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Hydro-chemical Time-Series for Cairo-Nile Water and Atmospheric Moisture

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Abstracts: The study of hydro-chemical time-series data for study area and atmospheric moisture holds significant importance. By analyzing these data sets, researchers gain valuable insights into the dynamics of water resources and atmospheric conditions in the region. The aims of the current study are to start a record for Cairo-Nile hydrogeochemical changes, Estimate Cairo atmospheric moisture isotopic composition. The results focus that on winter the evaporation rate is lower due to the decrease in temperature, resulting in lower EC values. However, the opposite occurred, and the reason can be attributed to the salts that precipitated at the beginning of evaporation. The main reason for this is the deposition of calcite and sodium silicate. Calcite represents approximately 90% of the deposited salts, while 10% consists of sodium silicate. Calcite has a very peculiar property compared to other minerals, as most minerals dissolve as temperature rises, whereas calcite precipitates. The pH level in the winter season attains 7.8. This occurrence can be attributed to the precipitation of calcite, which results in the release of carbon dioxide from the water and the transformation of calcium carbonate into calcium bicarbonate. Consequently, there is a rise in the pH level. The Nile water evaporation is a steady-state process, so the EC values show ups and downs in relation to the inflow and weather conditions. In contrast, evaporation in Class-A pan experiment is unsteady process. Accordingly, salinity is ever increasing in the residual water. This loss to follow by the isotopic data and the change in the concentration of a conservative ion (e.g., Cl- ion). Conclusion, this study provides important insights into the hydrogeochemical dynamics of the Cairo-Nile system and the influence of evaporation processes on water quality. The findings contribute to a better understanding of water resource management in the region and can inform future strategies for sustainable water use.

Keywords: Isotope, Hydrology, Atmospheric Vapor Mixture, Waveform, Atmospheric Mixtures. (AVMs), Ternary AVMs Model, Cairo, Vapor Mixtures, Nile Delta Apex Vapor Sources.

1. INTRODUCTION

The meteorological conditions of the Mediterranean basin are in sharp mismatch to that of the Great Sahara and acute contrast with the European continent in the north, and the cultivated lands of the Nile Delta in the southeast. The main features of the weather conditions prevailing in Cairo City, at the Nile Delta apex, are well known and entirely reported by recording and analyzing the typical relevant meteorological parameters for long decades. However, hydrology research workers seldom publish the isotopic composition of precipitation (Zhang et al., 2020) and atmospheric vapor of the Mediterranean basin and for countries to the south in the region. This work is the first of its category for the 400 km2 Cairo city urban zone, 180 km south of the seashore.

The perpetual zonal drought that dominates the climatic conditions in northeastern Africa and southwestern Asia is the primary result of the compression of huge air-masses downdrift from the Troposphere, (Gasse, 2000), leading to powerful high-pressure cells, and subsequent adiabatic heating.

A valuable, high-end application is to determine the quantitative distribution of the vapor sources that make up the local AVMs in Winter and Summertime. Such an application is indispensable for any project that targets the artificial condensation of the high moisture contents retained in the local air-masses, especially in the hot season. The artificial condensation of the immense reserves of air-moisture over the hot terrains is a unique outstanding method in combating the dominant aridity in Egypt via the installation of an innovative human-made approach that fills the gap of lacking adiabatic cooling that imposes the rarity of precipitation at the southeast of the Mediterranean basin. When conventional hydrology cannot provide solutions for the local freshwater shortage problems, we mostly need non- conventional hydrology methods, procedures, and innovations. In meteorological hydrology, we need extensive information about the spatial and temporal moisture allowances in the air-masses over the agricultural regions affected by the freshwater scarcity that now extends, under the current human- made climate change, to Sub-Saharan Africa, Eastern Europe (Marchina, et, al. 2019), and Central Asia (Viviroli et al., 2020), not only the Sahara of the Arab countries and other nations in the Middle East. The downstream Nile basin is a unique riverine system in its historical and current hydrological conditions in the dry and hot Sahara. The Nile Delta has seen elaborate natural and human changes in the last few thousands of years. The interaction of old climate change and the human-made interventions (and their impact on the Nile downstream system) resulted in remarkable modifications in the water budget and land use in Egypt since the start of the written history, with aridity becoming more accentuated in the last two thousand years, (Flaux et al., 2013). Such excessive aridity is a candidate to accentuate ahead from the present-day situation, (Stephens, et al., 2020), and (Khozyem, 2020). Besides, at present, there are intentional exterior dangers that threaten the Egyptian Nile in ow continuity, for the first time in history, by building dams on the Blue Nile, at the far head reaches, of such a river, old of six million years in Egypt, connected to the Blue Nile since 650 thousand y BP., after significant topographic and climatic changes in the northern and eastern African belts. The builders of dams on the Blue Nile falsely pretend that Egypt confiscates the Blue Nile discharge while the reality is that the Nile's head reaches have another twelve rivers and receive >1000 BCM of precipitation per year whereas Egypt receives 5.50% of that colossal water deposition on the Nile basin. Moreover, they falsify everything to forget that this is God's water in the skies, not even the Ethiopians water on the ground. By the international law of water rights in force and action, no upstream land has the right to cut off the river water flow to the downstream countries. Otherwise, they are practicing a dirty little game of war declaration, and they do not ever know what destructive war may come to them; they would have to pay a heavy price for their primitive madness of trying to kill Egypt via thirst and hunger. The field of the isotopic composition and quantitative distribution of three moisture sources in the local AVMs, at Cairo City, along with the change in the contribution of these vapor sources in Winter and Summer, primarily through the conjunctive use of d18O and specific humidity data. The purpose is not only to elucidate the internal mixing processes and to reveal its isotopic impact on the local AVMs isotopic signals but also to follow the trend of change in the contribution of each vapor source in the two seasons. The details of daily and seasonal isotopic signatures of the local AVM can be beneficial for the experimental work on the estimation of the evaporative losses from local and regional surface water bodies under the steady and unsteady regimes. Such experiments are of prime interest for the follow up of the local and regional water budgets, (Benettin et al.,2018) and (Zhao et al., 2014). The objectives of the current study are: Start a record for Cairo-Nile hydrogeochemical and isotopic changes and Estimate Cairo atmospheric moisture isotopic composition.

2. MATERIAL AND METHODS

The study employed a comprehensive methodology to investigate the hydro-chemical dynamics of the Cairo-Nile system, involving measurements, experimental evaporation, and data processing. The methodology can be summarized as follows:

1. Measurements on Cairo-Nile Water Samples: Daily collection of Nile water samples for analysis, measurement of electrical conductivity (EC) at 25°C using a calibrated EC electrode, pH measurement at 25°C using a calibrated pH meter electrode, time-series charts were generated to visualize the collected data and monthly full chemical analysis of Nile water samples, including pH, EC, total dissolved solids (TDS) and Cl Saturation indices (SI) were calculated using the NETPATH database model of the USGS to assess the water's equilibrium state (Mona El-Sayed and W.M. Salem, 2015).

2. Isotopic Measurements:

Weekly sampling of water samples, except for thunderstorm days, where daily sampling was conducted. Isotopic measurements were performed in a specialized laboratory using the LASER Quenching method. The ratios of $^{18}O/^{16}O$ and $^{2}H/^{1}H$ were determined, and the isotopic composition ($d^{18}O$ and $d^{2}H$) was calculated relative to the V-SMOW standard.

3. Experimental Unsteady-State Evaporation:

Class-A pan experiments were conducted using a specific pan size. In situ measurements and daily sampling were performed for isotopic measurements. The evaporation run was carried out during both the Winter and Summertime to capture seasonal variations.

4. Data Processing and Charting:

The wave function was fitted to the data, and wave parameters such as average L and modulation contrast ratio m were calculated as functions of angular frequency (omega) and periodic time (T) for both the river and thunderstorms. Isotopic mixing of thunderstorm rainwater with Nile water was estimated to determine its contribution to river discharge. Extrapolation techniques were used to predict the impact of ancient paleorainfall on the isotopic composition of Wadi Natron groundwater. The Ln function was used to separate solute components into two fractions related to evaporation and dissolution, employing direct and inverse solutions. Observations from the class-A pan experiment were plotted to estimate unsteady water losses. Steady-state water losses were estimated using the chemical and isotopic composition of river water.

3. RESULTS AND DISCUSSION

The provided fifteen diagrams are showing the experimental and simulated data.

The experimental data, figs 1 to 7, are for Winter and Summer 2020 runs of two unsteady-state evaporation experiments, carried out in the Zankaloun Experimental Station, Zagazeig. Figs 8 and 9 show computer simulation of five water samples, including Cairo Nile water. Figs 10 to 14 are for the theoretical calculations obtained *via* running the Hydro-Calculator Isotope Hydrology and Geochemistry code.

The simulations have made use of the measured isotopic composition of Cairo Nile water, the average isotopic composition of Cairo atmospheric water vapor mixtures, and Cairo meteorological data and assumed average values for temperature and relative humidity.

Some of current diagrams will be modified and enhanced by the addition of the isotopic signatures of the residual water in the Class-A Pans when the measurements of the experimental isotopic contents become available. Besides, measurements of chloride ion concentrations must be carried out in each other day of the residual water samples since the EC parameter is not conservative as significant mineral deposition (primarily Calcite) takes place in the early evaporation stages.

The counterintuitive observations on the Nile water isotopic and chemical composition in the studied time-series are the following. The peak of EC values appears in mid-Winter, and the EC trough shows up in mid-Summertime. Also, the 18O values almost show up in the same way, contrary to the pure intuition. The isotopically enriched Nile water pools appear in Cairo in early Spring.

In contrast, the isotopically depleted, fresh. Waters show up by the late Summertime. As such, the isotopic waveform has a definite three-month delay for the climax and bowl of the heavy isotopic content when compared to the EC waveform behavior. Albeit the expected high evaporation rate in Summertime, the higher discharge rate released from Lake Nasser masks the EC increase by evaporation downstream in the hot season. The inverse of the last statement takes place in Winter as following. In that cold season, the discharge rate is to formally diminish (by the rigorous hydraulic regulations applied at the High Aswan Dam) as the field crops cultivated downstream have low water demand in that cold season. The total annual evaporation rate from the river stem between Aswan and Cairo was estimated as about one BCM y-1.

The daily meteorological evaporation experiments carried out in four years (2017-2020) in Cairo downtown (work that appears in another article by the author) showed that high evaporation rates are shouting in early Spring than in Summertime primarily due to the lower RH in Springtime.

As such, we understand the isotopic signature as a sensitive tracer to the change in the evaporation rate, and thus shows up the enriched heavy isotope content in Spring. The adverse is the reluctance of the electrical conductivity change, which is expressing solute transport toward the downstream river-sector much more than reflecting differences in the evaporation rate. The higher solute-load in Cairo Nile water in Winter is the result of the transfer of the dissolved ions and pollutants in the river in Upper Egypt, mostly by late Autumn. In this regard, we must remember that the main river course in Upper Egypt started to work as a colossal drain for its floodplain since the year 1970. Besides, this riverain course sadly still receives the discharge of about 40 municipal, industrial, and agricultural return water canals in Upper Egypt. These unsafe discharges contribute to the river water solute loads that later appear in Cairo.

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Evaporation Class-A Pan Experiment, Zankalon, starting on 24 February 2020 (Winter, summer).

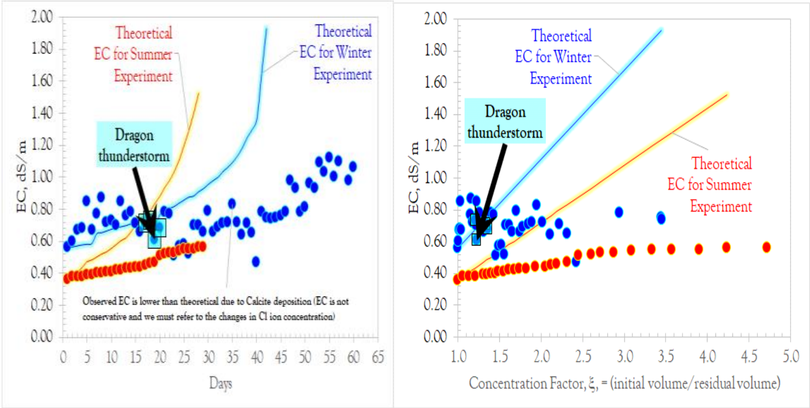

Fig.1. The observed residual water EC, dS/m, in the two unsteady-state evaporation runs in Zankalon in relation to time (days) and the concentration factor, □, in Zankalon, in Winter and Summer, 2020.

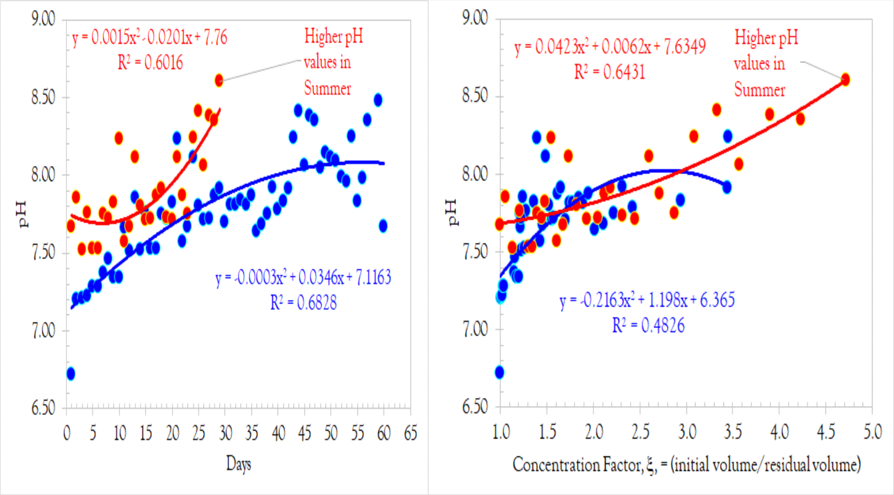

Fig. 2. The observed the residual water pH in the two unsteady-state evaporation runs in Zankalon in relation to time (days) and the concentration factor, □, in Zankalon, in Winter and Summer, 2020

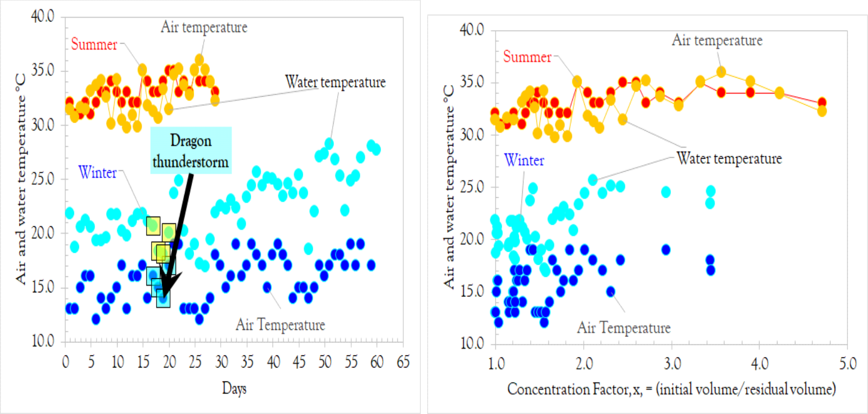

Fig.3. The observed water temperature °C in the two unsteady-state evaporation runs in Zankalon in relation to time (days) and the concentration factor, □, in Zankalon, in Winter and Summer, 2020.

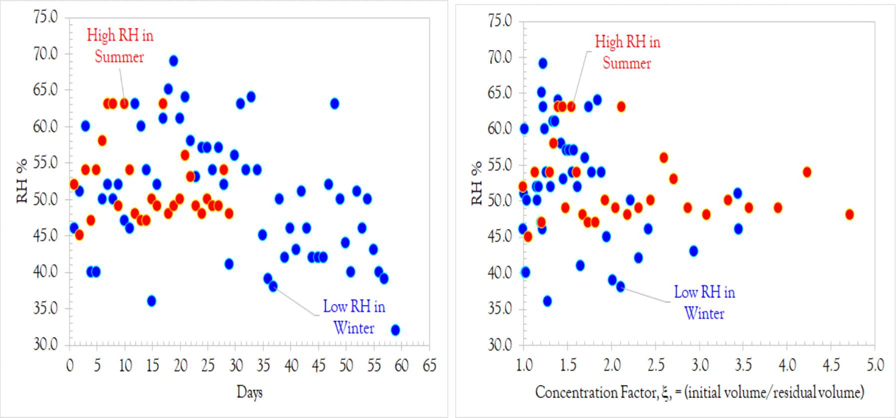

Fig. 4. The observed RH values during in the two unsteady-state evaporation runs in Zankalon in relation to time (days) and the concentration factor, □, in Zankalon, in Winter and Summer, 2020.

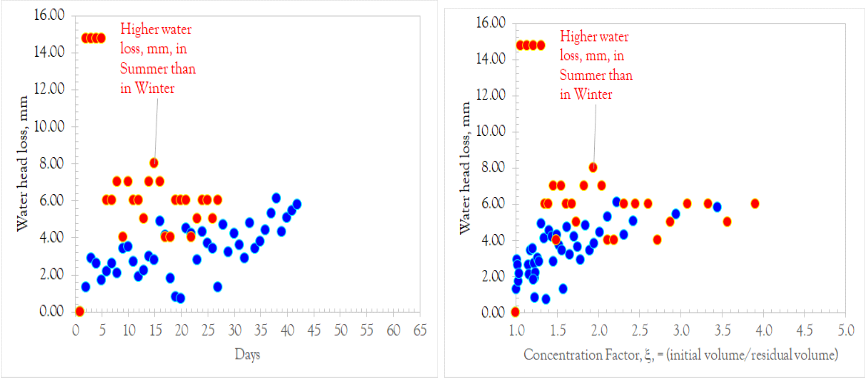

Fig.5. The observed water losses, mm, in the two unsteady-state evaporation runs in Zankalon in relation to time (days) and the concentration factor, □, in Zankalon, in Winter and Summer, 2020.

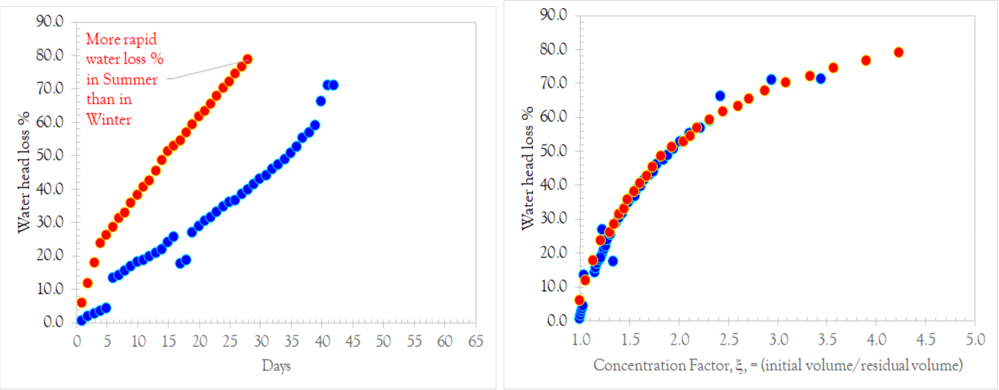

Fig. 6. The observed percent water losses in the two unsteady-state evaporation runs in Zankalon in relation to time (days) and the concentration factor, □, in Zankalon, in Winter and Summer, 2020.

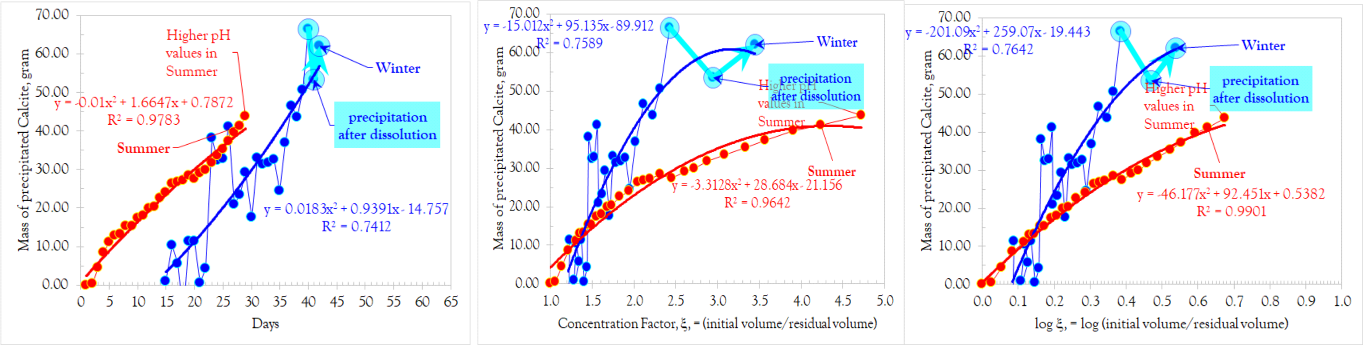

Fig.7. The mass of precipitated Calcite in the two unsteady-state evaporation runs in Zankalon in relation to time (days) and the concentration factor, □, in Zankalon, in Winter and Summer, 2020.

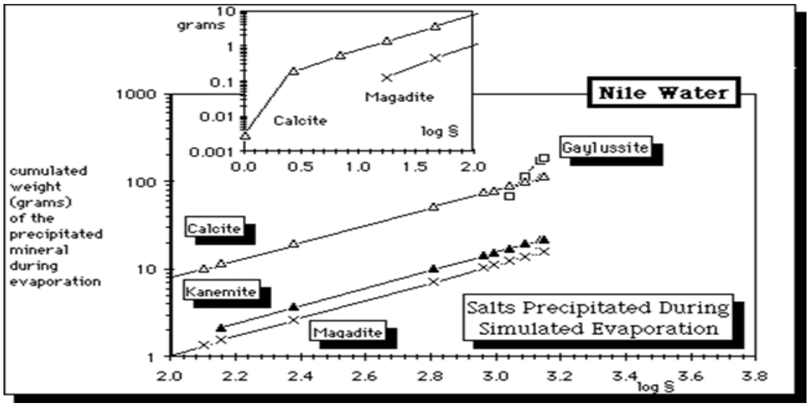

Fig. 8. Simulated evaporation (obtained computer calculations for Cairo ile water)

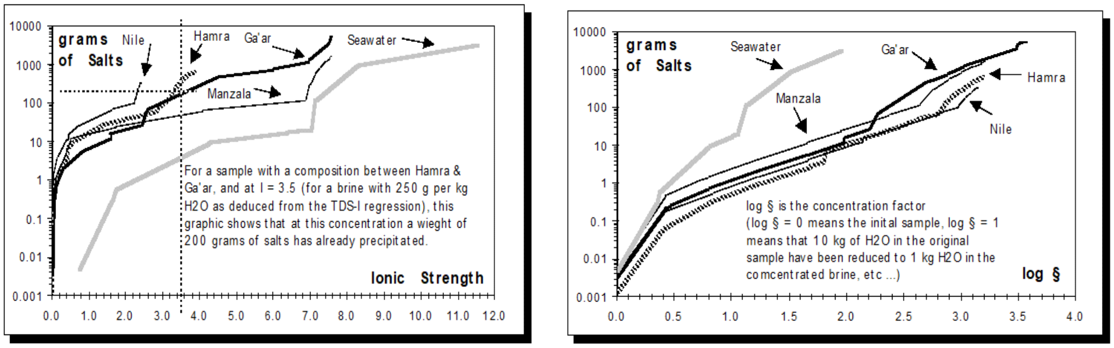

Fig.9. Simulated evaporation (obtained computer calculations for Cairo Nile water, Hamra and Ga'ar Springs of Wadi Natron, Manzala Lake and Sea water).

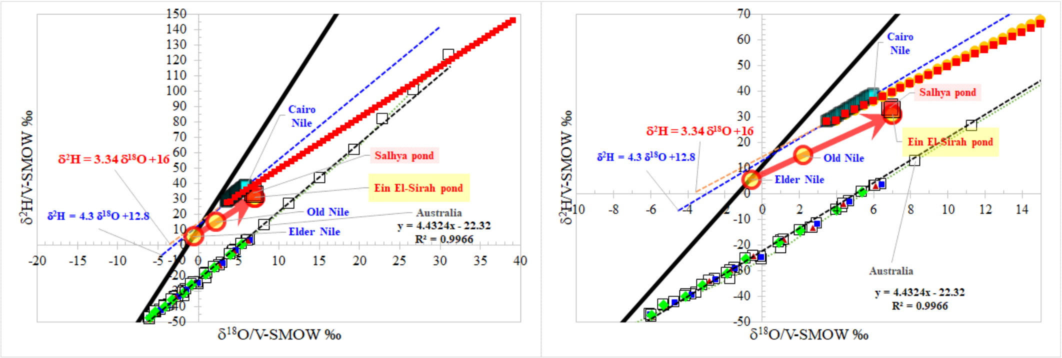

Fig. 10. Measured and theoretical changes in Nile water isotopic composition, d^{18}O and d^{2}H per mil, under steady-state evaporation, at Cairo.

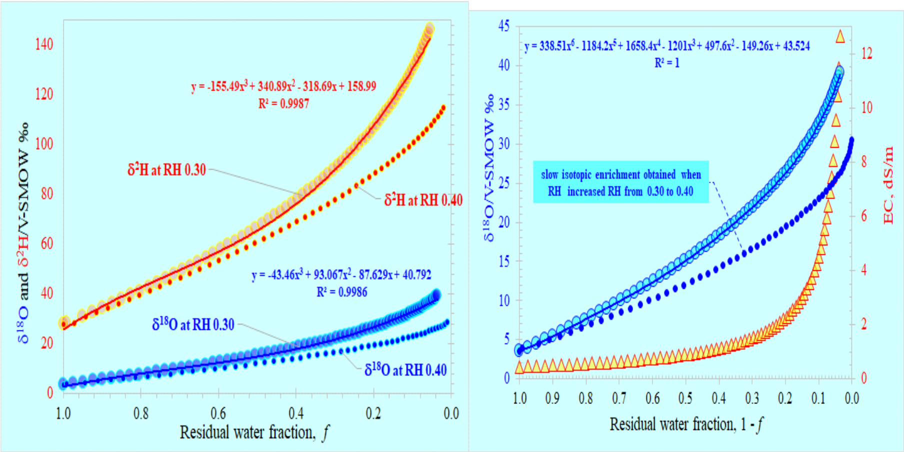

Fig. 11. Theoretical change in the isotopic composition, d^{18}O per mil, and EC, dS/m, in unsteady-state evaporation.

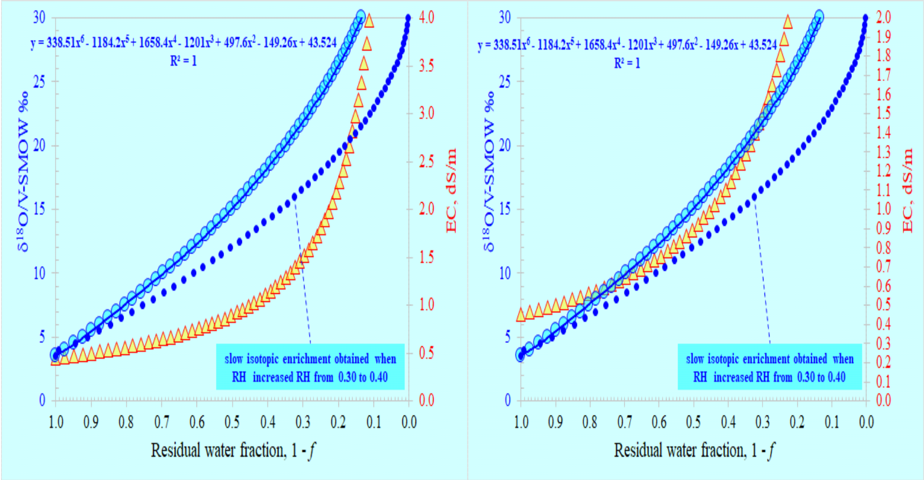

Fig.12. Theoretical change in the isotopic composition, d^{18}O per mil, and EC, dS/m, in unsteady-state evaporation.

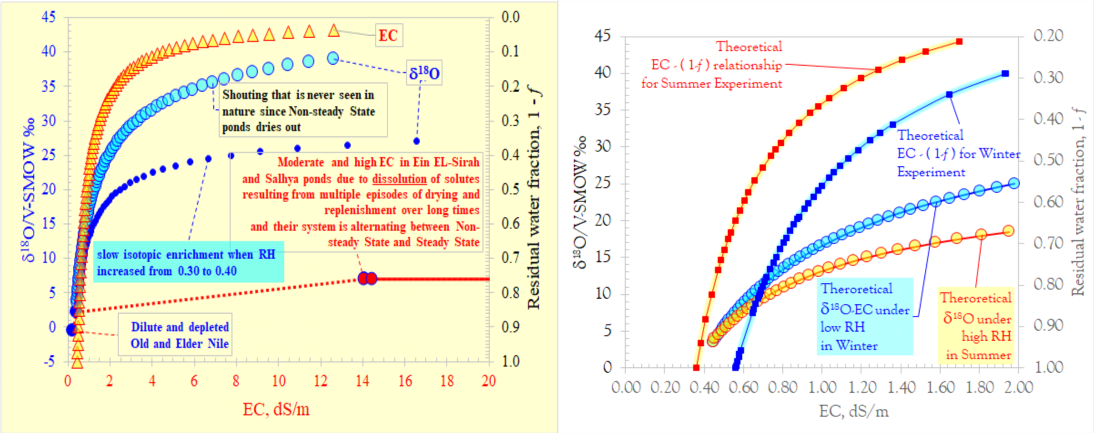

Fig.13. Theoretical relationship of the isotopic signature, d^{18}O per mil, water by losses, and salinity build-up, EC, dS/m, in the two experiments of the unsteady state evaporation run in Zankalon, in Winter and Summer, 2020.

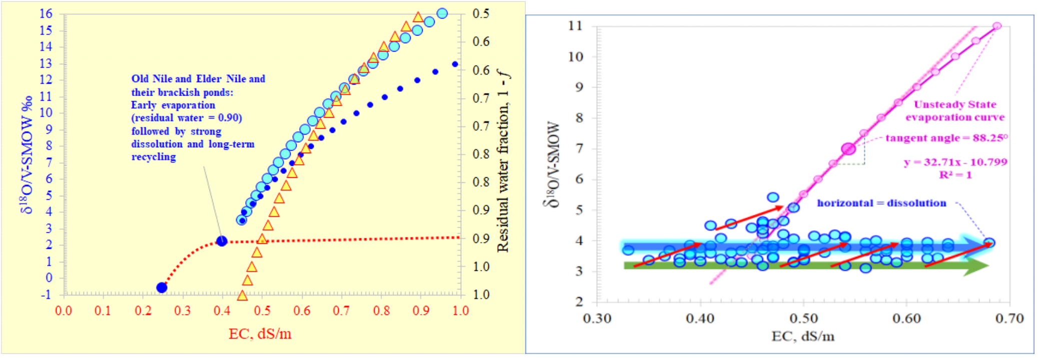

Fig. 14. Quantitative illustrations for the two major mechanisms of salinity build-up in the river water.

CONCLUSION

Ec change is not conservative both in summer and winter mainly due to calcite precipitation. Accordingly, we shall refer to cl- ion concentration changes. The increase in ph is due to the aqueous co2 gas loss from water. Such a gas loss leads to changes in the dissolved carbonate-species and the ionic activities. Water loss is higher in summer than winter due to higher temperature. The total precipitated calcite mass in winter is higher than in summer due to kinetic barrier acting as the limiting factor and dominating the thermodynamic reactions. The sahara vapor contribution is systematically slightly higher in summertime than in winter. Significant isotopic enrichment takes place when the atmospheric humidity (specific humidity, s, and rh) is low. In contrast, such enrichment is little when humidity is high. The residual water fraction in summer and winter shows a is convex curvilinear behavior because of the acting complex processes. The origin of salinity build source in nile river can be attributed to the three processes, a, b and c, as shown below, dissolution (where salinity increases with no isotope content change),b. Evaporation (where both the salinity and the isotopic content are increasing),c. Combined impacts of dissolution and evaporation. The basic concept to follow is the water balance. The isotopic depletion starts by late spring whereas net isotopic enrichment takes place in winter. The nile water evaporation is a steady-state process, so the ec values show ups and downs in relation to the inflow and weather conditions. In contrast, evaporation in class-a pan experiment is unsteady process, accordingly, salinity is ever increasing in the residual water. This loss to follow by the isotopic data and the change in the concentration of a conservative ion (e.g., cl- ion).

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