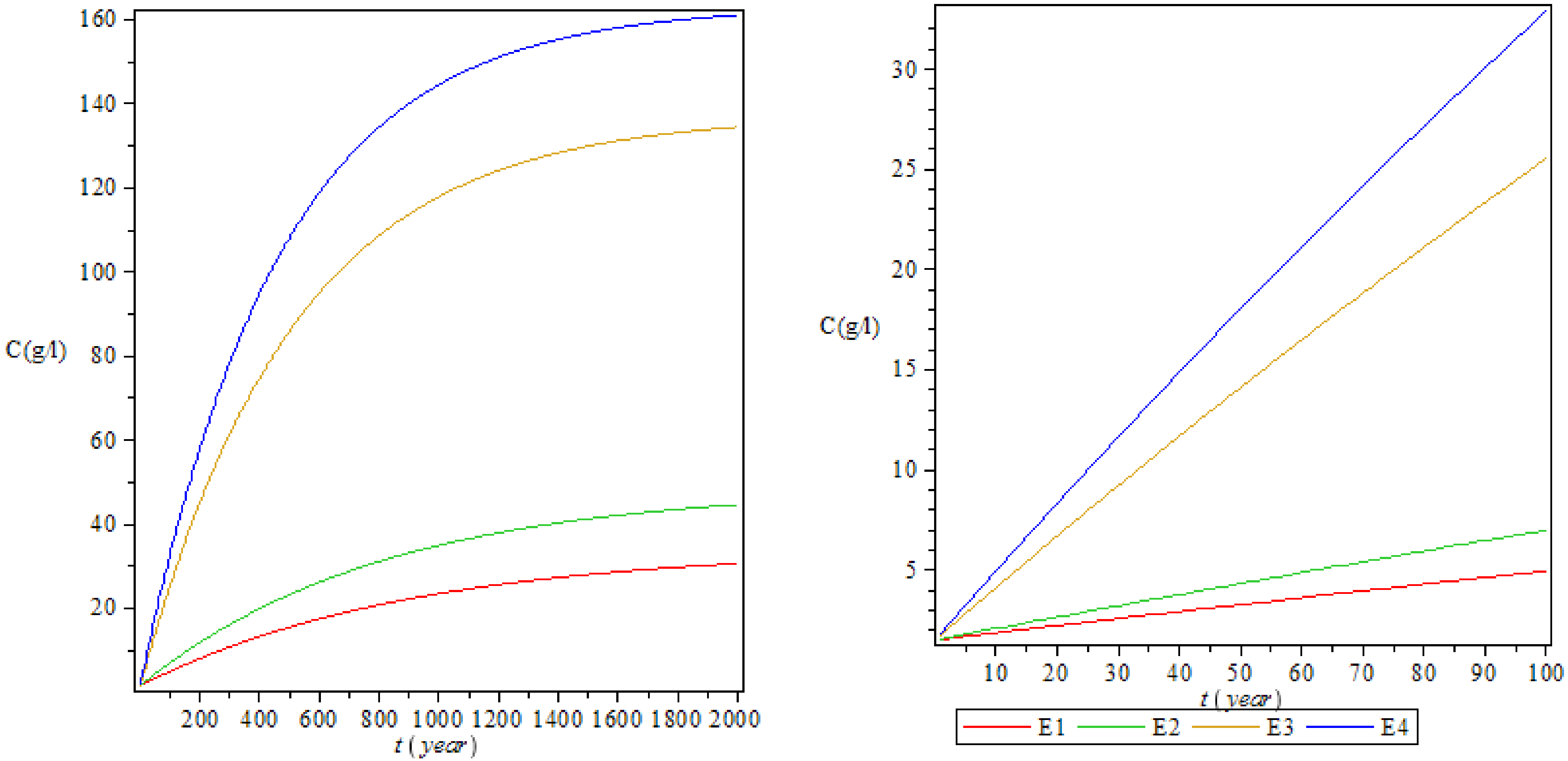
Hypothesis

V= constant $Q_{in} + Q_p - (Q_{ev} + Q_{out}) = 0$

$$Q_{in} - Q_{out} = Q_{ev} - Q_p$$

Q_p= β (P*S) et Q_{ev} = α (ET0*S)

Where S: surface of the study area, P: precipitation or rain, ET: evapotranspiration
B: rate of infiltration



P= 104 mm/year
Ev= 1100 mm/year

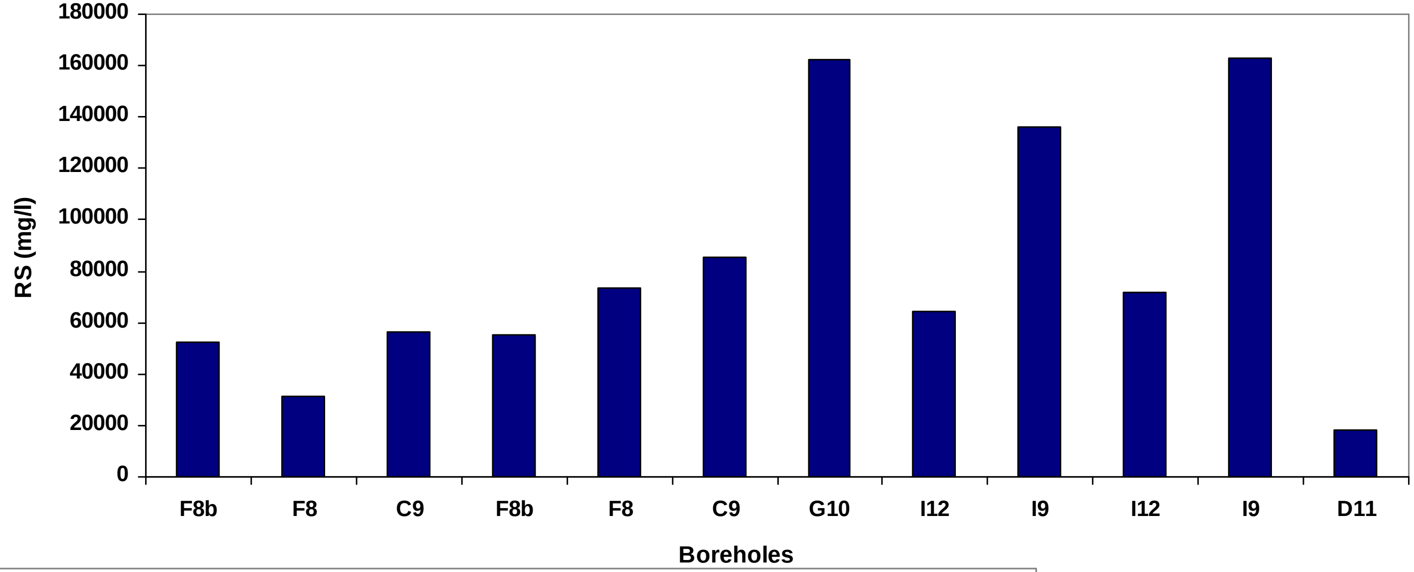
Figure. Sensitivity test

Tests	α (Ev)	β (P)
E1	0.01005	0.03
E2	0.009100	0.02000009
E3	0.01750	0.10890
E4	0.015809198	0.0910

Hydrochemical characteristics and brine evolution paths

Table. Major Ion concentrations of inflow waters and basin center samples brine in Sebkha Oum El khielette. All units are in mg/l

Boreholes	Ca^{++}	Mg^{++}	Na^{+}	SO_4^{--}	Cl^{-}	HCO_3^{-}	pH	RS
C4	560	3696	27025	16128	40115	219	7.5	95 000
D11	480	2788	31970	55200	17750	311	7.5	109000
I9	400	9552	43125	40320	69225	248	7.5	178200
F8	400	3676	37260	62400	25205	355	8	132000
F8B	480	5472	41920	80640	34435	387	8.1	170720
I12	460	2486	38870	74880	12780	278	7.9	130120
G10	560	3523	38870	81600	12425	483	7.7	133520
6631/5	176	119	495	1008	919	89	7.05	2480
6964/5	496	258	945	1536	1775	103	7.2	5000
5646/5	387	361	874	1121	1846	306	7.35	4950
7751/5	680	193	380	2880	976	123	7.25	5580



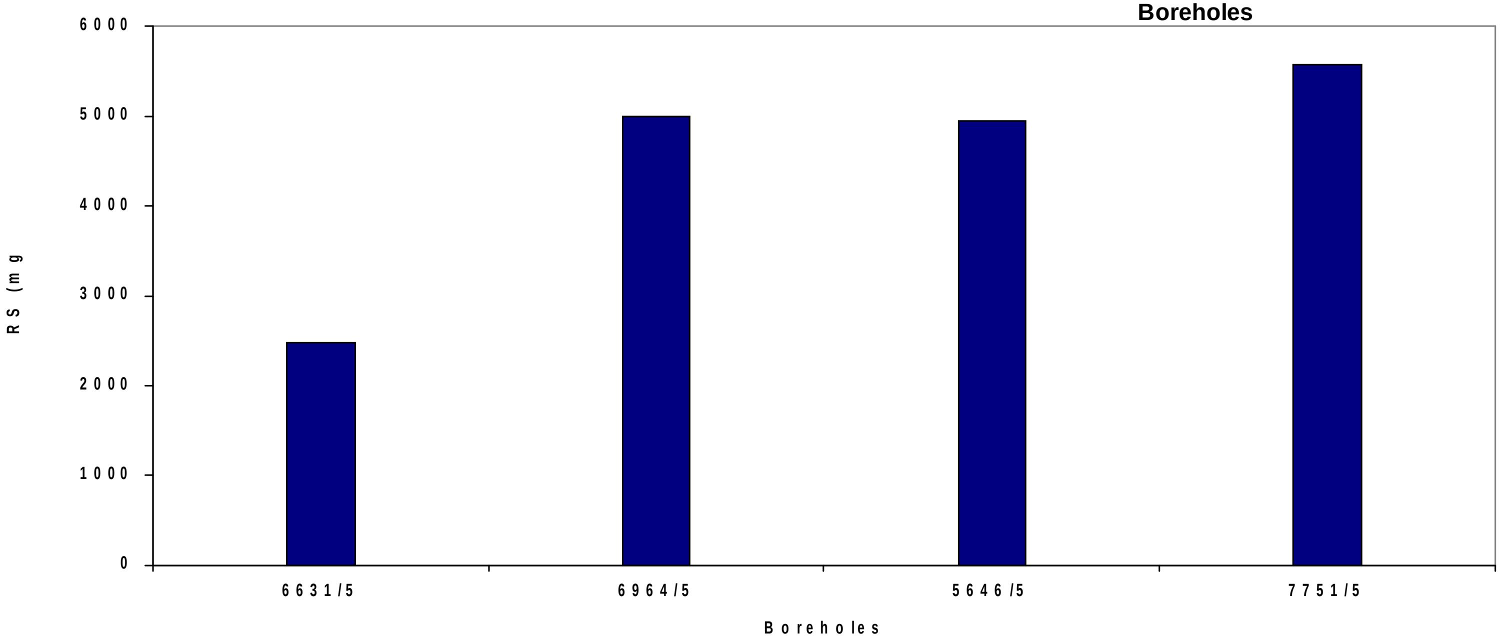


Fig. Dry residue for samples of sabkha

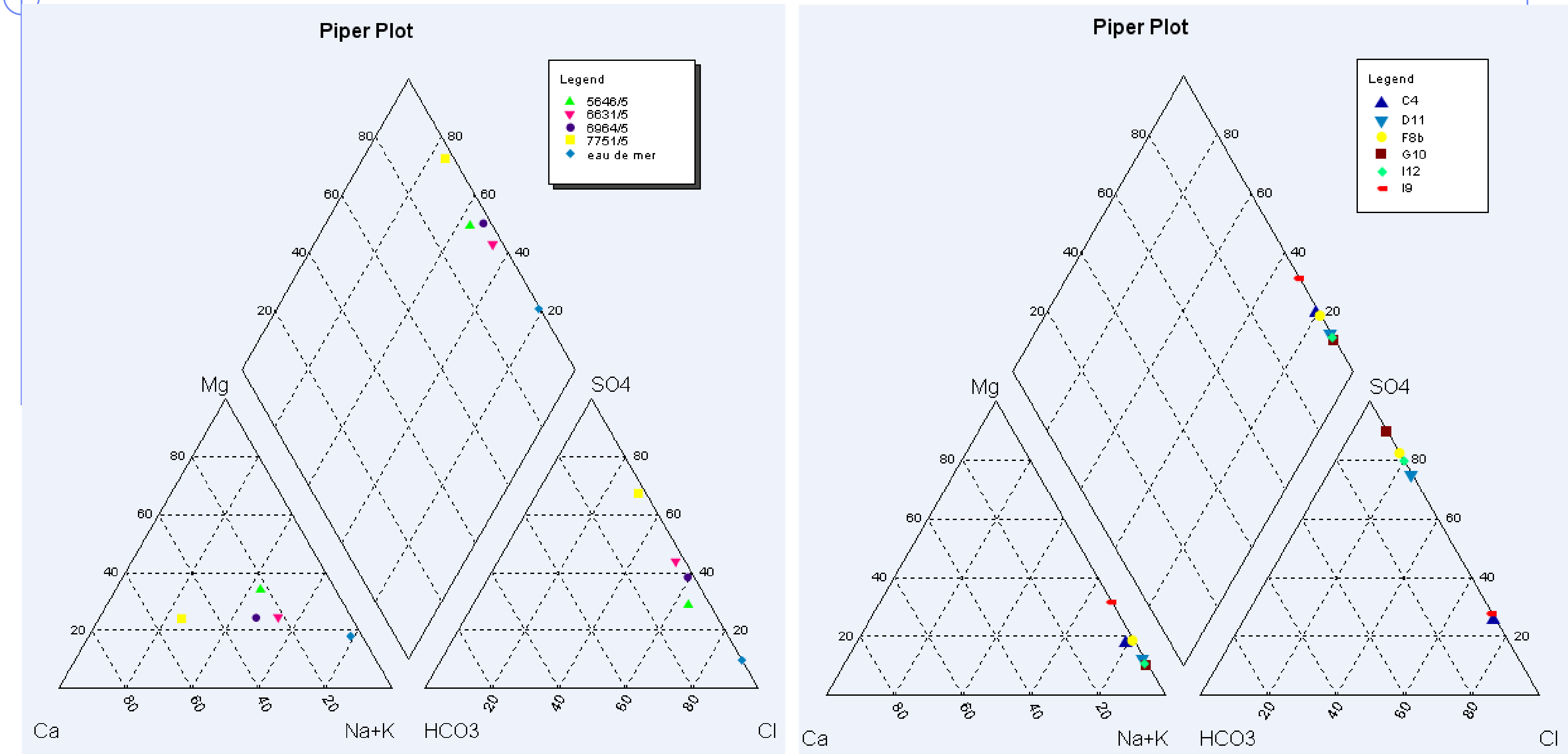


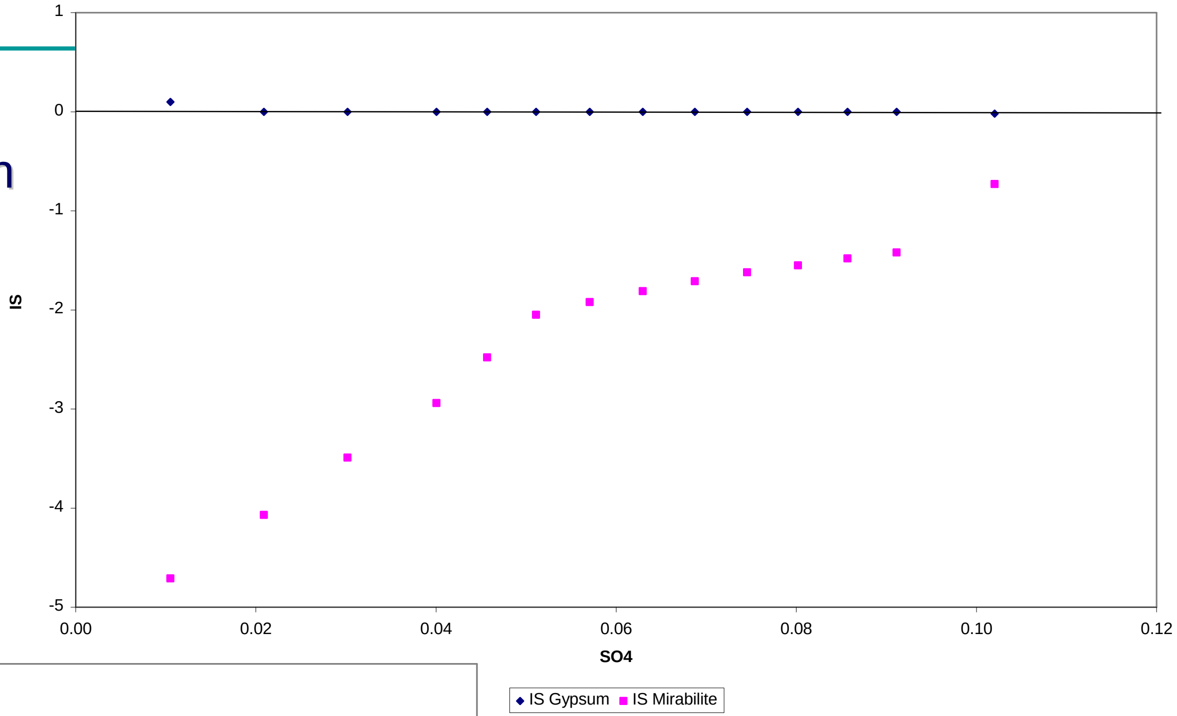
Fig. Piper plot of groundwater samples in central and at the margin of sebkha

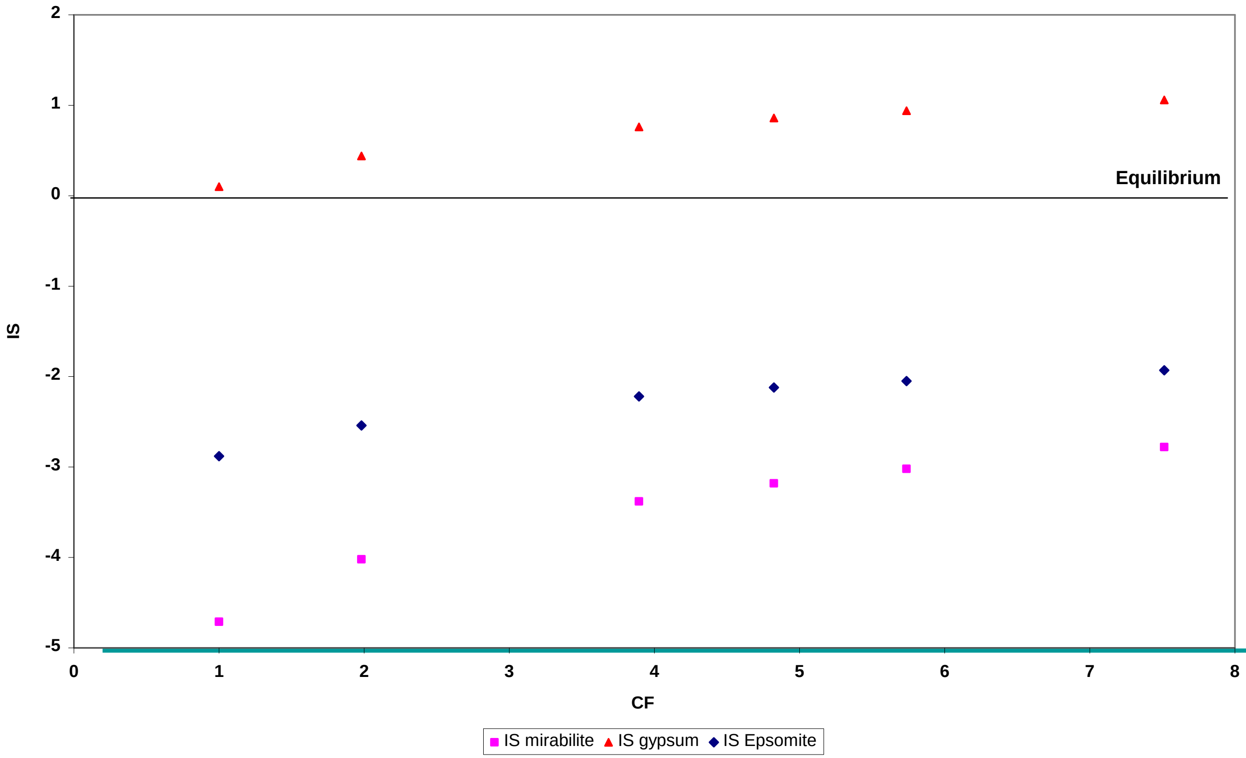
Modelling:

- PHRQPITZ was used to obtain aqueous speciation and to calculate mineral saturation indices for water samples.
- It permits to calculate geochemical reactions in brines of low to high ionic strength and at different stages of temperature.
- The evaporating steps were performed at different steps of temperature of 25 °C to 0°C

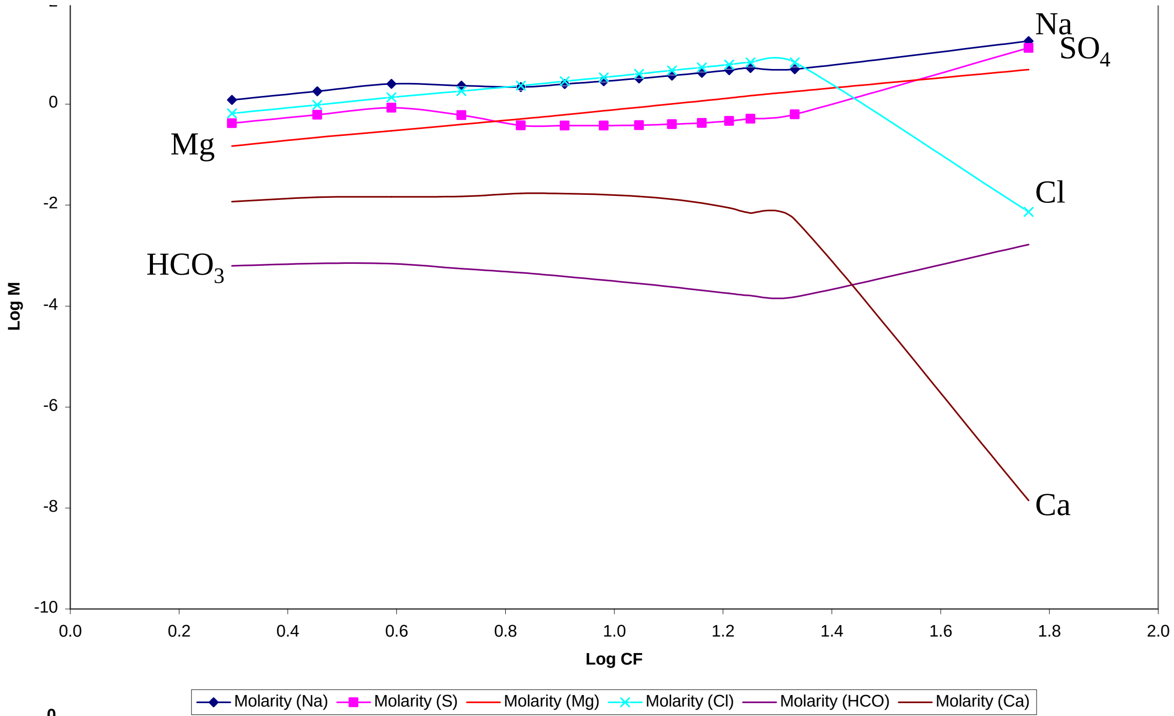
→ To follow the mineral precipitation sequence in sebkha of Oum El Khialate

a) Saturations index of common SO_4 minerals (Gypsum, Mirabilite) as a function of SO_4 concentrations





Relationship between the saturation indexes of Mirabilite, Gypsum, Epsomite and Concentration Factor



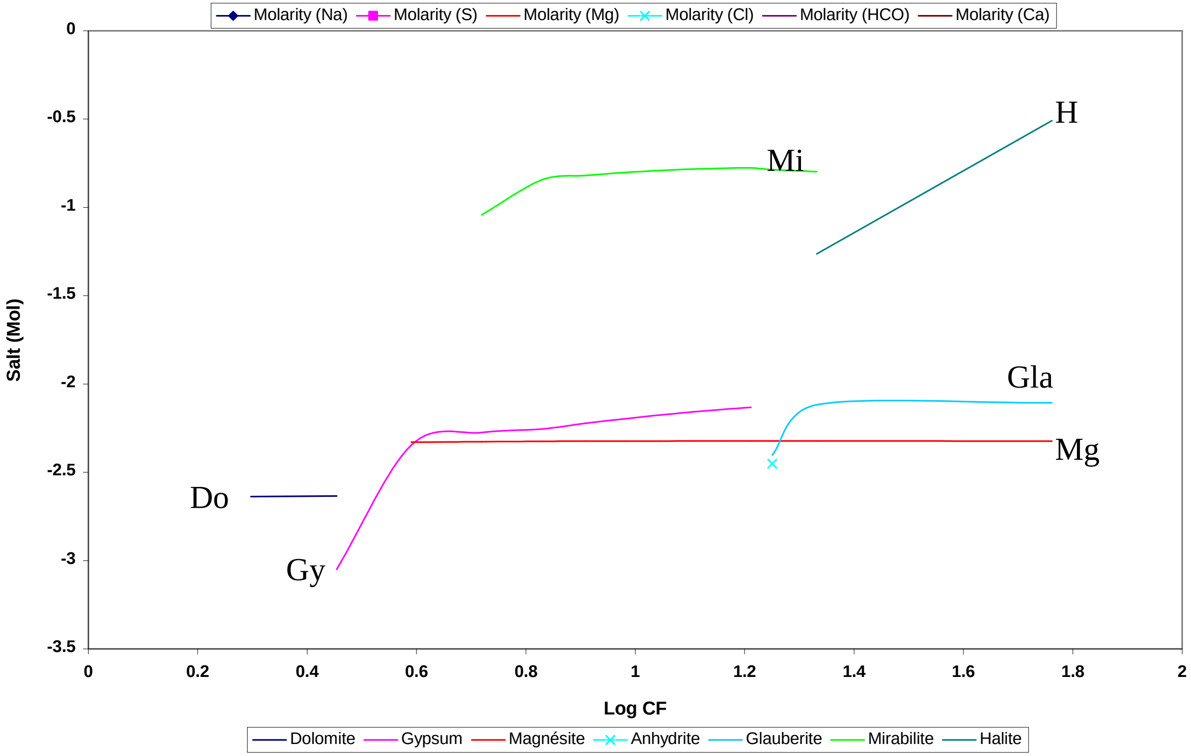


Fig. Example of Simulated evaporation of brine

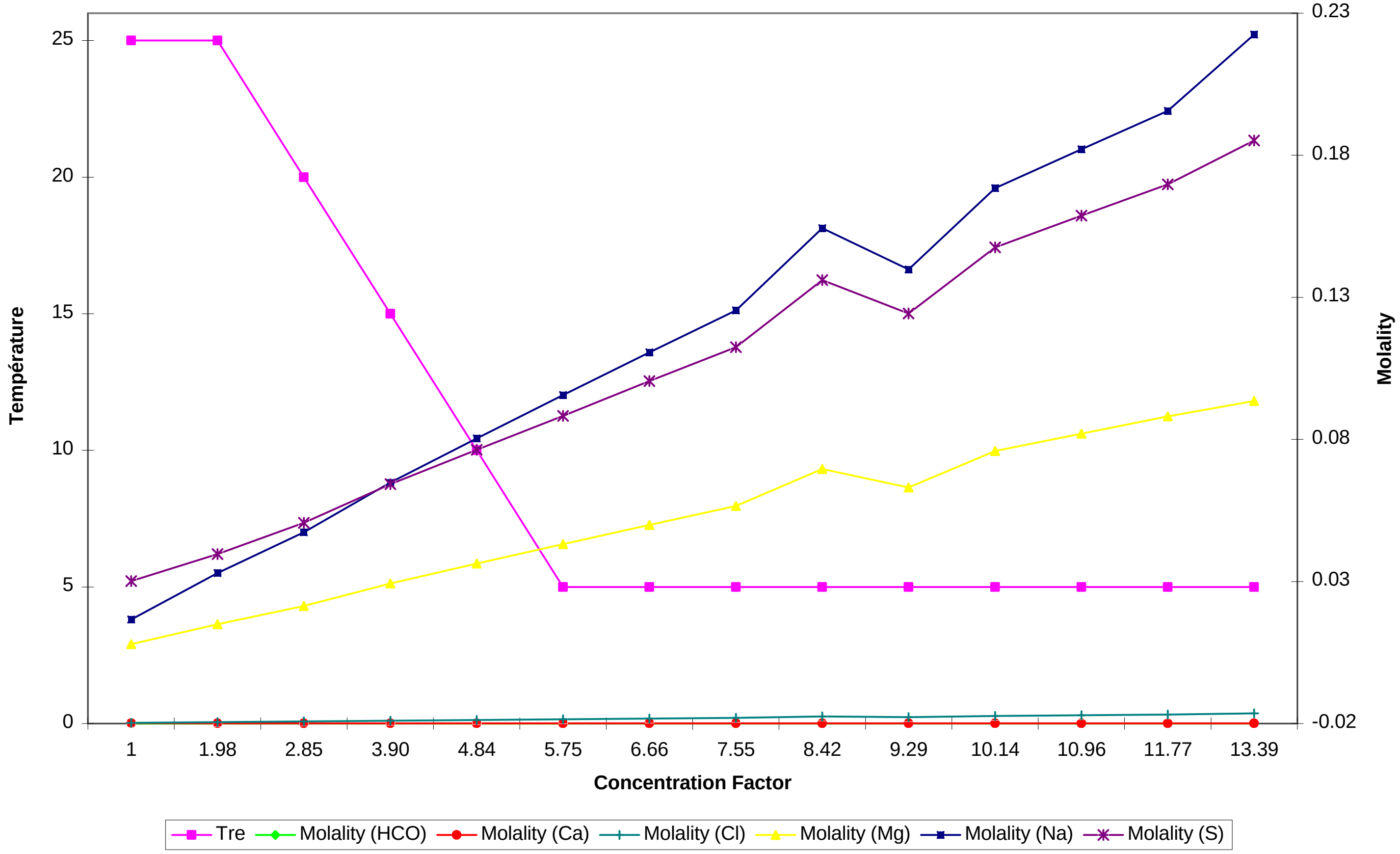


Fig. Molality of elements as a function of concentration factor and temperature

Conclusion

- A hydrological analysis show the importance of evaporation on brine evolution.

- The geochemical composition of different samples in sebkha of Oum EL Khielette:

A major water type Na-SO_4-Cl in central of sebkha and Na-Mg-Cl-SO_4or Na-Mg-Ca for samples situated in the margin of the sebkha.

- The simulation of the brine evaporation process was carried out using PREEQC included data base Pitzer geochemical equilibrium-reaction model.

- The sequence of minerals precipitation's is controlled mainly by evaporation.

- Also mineral-brine reactions are important during the process of evaporation.
- The mixing is another process to be considered after.

Perspectives

- Based on a conceptual model:
  - ✓ Genesis of brine through the paleoclimatic condition
  - ✓ Coupled modelling hydro-geochemical will be proceed using GEODENS (code developed by Bouhlila, 1999) or Hydrus 3D-PHREEQ PITZER.


Thanks for your intention