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# Impacts of Dams on the Chemical and Isotopic Properties in Damietta Branch of Nile River

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## Abstract:

Impacts of constructed dams on Damietta branch of river Nile were investigated for their effect on the chemical and isotopic composition of the Nile water in Damietta branch. Environmental isotopes, namely $^{2}H$ and $^{18}O$ were employed along with major chemical ions to study the Damietta branch water characteristics. The three dams Delta, Zefta, and Faraskour, which are constructed on the branch segregate it into two main parts; fresh and marine character. Chemical and isotopic results show that Delta and Zefta dams affect evaporation, recharging and salination processes while Faraskour dam is totally isolate the last sector of the branch and make it with marine character. Isotopic techniques prove that the salination of the last sector was due to the intrusion of Mediterranean seawater rather than the up-effluent from saline groundwater.

## 1. Introduction

Dams is known to modify aquatic ecology and river hydrology upstream and downstream, affecting water quality, quantity and breeding grounds [1]. Dams affect the water quality and physical changes, where downstream of the dam may change to pools during the dry seasons due to decreased water discharges and elevated temperature in daytime [2].Moreover, dams have a severe effects on fish, impoundment [2], basin erosion [3,4], material fluxes [5] and nutrient characteristics [6,7]. Although much of studies investigated the impact of dams on the rivers, there is almost no publications had studied the effect of dams on the chemical and isotopic characteristics of the rivers.

In Egypt, the River Nile is the main source of drinking water. It enters the delta's depression about 20 km to the north of Cairo city, where it divides into two branches (Rosetta and Damietta), each of which meanders separately through the delta to the sea. Damietta branch begins at the Delta dam and ends 220 km downstream at Faraskour dam near Damietta city [8]. Damietta branch is the main source of irrigation for most of lands located around it. Moreover, it feeds several canals such as El-Tawfiqi and El Abaasy Rayahs, and it receives the returned drainage water from several drains [8].

This study aims to investigate the effects of the constructed dams on Damietta branch chemical and isotopic characteristics.

## 2. Physical Sitting

The Nile River travels along Egypt for about 940 km behind the High Dam. After passing Cairo, it divides at the Delta dam into two branches, each of which runs separately to the Mediterranean Sea, forming the Delta region between both branches. The western branch is Rossetta branch (239 km in length) and the eastern branch is Demietta Branch, about 242 km in length [9]. Damietta branch is located in the area between 30º 10`12``N and 31º 31`48``N and between 31º 07`E and 31º 50`E. The Egyptian government divides it administratively into six sectors; Qanater, Benha, Zefta, El Mansoura, Sherbien and Faraskour as shown in **Figure 1**.

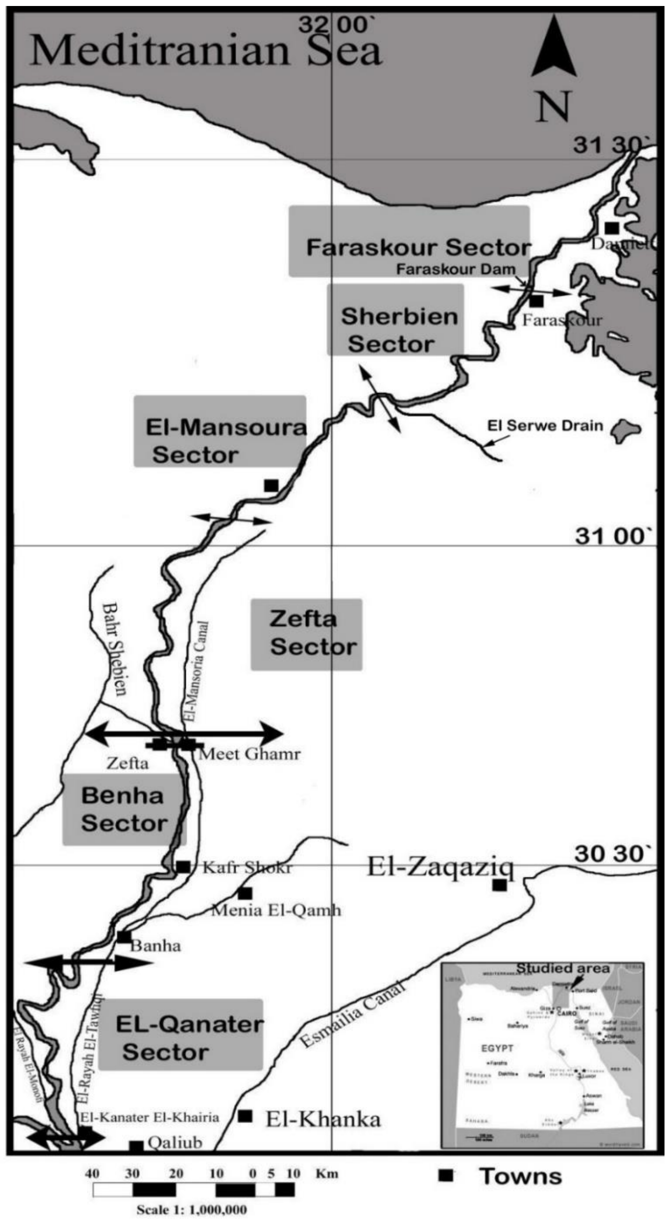



**Figure 1: Physical sitting of the study area.**

Climatologically, Damietta branch is located in the arid zone belt of northeast Africa and southwest Asia, which characterized with warm winter, hot summer, low rainfall and high evaporation rates [10]. The mean monthly temperatures range from 12° C in winter to 27° C in summer. The average annual rainfall is between 25 mm at the southern part and 150 mm at the northern part of the branch. The mean daily water evaporation is about 2 mm in December and 9 mm in July [11].
It is widthwise to indicate that Delta, Zefta and Faraskour dams had been constructed on Damietta branch to control the water flow. The features of these dams are described in **Table 1**.

**Table 1: The Main dams on Damietta Branch (8).**

| Serial | Name | Date of Construction | Gates | | |
|---|---|---|---|---|---|
| | | | Number | Width | Water Level |
| 1 | Delta Dam | 1939 | 34 | 8 m | 11 m |
| 2 | Zefta Dam | 1901-1903 | 50 | 5 m | 3.5 m |
| 3 | Faraskour Dam | 1985-1988 | 5 | 5.25 | |

## 3. Materials and Methods

### 3.1 Water sampling

During the period May 2006 to March 2008, 146 samples of fresh Nile water were collected from Damietta branch. Theses samples were collected from middle and both sides of the branch at a depth of 1.5 m. After collection, samples were filtered through Whatman No. 42 filter paper and stored in 1 L polyethylene bottles for chemical analysis. For isotopic analysis samples were preserved in 50 mL completely filled airtight polyethylene bottles to avoid evaporation and moisture exchange.

### 3.2 Reagents and standards

All chemicals were obtained from BDH company (England). The analytical grade (ANALAR) was used for preparation the standards and reagents.

### 3.3 Chemical Analysis

Chemical analysis of the water samples was carried out according to "Standard Methods for Examination of Water and Wastewater"[12]. The hydrogen ion concentration (pH) and the electrical conductivity (EC) of water samples were measured in the field, while total dissolved salts (TDS) in mg/L was calculated based on the empirical relationship with conductivity (TDS (mg/L) = EC (µS/cm) * 0.65 [12]. Sodium ($Na^+$) and potassium ($K^+$) ions were measured using a flame photometer. Calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$) cations were determined titrimetrically using the comlexometric method against ($Na_2EDTA$) where calcium was determined by using (Muroxide) indicator in presence of sodium hydroxide, while magnesium was estimated by subtracting the calcium value from the ($Ca^{2+}$ + $Mg^{2+}$) value after their determination using (Eriochrome black T) in presence of suitable buffer solution (ammonium chloride and ammonium hydroxide). Bicarbonates anion ($HCO_3^-$) was determined titrimetrically by neutralization method against sulfuric acid using (Bromocresol Green) as an indicator. Chloride anion ($Cl^-$) was determined volumetrically by titration against silver nitrate by using (potassium chromate) as an

indicator. On the other hand, sulfate anion ($SO_4^{2-}$) was determined by the turbidity method using UV/visible Spectrophotometer (*Model: LABOMED-INC*), at wavelength 420 nm using suitable acid solution (HCl, Glycerol, and Ethanol) and barium chloride.
The stable isotopes, deuterium D ($^{2}H$) and Oxygen-18 ($^{18}O$) were measured using Mass-spectrometer (Finnigan Mass Delta S) after the treatment procedures for the production of a suitable gas from water samples using the equilibrium method [13,14,15]. This method depends on an equilibrium between two phases, liquid phase (2 ml water sample) and gaseous phases ($CO_2$ or $H_2$ of a certified gas cylinder). The sample rack is mounted on a sled in a way that the sample bottles are immersed in a water bath and shaken in a continuous way. The movement of the bottles ensures temperature homogeneity of the water path. The temperature of the path (18°C) is maintained constant. An aliquot of the equilibrated $CO_2$ or $H_2$ gas is then transported to the mass spectrum for $^{18}O/^{16}O$ or D/H measurements. The stable isotope results are then expressed as permil (‰) deviation from reference standard, Vienna Standard Mean Ocean Water **(VSMOW)**.

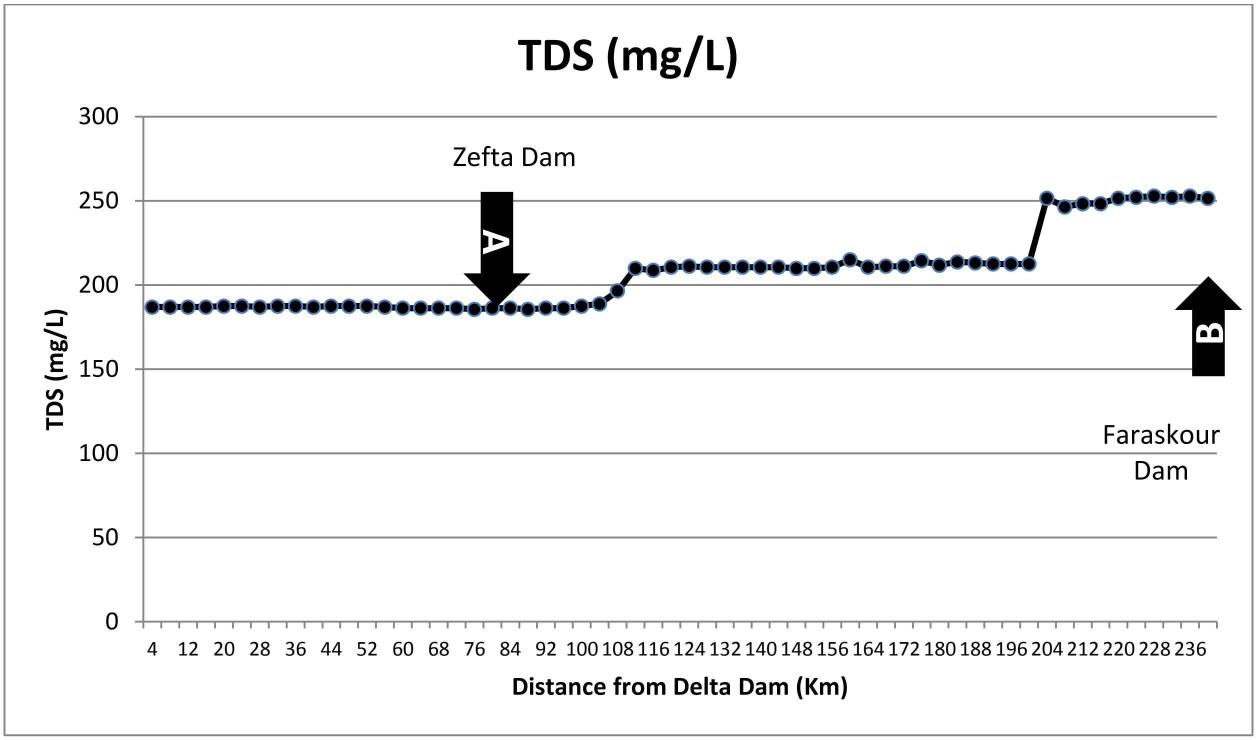
$$\delta‰ = \left[\frac{R_{Sample} - R_{Reference}}{R_{Reference}}\right] \times 1000$$

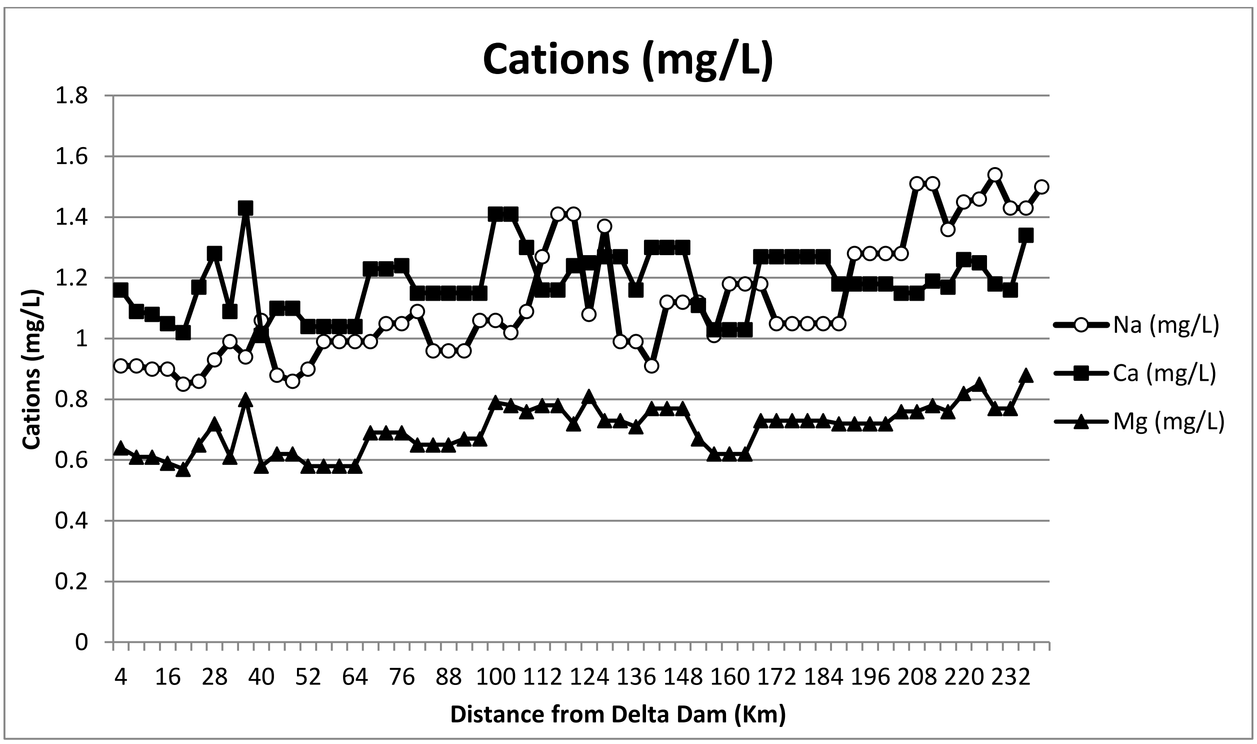
; where, R= $^{18}O/^{16}O$, D/H and the uncertainties is ±1.0 ‰ for Deuteriom and ±0.1 ‰ for $^{18}O$).

## 4. Results and Discussion

### 4.1. Hydochemical Investigations of Damietta Branch:

The results of the chemical analysis of the studied samples indicate that Damietta branch is divided into two regions; the fresh water region which represents Qanater, Benha, Zefta, El-Mansoura and Sherbien sectors, and the mostly marine region which represents Faraskour sector. The total salinity and the concentration of the major ions in the fresh Nile water region exhibit moderate increases in the direction of flow from south to north until Faraskour sector due to the effect of evaporation, **Figure 2**. It is obvious that there are two increases in the salinity in the area between Zefta Dam and Faraskour, which can be interpreted due to anthropogenic effects due to disposing of wastewater from domestic and industrial units around the branch. On the other hand, there is an extreme increase in the TDS values at Faraskour sector (31200 mg/L), **Table 2**. This could be attributed to the seawater intrusion, a phenomenon that appeared after the construction of Faraskour dam. Overall, we can say that Faraskour dam acts as artificial barrier which prevents natural equilibrium between Damietta branch and the Mediterranean Sea.


TDS (mg/L)
Zefta Dam
A
B
Faraskour Dam
TDS (mg/L)
Distance from Delta Dam (Km)


Cations (mg/L)
Na (mg/L)
Ca (mg/L)
Mg (mg/L)
Cations (mg/L)
Distance from Delta Dam (Km)

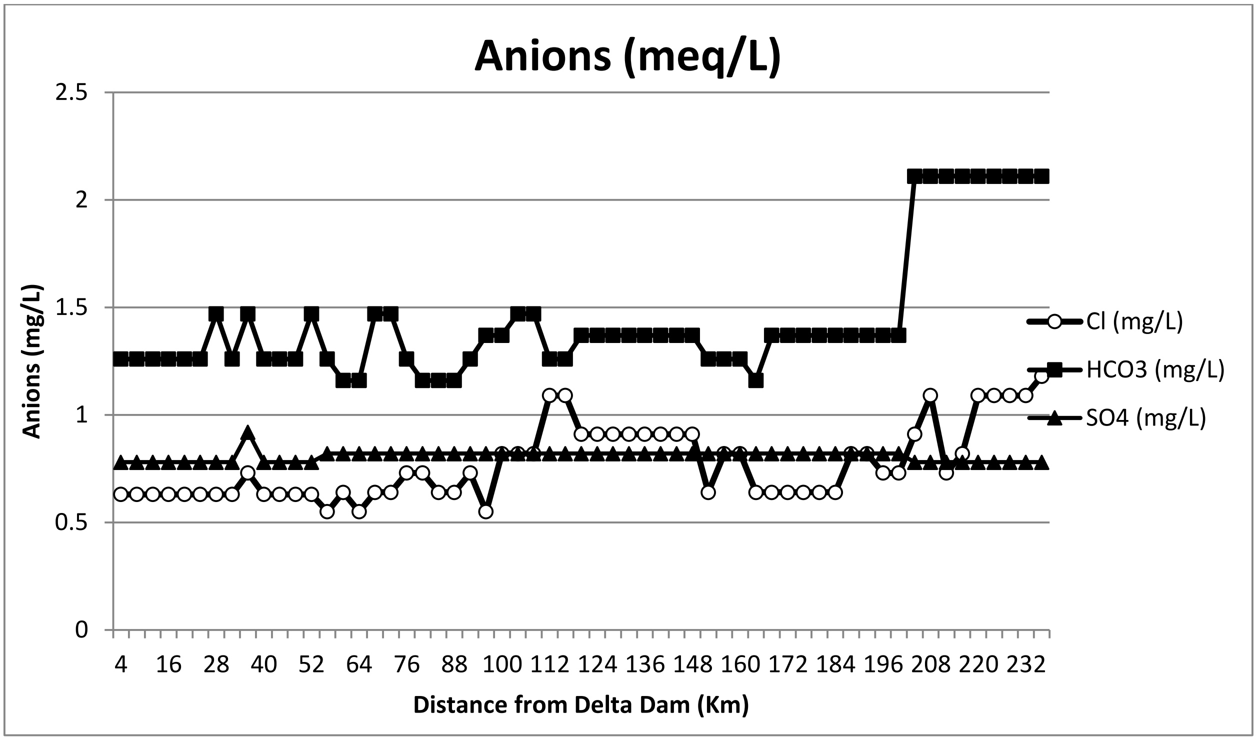



**Figure 2: variations of TDS, cations and ions in Damietta branch.**

**Table 2: Mean TDS and Hydrochemical ions for different sectors of Damietta branch**.

| | Ec | TDS (mg/L) | pH | $Na^+$ (meq/l) | $K^+$ (meq/l) | $Ca^{++}$ (meq/l) | $Mg^{++}$ (meq/l) | $HCO_3^-$ (meq/l) | $Cl^-$ (meq/l) | $SO_4^{2-}$ (meq/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Qanater** | 292.11 | 186.95 | 8.10 | 0.89 | 0.10 | 1.10 | 0.61 | 1.26 | 0.63 | 0.78 |
| **Benha** | 291.84 | 186.78 | 8.30 | 0.98 | 0.11 | 1.14 | 0.64 | 1.29 | 0.63 | 0.81 |
| **Zefta** | 309.79 | 198.27 | 8.02 | 1.14 | 0.14 | 1.24 | 0.73 | 1.35 | 0.78 | 0.82 |
| **El Mansoura** | 330.83 | 211.73 | 8.19 | 1.11 | 0.13 | 1.21 | 0.71 | 1.34 | 0.78 | 0.82 |
| **Sherbien** | 393.17 | 251.63 | 8.36 | 1.46 | 0.15 | 1.20 | 0.79 | 2.08 | 1.02 | 0.78 |
| **Faraskour** | 4655.71 | 33051.43 | 7.71 | 379.81 | 8.61 | 11.18 | 56.14 | 2.35 | 514.44 | 56.090 |

The categorization of water samples on Grid diagram, **Figure 3** indicates that all the water samples before Faraskour dam lie in the freshwater zone of the grid classification, which characterized by the domination of $HCO_3^-$ anion followed by $SO_4^{2-}$ and $Cl^-$ or followed by $Cl^-$ and $SO_4^{2-}$. The cationic order of the fresh water samples is dominated by $Ca^{2+}>Na^+> Mg^{2+}$ for all Qanater and Benha samples and bout 79% and 84% for Zefta and El Mansoura respectively. Moreover, $Na^+$ becomes dominant to $Ca^{2+}$ and $Mg^{2+}$ for all Sherbien samples, and the rest of Zefta and El Mansoura samples due to the effect of cation exchange processes through the clay layer of

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the branch bed [16,17]. On the contrary, downstream Faraskour dam, samples lie in the marine zone of the grid classification where $Cl^{-} > SO_4^{2-} > HCO_3^{-}$ and $Na^{+} > Mg^{2+} > Ca^{2+}$.

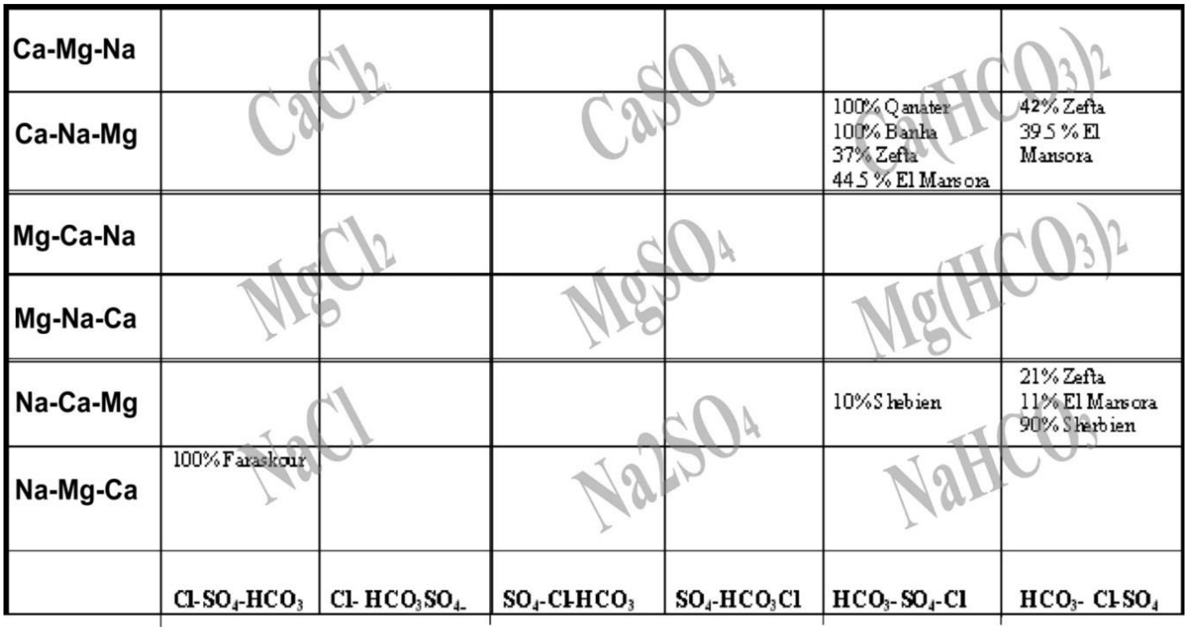


**Figure 3: Grid classification for each section in Damietta branch**

The hypothetical salt combinations [18] of the studied water samples are grouped into three assemblages as indicated in **Table 3**. Samples of Qanater, Benha, Zefta, El Mansoura and most of Sherbien have the same fresh water salt combinations "NaCl, $Na_2SO_4$, $MgSO_4$, $Mg(HCO_3)_2$, $Ca(HCO_3)_2$", whereas the rest of Sherbien samples have the chemical composition "NaCl, $Na_2SO_4$, $NaHCO_3$, $Mg(HCO_3)_2$, $Ca(HCO_3)_2$". On the other hand, all samples of Faraskour sector have the marine nature "NaCl, $MgCl_2$, MgSO4, $CaSO_4$, $Ca(HCO_3)_2$". The regime of the deduced salt combinations indicates homogeneity and complete mixing along upstream and midstream of the branch except some locations in Sherbien sector, which show the presence of $NaHCO_3$ salts due to groundwater discharge as well as anthropogenic activities.

**Table 3: The salt combinations in the studied area.**

| Hypothetical Salt combinations | Qanater | Benha | Zefta | Mansoura | Sherbien | Faraskour |
|---|---|---|---|---|---|---|
| **$NaCl, Na_2SO_4, MgSO_4, Mg(HCO_3)_2, Ca(HCO_3)_2$** | 100% | 100% | 100% | 100% | 72% | 0% |
| **$NaCl, Na_2SO_4, NaHCO_3, Mg(HCO_3)_2, Ca(HCO_3)_2$** | 0% | 0% | 0% | 0% | 28% | 0% |
| **$NaCl, MgCl_2, MgSO_4, CaSO_4, Ca(HCO_3)_2$** | 0% | 0% | 0% | 0% | 0% | 100% |

Overall, Qanater and Zefta dams affect Damietta branch by the retarding normal flow of the stream leading to salinity increases as well as the river self-cleaning decreases. Contrariwise, Faraskour Dam prevents water flow to the Mediterranean sea, which gives the chance to the sea to enter the branch under the effect of tides motion and gravity.

### 4.2. Environmental Isotopic Investigation

In the fresh water region of Damietta branch (between Delta and Faraskour dams), the water samples exhibit a regular enrichment (increases) in the isotopic characteristics, where $^{18}O$ enriches from 2.94±0.1‰ to 3.2‰±0.1‰) and $^{2}H$ (D) enriches from 28.35±1.0‰ to 29.19±1.0‰, **Table and Figure 4**. While, $D_{excess}$ deplete (decrease) in the same area (from 4.79±0.2‰ to 2.61±0.2‰).

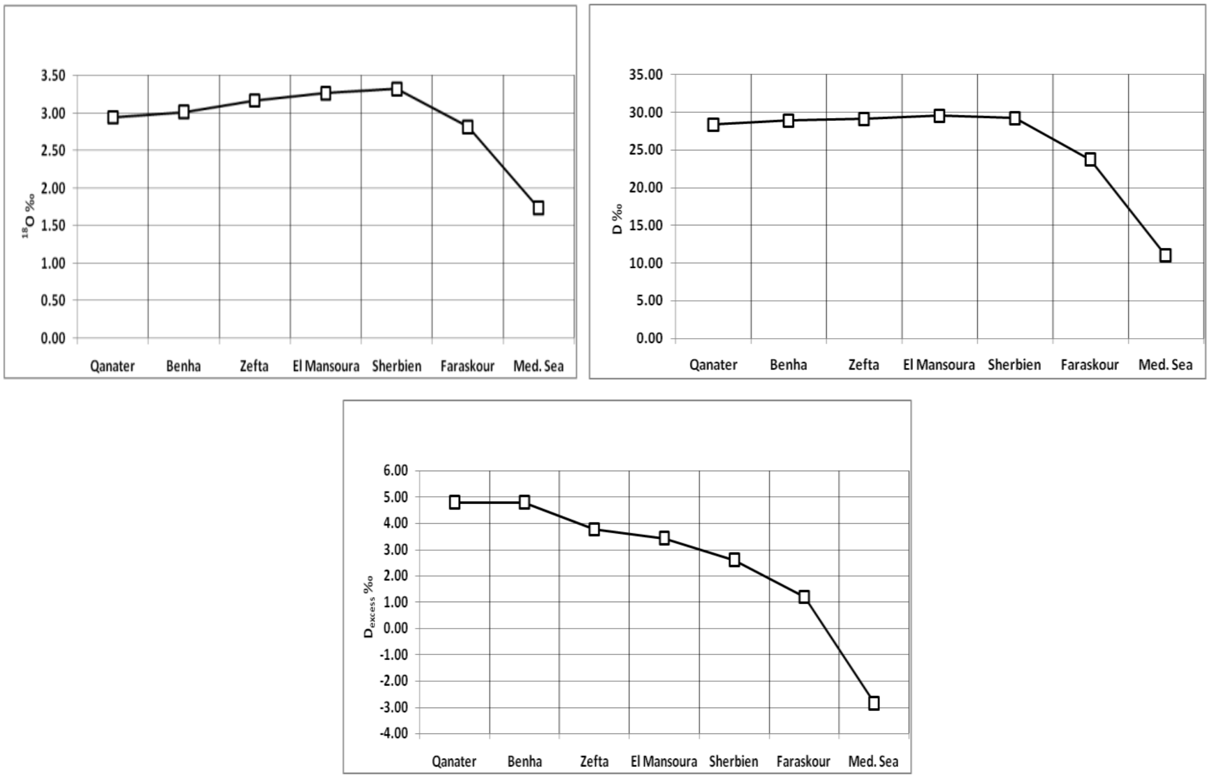


**Figure 4: Mean variations of $^{18}O$, D and $D_{excess}$ in Damietta branch.**

**Table 4: mean values of isotopic compositions in different sectors of Damietta branch**

| Sector | $^{18}O$ | D | $D_{excess}$ |
|---|---|---|---|
| Qanater | 2.94 | 28.35 | 4.79 |
| Benha | 3.01 | 28.91 | 4.8 |
| Zefta | 3.17 | 29.09 | 3.76 |
| El Mansoura | 3.26 | 29.55 | 3.44 |
| Sherbien | 3.32 | 29.19 | 2.61 |
| Faraskour | 2.82 | 23.73 | 1.2 |

On the other hand, in the marine region of Damietta branch (after Faraskour dam). The water samples show a depletion in the isotopic contents (23.73±1.0% and 2.82±0.2‰ for $^{2}H$ and $^{18}O$ respectively), while D excess continues depletion to 1.2±0.2‰.

Generally, the gradual enrich of $^{18}O$ and D values accompanied with a depletion of $D_{excess}$ between Qanater and Faraskour dams reflect the effect of evaporation. Meanwhile, the unexpected depletion of $^{18}O$ and D continuous decrease of excess while D excess continues depletion highlights that evaporation has been retarded by the effect of sea water intrusion from the Mediterranean sea.

This interpretation was confirmed using the D/$^{18}O$ relationship, **Figure 5**, where the distribution of sample points shows their scattering in a limited narrow section with a slope of (18.48). This slope is quite less than that of the Global Meteoric Water Line (GMWL=10) [8], which reflect the effect of evaporation.

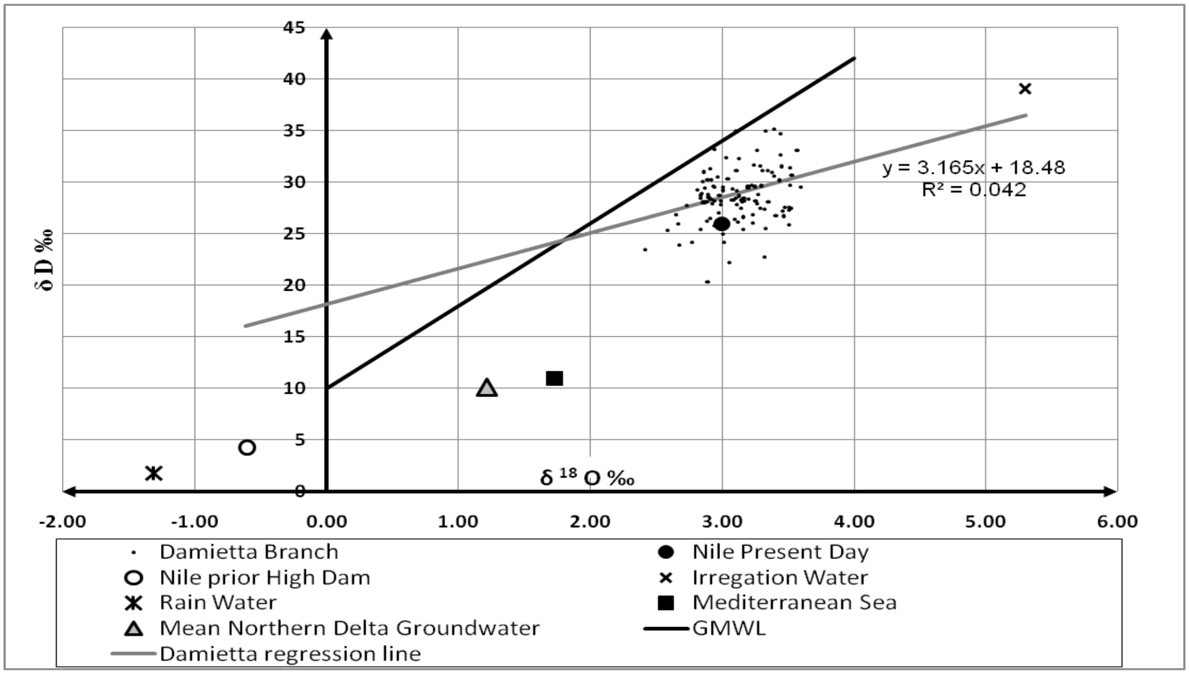


**Figure 5: δD‰ vs. δ$^{18}$O‰ relationship for Damietta branch.**

In order to study the combined effect of evaporation and anthropogenic on the branch a relationship between mean values of δ$^{18}$O‰ as isotopic variable and mean values of $Cl^-$ content as hydrochemical variable for each sector was established, **Figure 6**. The variation of salinity is clearly more than $^{18}O$ especially in Sherbien sector. This reflects the effect of anthropogenic activities and salinization processes.

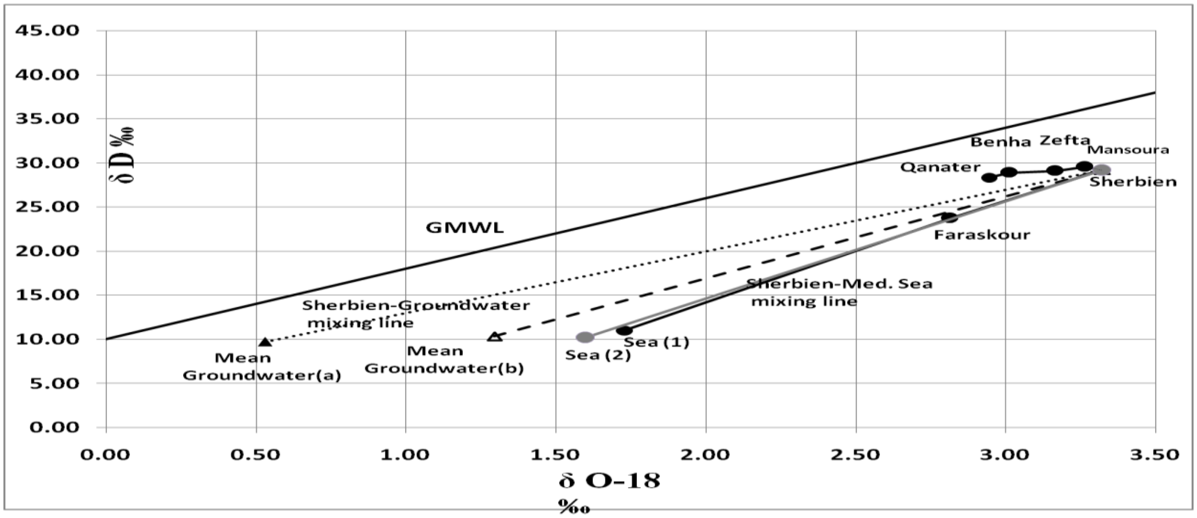


**Figure 6: Mean δD‰ vs. Mean δ[18]O‰ relationship for different sectors of Damietta branch water; Mean Groundwater (a) represents the mean groundwater in the northern sector in the present study; Mean groundwater (b) is obtained from a previous study (19); Sea(1) represents mean Mediterranean sea for the present study; Sea(2) represents Mediterranean sea from previous study (19).**

Isotopes was also used to study the salinity of the water at Faraskour in order to investigate the source of salinity whether it is from the up-effluents of the saline groundwater or from the intrusion of the seawater. Mean values of $^{8}$O and D for the groundwater in the northern part of a previous study [19] as well as Mediterranean Sea were used to compare the results. The mid-line that connects the points of Qanater, Benha, Zefta and Sherbien sectors exhibits slight, gradually increasing due to the effect of evaporation **Figure 7.** The trend of the line is inverted after Sherbien and directs toward the lower isotopic values at Faraskour. It is obvious that the point which represents Faraskour lies on the line which connects Sherbien and seawater points, and away from the line that connects Sherbien and groundwater points. This abolishes the previous studies states that saline groundwater effluents are the main source of salination in Faraskour sector.

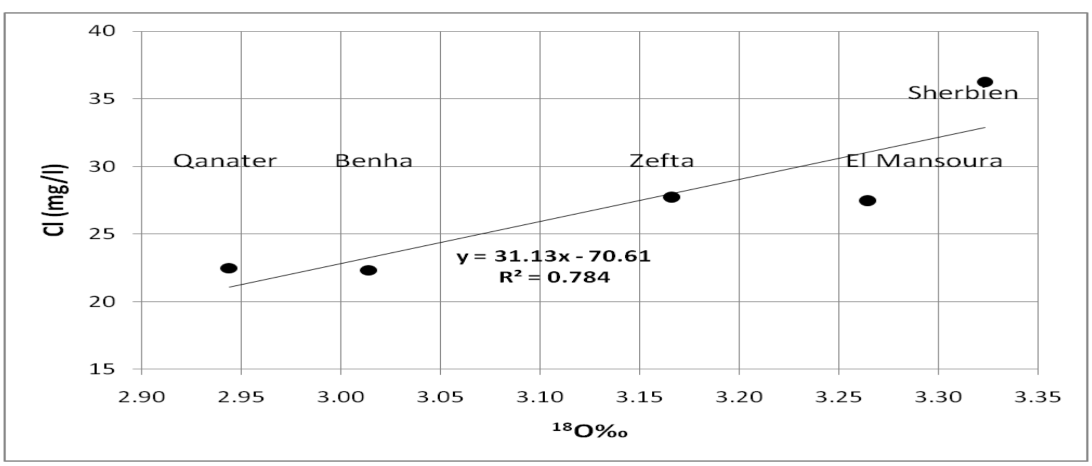


**Figure 7: Mean δ[18]O‰ vs. Mean Cl concentrationx (mg/L) for different sectors of Damietta branch water.**

The impact of dams on the evaporation rates and water losses from the Damietta branch were estimated using (through-flow) approach of Gibson and coworkers [20]. The concept of this approach states that the degree of natural evaporative isotopic enrichment in rivers is a sensitive indicator of rivers water balance parameters, specifically the partitioning of water losses by evaporation versus liquid outflow. So, it can be used to trace temporal changes in river balance, including inflow runoff from the catchment [21,22,23].

The through-flow indices (*E/I*), **Table 5** were calculated [20], and accordingly evaporated water has been estimated for different sectors of the Damietta branch supposing that the mean annual inflow released to Damietta branch is 9158.700 million $m^3$/year and the mean relative humidity is 0.75 [24].

**Table 5: Through-flow indices and evaporated water estimations in Damietta branch.**

| Sector | $\delta^{18}O$‰ | E/I | $M.m^3/year^{(1)}$ | $M.m^3/year^{(2)}$ |
|---|---|---|---|---|
| Qanater | 2.94 | 0.001 | 11.08 | 11.08 |
| Benha | 3.01 | 0.003 | 28.70 | 17.63 |
| Zefta | 3.17 | 0.007 | 67.68 | 38.97 |
| El Mansoura | 3.26 | 0.010 | 93.40 | 25.73 |
| Sherbien | 3.32 | 0.012 | 108.87 | 15.46 |

(1) Cumulative water lost by evaporation.

(2) Water lost by evaporation for each sector.

As shown, (*E/I*) increases from 0.1% at Qanater to 1.2% at Sherbien. The maximum volume of lost water by evaporation was at Zefta sector (38.97 Million $m^3$/year), which can be attributed due to Zefta barrage, while minimum volume lost was at Qanater sector (11.08 Million $m^3$/year) which represents the start point of the branch.

Overall, Delta, Zefta and Faraskour dams affect the nature, chemicals and isotopic compassions of water in the branch mainly due to the effect of evaporation before Faraskour dam, and due to the effect of seawater intrusion after Faraskour dam.

## 5. Conclusion

This study provides insights into the effects of constructed Dams on the chemical and isotopic compositions as well as salts evolutions of Damietta branch water. Both Delta and Zefta dams affect the natural flow of water in Damietta branch and increase the rates of evaporations and water losses, meanwhile they decreases the rates of branch self washing. On the other hand, Faraskour dam completely alters the chemical characteristics of water in this area and convert it to marine character. It acts as a barrier prevents the natural equilibrium and mixing between the Damietta branch and the Mediterranean Sea. This was confirmed using the isotopic techniques, which proved that seawater intrusion has the major role in the salination of the northern Damietta branch sector (Faraskour sector) more than ground water has. This abolishing the previous studies that states that groundwater is the major source of Faraskour sector marine character. The amounts of evaporated water due to the effects of the constructed dams on Damietta branch were calculated and estimated.

## 6. Acknowledgement

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