# Hydrochemical Evaluation of Belbies District Groundwater, South El Sharkia Governorate, Egypt

Abd-Alrahman A. Embaby[1*], Sofia Y. Afifi[2], Nagwa M. El Atabany[1]

[1] Geology Department, Faculty of Science, Damietta University, New Damietta, Egypt.
[2] Nuclear Materials Authority, Cairo, Egypt.
*E-mail: embaby@du.edu.eg

**Abstract**: Groundwater of the Quaternary aquifer in Belbies district, south El Sharkia Governorate, Egypt has a special significance, where it is the second source for freshwater used for domestic, agricultural and industrial purposes. It is the main source for drinking water stations. Thirty seven representative groundwater samples were collected to evaluate its suitability for different purposes. Chemical analyses were carried out to determine the geneses and type of water. Total dissolved salts of these groundwater samples range from 224 to 855 mg/l which means fresh water. Most of the Quaternary aquifer samples reflect water of marine affinity with the predominance of sodium and chloride and/or sulphate ions, which may be due to leakage from deep Miocene aquifer. The main types of groundwater are chloride-sodium, chloride-calcium and sulphate-sodium. From this study it was found that all the studied groundwater samples suitable for drinking according to the concentration of cations, anions, nitrate and trace elements, while they are unsuitable for drinking purposes according to the content of phosphate and lead. All the studied groundwater samples are suitable for irrigation purposes.

[Abd-Alrahman A. Embaby, Sofia Y. Afifi and Nagwa M. El Atabany. **Hydrochemical Evaluation of Belbies District Groundwater, South El Sharkia Governorate, Egypt.** *Life Sci J* 2014;11(12s):1074-1092]. (ISSN: 1097-8135).http://www.lifesciencesite.com. 228

**Keywords:**Quaternary; aquifere; Belbies district; east Nile Delta; hydrochemical; evaluation.

## I. Introduction

Groundwater in Egypt is the second most abundant water source, 2/3 of which is consumed within the Nile Delta and the Nile Valley (EEAA, 1992). In El Sharkia Governorate as in other parts of the Nile Delta, there used the groundwater from Quaternary aquifer as the main source for the drinking water stations as in Belbies district too.

Belbies district is located 20 km south of El Zagazig city between Long. 31° 24' and 31° 39' E and Lat. 30° 19' and 30° 29' N (Fig. 1). Belbies district, bounded at the north by El Zagazig, at the east by Abu Hammad, at the west by Minia El Kammh and in the south by the Tenth of Ramadan City districts. In the center of Belbies there is the Ismailia Canal and Belbies drain which is subsidiary of Bahr El Baqar drain system.

Belbies district, as a part of the east Nile Delta, constitutes a portion of an arid belt of north Egypt. It is characterized by a long dry summer and short temperate winter with a rainfall period from October to March. The climate is hot in summer; the average temperature is in the range of 19.7°C and 34.7°C, while during winter it ranges from 7.4°C and 18.4°C (Egyptian Meteorological Authority, 2003).

Belbies district and its environ represents a wide morphotectonic northward sloping plain which is disturbed in the southern part by a structurally controlled east west G. Umm Qamar and G. El Hamza ridge (about 220 m). This ridge separates between two wide morphotectonic basins, Heliopolis basin to the south and the southern fingers of the Nile Delta basin (El Shamy and Mohammed, 1999). It is occupied by several geologic formations belong to Quaternary age. Quaternary deposits consists of different types as; the Nile Delta flood plain deposits and El Khanka, G. El Asfar sand dunes. Hydrogeologically, the study area and it's environ is occupied by four hydrogeologic units belonging to Quaternary, Miocene, Oligocene and Eocene ages.

In Belbies district, the people use the Quaternary groundwater in domestic and irrigation purposes because the surface water resources are so little. The pumping of groundwater from the Quaternary aquifer and the subsequent use as irrigation water will cause changes in the groundwater quality in space and time. The previous studies show that in a 100-year period following the start of pumped groundwater for irrigation in the Nile Valley, the TDS values of the pumped groundwater increase from 530 to about 700 mg/l and the SAR increase from 4 to 6 (Lennaerts *et al*., 1988). The majority of the wells within the Delta and Valley, dug between the depths of 15-35 meters, may be seriously contaminated by seepage from nearly septic tanks and agricultural drains (Attia and Hefny, 1993).

Due to intensive agricultural practice, which involves the application of chemical fertilizers and pesticides, many soils and shallow aquifers are contaminated. Consequently, pollution of groundwater has become a major concern in recent years (Embaby and Dawoud, 2009). Wastewater disposed in canals can diffuse in groundwater. The main pollutants include nitrates and phosphates (Diab, 1982).

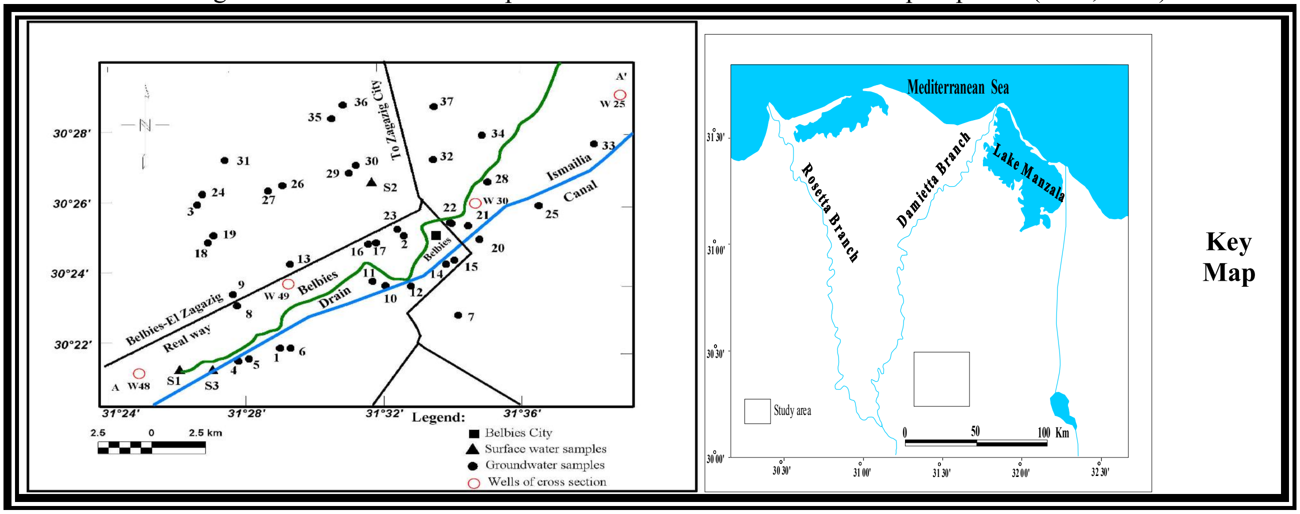

**Fig. (1): Location map of water samples, Belbies district, south El Sharkia Governorate, Egypt.**

The main aim of the present work is to evaluate the groundwater of the Quaternary aquifer in Belbies district, south El Sharkia Governorate, Egypt and its suitability to use in different purposes by carrying out the most interesting hydrogeochemical properties.

**II. Sampling and Analytical Techniques**

Three surface water and thirty seven groundwater samples were collected from different wells in the drinking water stations of Belbies district (60-90m depth), which are generally owned by El-Sharkia Potable Water Organization (Fig. 1 and Table 1). The temperature, electrical conductivity (EC), total dissolved solids (TDS) and pH values were determined in the field as soon as the water samples were collected. The chemical analyses carried out including the main cations $K^+$, $Na^+$, $Mg^{++}$ and $Ca^{++}$ and anions $Cl^-$, $SO_4^{--}$, $CO_3^{--}$ and $HCO_3^-$ with nitrate and phosphate. All chemical analyses were carried out in Nuclear Materials Authority Laboratories, Anshas, Egypt, using standard methods adopted by Hem (1989), Hach (1990) and recommended by American Public Health Association (1985) and others. After filtration and acidification with $HNO_3$, the trace elements constituents (Cu, Fe, Mn, Pb, and Zn) were determined using the Inductively Coupled Plasma Mass Spectrometry "ICP-MS' technique at Central Lab, Water and Soil Analyses Unit, Desert Research Center.

**III. Hydrogeological Setting**

The aquifer south of El Sharkia Governorate is a part from the main Quaternary aquifer system of the Nile Delta. It consists of thick layers of graded sand and gravel intercalated by clay lenses. The thickness of this aquifer increases towards the north and northwest directions. It directly rests on the Miocene hard limestone. The aquifer is covered by a layer of clay-silt deposits, which acts as a semi-pervious aquitard of thickness ranging from 5m to 9m. The groundwater occurs under semi-confined condition due to the presence of these clay-silt deposits. The transmissivity of the main Nile Delta aquifer system is considerably high; with an average of about 10,000 $m^2$/day (Attia, 1985). While, the average value of hydraulic conductivity in the eastern portion of Delta is about 100m/day and the transmissivity is about 15,000 $m^2$/day (Kotb, 1988).

The Nile Delta aquifer is properly renewable and the main recharge source of the Quaternary aquifer in Belbies district is the subsurface flow from the huge Nile Delta aquifer, as well as infiltration and deep percolation from the excess water application for agricultural lands, seepage from Ismailia Canal, the irrigation and drainage systems, seepage from the drinking water supply network and from the sewage trenches. On the other hand, discharge occurs as; groundwater withdrawals, groundwater return flow to the river and interception by the sewage system. The possible evaporation and evapotranspiration is also another effective cause of discharge (Farid, 1985).

The geochemical modeling (NETPATH) technique was utilized to deduce the geochemical evolution of Na-Cl and Na-$SO_4$ water types along flow path in the Quaternary aquifer system in Belbies area, east Nile Delta, Egypt. The results indicate that the ion exchange and dissolution are the main processes along flow path respect to Na-Cl water type. The cation exchange process proceeds by uptake of $Ca^{++}$ to release more $Na^+$ in groundwater. The Na-$SO_4$ flow path is characterized by the dissolution of dolomite to dedolomitization process, where $CaCO_3{}^0_{aq}$ decrease and $Ca^{++}$ increases with an increasing gypsum saturation index (Shehata and El-Sabrouty, 2014).

The Quaternary deposits are storage aquifer of groundwater in the east of the Nile Delta region. The lateral and vertical variations in the facies of the Quaternary sediments lead to their classification into a number of distinguishable units. Each of these units has its own characters such as porosity, hydraulic conductivity, ability for refining and yielding water and mode of water occurrence rather than water quality. The unconsolidated Quaternary deposits are mostly of fluviatile origin down to 300m (El Haddad, 2002).

Accordingly, a cross-sections was constructed to reveal the subsurface Quaternary aquifer system (Fig. 2), where it was classified based on the lithologic facies variation into three zones; the top Holocene clay cap, which is composed of clay, Nile silt and sandy clay. It acts as an aquitard for the aquifer. This Holocene cap layer is underlain by the Late Pleistocene aquifer, which consists of fluviatile and fluviomarine sand with intercalations of clayey sand. This layer overlay the Early Pleistocene aquifer, which consists of coarse quartizitic sands with cherty and flinty pebbles.

Piezometric levels of the Quaternary aquifer are topographically controlled and decrease from south to north near El Manzala Lake and Mediterranean Sea (Elewa *et al.,* 2013).

**IV. Chemical Characteristics of Groundwater**

The collected groundwater samples have pH values range between 8.3 and 9.1 (Table 1) which indicate alkaline nature. The total dissolved solids (TDS) range between 224 and 855 mg/l with an average of 434 mg/l. All the collected groundwater samples of the Quaternary aquifer are belonging to fresh water class where TDS less than 1500 mg/l.

**Table (1): Chemical analyses of the collected water samples from Belbies district, south El Sharkia Governorate, Egypt (January, 2011).**

| Sample No. | Locality | | EC | TDS | pH | Cations | | | | Anions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $K^+$ | $Na^+$ | $Mg^{++}$ | $Ca^{++}$ | $Cl^-$ | $SO_4^{--}$ | $CO_3^{--}$ | $HCO_3^-$ | $NO_3^-$ | $P^{-3}$ |
| S1 | Belbies drain | ace wat | 825 | 528 | 8.6 | 15.5 | 109 | 12.1 | 40.1 | 141.8 | 148.1 | 15.5 | 30.5 | 2.2 | 9.0 |
| S2 | El Gosaq drain | | 1358 | 869 | 8.6 | 32.2 | 154 | 24.3 | 80.2 | 212.7 | 316.6 | 15.5 | 30.5 | 14.5 | 11.3 |
| S3 | Ismailia Canal | | 355 | 227 | 8.0 | 5.55 | 47 | 12.16 | 20.8 | 53.17 | 79.68 | 15.5 | 30.5 | - | - |
| 1 | El Ahmadia hand pump | Groundwater Samples (Quaternary aquifer) | 378 | 242 | 8.5 | 7.8 | 17.7 | 12.2 | 40.1 | 88.6 | 55.6 | 15.5 | 30.5 | 23.1 | 6.67 |
| 2 | Mit Hammad hand pump | | 1138 | 728 | 8.3 | 7.8 | 81.2 | 24.3 | 120.2 | 195 | 250 | 15.5 | 30.5 | - | - |
| 3 | El Balashon hyand pump | | 816 | 522 | 8.7 | 4.2 | 145.8 | 12.2 | 20.8 | 177 | 112.3 | 15.5 | 30.5 | - | - |
| 4 | El Zawamel Station | | 350 | 224 | 9.1 | 6.7 | 32.5 | 12.2 | 20.8 | 70.9 | 27.4 | 15.5 | 30.5 | - | - |
| 5 | El Awqaf Station | | 450 | 288 | 8.8 | 7.8 | 33.8 | 12.2 | 40.1 | 88.6 | 55.6 | 15.5 | 30.5 | - | - |
| 6 | El Ahmadia Station | | 566 | 362 | 8.5 | 5.6 | 56.0 | 12.2 | 40.1 | 53.2 | 146.9 | 15.5 | 30.5 | - | - |
| 7 | 105 Fadan Station | | 875 | 560 | 8.3 | 6.7 | 143.3 | 12.2 | 40.1 | 277.2 | 27.8 | 15.5 | 30.5 | 6.52 | 8.75 |
| 8 | Salamnt Station | | 531 | 340 | 8.8 | 10.4 | 50.0 | 12.2 | 40.1 | 88.6 | 92.5 | 15.5 | 30.5 | 1.41 | 7.92 |
| 9 | Anshas El Raml Station | | 389 | 249 | 8.7 | 4.2 | 44.4 | 12.2 | 21.0 | 88.6 | 24.9 | 15.5 | 30.5 | - | - |
| 10 | El Salam Station | | 547 | 350 | 8.6 | 8.9 | 36.8 | 12.2 | 60.1 | 141.8 | 38.9 | 15.5 | 30.5 | - | - |
| 11 | Gheta Station | | 419 | 268 | 8.7 | 6.7 | 29.7 | 24.3 | 60.1 | 177.0 | 22.2 | 15.5 | 30.5 | - | - |
| 12 | El Adlyia Station | | 469 | 300 | 8.5 | 7.8 | 36.6 | 12.2 | 40.1 | 88.6 | 61.1 | 15.5 | 30.5 | 7.31 | 6.46 |
| 13 | El Saedyia Station | | 438 | 280 | 8.9 | 2.8 | 52 | 12.2 | 21.0 | 70.1 | 63.2 | 15.5 | 30.5 | 6.30 | 7.92 |
| 14 | El Bar El Gharby 1 | | 434 | 278 | 8.5 | 4.2 | 33.1 | 12.2 | 40.1 | 88.6 | 50.0 | 15.5 | 30.5 | - | - |
| 15 | El Bar El Gharby 3 | | 417 | 267 | 8.5 | 5.6 | 31.3 | 12.2 | 40.1 | 88.6 | 38.9 | 15.5 | 30.5 | - | - |
| 16 | Tall Rozen Station 1 | | 384 | 246 | 8.6 | 9.2 | 34.5 | 12.2 | 21.0 | 35.5 | 83.3 | 15.5 | 30.5 | - | - |
| 17 | Tall Rozen Station 2 | | 358 | 229 | 8.5 | 4.6 | 34.5 | 12.2 | 21.0 | 53.2 | 52.8 | 15.5 | 30.5 | - | - |
| 18 | Qremla before filtration | | 822 | 526 | 8.7 | 6.7 | 100.5 | 24.3 | 41.0 | 159.5 | 139.6 | 15.5 | 30.5 | 4.30 | 8.33 |
| 19 | Qremla after filtration | | 822 | 526 | 8.8 | 5.6 | 103.0 | 24.3 | 41.0 | 159.5 | 144.3 | 15.5 | 30.5 | - | - |
| 20 | El Bar El Sharky Station | | 472 | 302 | 8.6 | 5.6 | 44.4 | 12.2 | 40.1 | 124.1 | 26.9 | 15.5 | 30.5 | - | - |
| 21 | El Saha Station | | 563 | 360 | 8.5 | 13.3 | 40.0 | 24.3 | 41.0 | 159.5 | 27.8 | 15.5 | 30.5 | - | - |
| 22 | El Syana Station | | 1113 | 712 | 8.3 | 21.8 | 100.0 | 36.5 | 80.2 | 283.6 | 138.9 | 15.5 | 30.5 | 8.40 | 8.75 |
| 23 | Mit Hamal Station | | 1191 | 762 | 8.5 | 4.4 | 140.8 | 24.3 | 80.2 | 212.7 | 250.0 | 15.5 | 30.5 | 6.05 | 9.79 |
| 24 | El Balashon Station | | 694 | 444 | 8.8 | 4.2 | 74.1 | 24.3 | 41.0 | 177.3 | 58.5 | 15.5 | 30.5 | 6.00 | 9.37 |
| 25 | Gelfena Station | | 406 | 260 | 8.6 | 4.2 | 17.0 | 12.2 | 40.1 | 88.6 | 16.7 | 15.5 | 30.5 | 7.10 | 5.21 |
| 26 | New Shobra El Nakhla | | 758 | 485 | 8.6 | 6.7 | 99.1 | 12.2 | 40.1 | 124.1 | 142.5 | 15.5 | 30.5 | 9.82 | 9.58 |
| 27 | Old Shobra El Nakhla | | 694 | 444 | 8.7 | 5.6 | 81.0 | 24.3 | 41.0 | 195.0 | 45.3 | 15.5 | 30.5 | - | - |
| 28 | Ibrahem El Aydy Station | | 425 | 272 | 8.6 | 5.6 | 50.0 | 12.2 | 21.0 | 53.2 | 79.7 | 15.5 | 30.5 | - | - |
| 29 | Mit Habbib before Filteration | | 1336 | 855 | 8.4 | 8.9 | 98.7 | 24.3 | 140.3 | 195.0 | 333.3 | 15.5 | 30.5 | 10.8 | 8.12 |
| 30 | Mit Habbib after Filteration | | 1205 | 771 | 8.7 | 8.9 | 121.7 | 24.3 | 100.2 | 248.2 | 216.7 | 15.5 | 30.5 | - | - |
| 31 | Mit Gaber Station | | 469 | 300 | 8.8 | 4.2 | 63.7 | 12.2 | 21.0 | 124.1 | 17.0 | 15.5 | 30.5 | 18.6 | 8.75 |
| 32 | Mit Rabiaa Station | | 980 | 627 | 8.3 | 10.0 | 86.7 | 24.3 | 80.2 | 160.0 | 216.0 | 15.5 | 30.5 | 5.15 | 8.50 |
| 33 | El Khraksha Station | | 459 | 294 | 8.8 | 9.2 | 58.0 | 12.2 | 21.0 | 88.6 | 52.8 | 15.5 | 30.5 | 1.00 | 8.33 |
| 34 | Awlad Sayf Station | | 534 | 342 | 8.6 | 7.8 | 56.0 | 12.2 | 40.1 | 124.1 | 52.8 | 15.5 | 30.5 | 25.0 | 8.33 |
| 35 | Sandanhour Station | | 919 | 588 | 8.7 | 4.2 | 140.0 | 12.2 | 40.1 | 195.0 | 126.4 | 15.5 | 30.5 | - | - |
| 36 | El Manshiya Station | | 1019 | 652 | 8.3 | 7.8 | 76.7 | 24.3 | 100.2 | 177.3 | 216.7 | 15.5 | 30.5 | 2.53 | 7.21 |
| 37 | El Nuba Station | | 1111 | 711 | 8.3 | 6.7 | 100.0 | 24.3 | 100.2 | 212.7 | 216.7 | 15.5 | 30.5 | 10.5 | 7.92 |

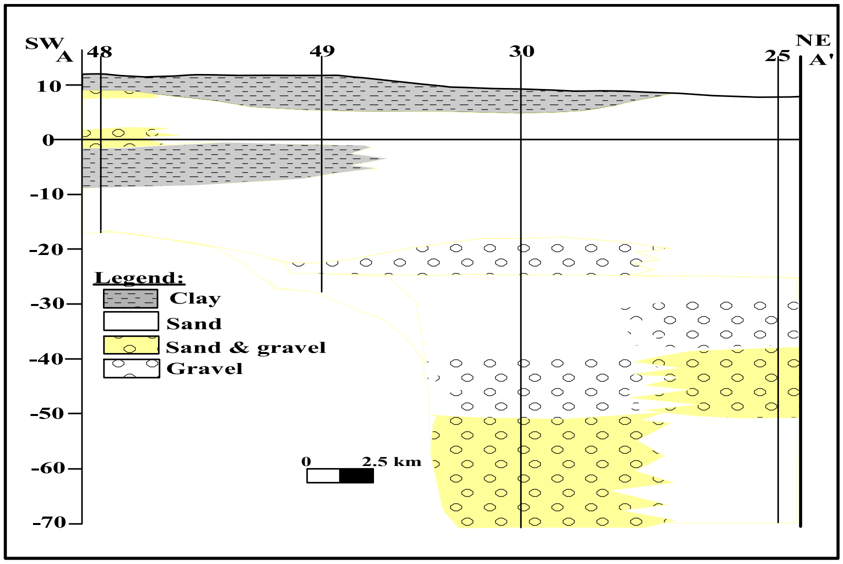


**Fig. (2): Geological cross section along the direction A-A' (wells data after Research Institute for Groundwater "RIGW", 1980).**

Potassium mainly represents the least dominant cation; range between 3 to 22 mg/l with an average of about 7 mg/l, meanwhile sodium represents the dominant cation in the majority of the analyzed groundwater samples. It varies between 17 and 146 mg/l with an average 69 mg/l. Sodium has different roles in the human body where its play an important role in the function of the nervous system, membrane system, and excretory system (Ketata *et al.,* 2011). Magnesium ranges between about 12 and 36 mg/l with an average of about 17 mg/l. Calcium ranges between about 20 and 140 mg/l with an average of about 84mg/l.

Chloride ranges between 35 and 283.6mg/l with an average of about 139mg/l in the analyzed groundwater samples. Sulphate content ranges between 17 and 333 mg/l with an average of about 99.6 mg/l. The high values of sulphate may be due to dissolution of sulphate-bearing sediments and input from sulphate fertilizers applied in the cultivated lands. Carbonate within range 15.5 mg/l, bicarbonate in range of 30.5 mg/l (Table 2).

Nitrate is the most frequently introduced pollutant of groundwater system (Spaliding and Exner, 1993; Babiker *et al*., 2004). Groundwater contamination by nitrate is a globally growing problem due to population growth and increase of demand for food supplies. It usually originates from several sources such as intensive use of nitrogen fertilizers (N- fertilizers), animal excreta sewage effluents, septic tanks, municipal or industrial waste water, decaying plants, as well as atmospheric deposition (McLay *et al*., 2001 and Fields, 2004). Nitrate in the studied groundwater samples ranges between 1 to 25 mg/l with an average of about 12 mg/l. Phosphate ranges between 5.2 to 9.8 mg/l with an average of about 7.5 mg/l (Table 2).

**Table (2): Concentration ranges for cations and anions in the groundwater samples of the Quaternary aquifer in Belbies district.**

| Characters | | Minimum | Maximum | Average |
|---|---|---|---|---|
| The pH values | | 8.3 | 9.1 | 8.6 |
| E.C. ( µmohs/cm at 25°C ) | | 350 | 1336 | 674 |
| TDS | mg/l | 224 | 855 | 434 |
| $K^+$ | mg/l | 2.8 | 22.0 | 7.06 |
| $Na^+$ | mg/l | 17.0 | 145.8 | 68.7 |
| $Mg^{+2}$ | mg/l | 12.0 | 36.0 | 17.0 |
| $Ca^{+2}$ | mg/l | 20.0 | 140.0 | 84.2 |
| $Cl^-$ | mg/l | 35.0 | 283.6 | 138.7 |
| $SO_4^{-2}$ | mg/l | 16.6 | 333.0 | 99.6 |
| $CO_3^{--}$ | mg/l | 15.5 | 15.5 | 15.5 |
| $HCO_3^-$ | mg/l | 30.5 | 30.5 | 30.5 |
| $NO_3^-$ | mg/l | 1.00 | 25.00 | 12.05 |
| $P^{-3}$ | mg/l | 5.21 | 9.79 | 7.50 |

**V. Hydrochemical Characteristics**

The hydrochemical characteristics of groundwater samples of Belbies district can be expressed as the following:

**A) Ion ratios:**

1- The variation in $rNa^{+}/rCl^{-}$ ratio is used to differentiate between fresh and saline water, where the values are always higher than unity in meteoric water and less than unity in sea water or saline water. The $rNa^{+}/rCl^{-}$ ratio is generally less than unity in about 70 % of the samples, which refers to the combined action of dissolution and ion exchange (Tripathy and Sahu, 2005). The $rNa^{+}/rCl^{-}$ ratio is more than unity in 30% of the analyzed groundwater samples, which reflects the minor influence of fresh water recharge from Ismailia Canal water (Table 3).
2- The $rCa^{++}/rCl^{-}$ ratio of the groundwater of the Quaternary aquifer ranges from 0.22 to 1.33 with an average of 0.68. The $rCa^{++}/rCl^{-}$ ratio in all the analyzed groundwater samples less than the unity except in samples (2, 6, 16, 29 & 36).
3- The $rMg^{++}/rCl^{-}$ ratio ranges from 0.13 to 1.0 with an average of 0.40.
4- The calculated values of the parameter $rSO_4^{--}/rCl^{-}$ in 13.5 % of the groundwater samples nearly to the sea water value (0.103). This may reflect the effect of marine deposits or may be due to leakage from deep Miocene aquifer (Abd El Samie *et al*., 2002 and Embaby & El-Haddad, 2007). Meanwhile, 86.5% of samples more than the unity which indicates excess of sulphate. This may be due to the effect of evaporation and agricultural activities.
5- All the analyzed groundwater samples has $rCa^{++}/rMg^{++}$ more than the unity, which indicating the base exchange processes are active on the surface of clay minerals (Hem, 1970).
6- The $rCl^{-}/(rHCO_3^{-}+rCO_3^{--})$ ratio is one of the criteria to evaluate the presence of marine affinity. For the Mediterranean Sea, the $rCl^{-}/(rHCO_3^{-}+rCO_3^{--})$ value ranges from 200 to 500 (Custodio and Bruggeman, 1987). The $rCl^{-}/(rHCO_3^{-}+rCO_3^{--})$ ratio of the groundwater of the Quaternary aquifer ranges from 1 to 8 with an average of 3.81. According to Simpson (1946) classification, about 3% of the groundwater samples are located in slightly contaminated groundwater class, 38% are located in moderately contaminated ground-water class. While, 51% lie in the injuriously contaminated groundwater class and 8% highly contaminated groundwater class, which are in the central part of the study area behind Belbies city and in the southern part of Belbies district (Fig. 3).
7- The $(rCl^{-}-rNa^{+})/rCl^{-}$ ratio in the analyzed groundwater samples varies from -0.60 to 0.74, with an average of 0.24. This coefficient has low positive values in 78 % of the total samples and negative values in 22% of studied samples indicating active ion exchange.

**B) Water type:**

Water type is achieved with the help of sulin's graph (1948), Ovitchinikov's graph (1963) and trilinear water analysis diagram of Piper's (1944). The analyzed Quaternary groundwater samples comprise three main water types; $CaCl_2$, $MgCl_2$ reflecting the marine affinity and $Na_2SO_4$ water type which reflecting meteoric water affinity. About 19% of the analyzed groundwater samples are plotted in $CaCl_2$ triangle which indicates old marine water. While 51% of the samples located in $MgCl_2$ triangle which represents recent marine affinity. Meanwhile, 30% of the groundwater samples located in $Na_2SO_4$ field which represents deep meteoric water (continental) origin (Fig. 4).

According to trilinear diagram of Piper's 1944, the majority of groundwater samples (70%) are plotted in zones III, which represented by NaCl or $Na_2SO_4$ surface meteoric water salinity characters. While, 30% of the analyzed groundwater plots in the fourth diamond zones (IV), which is represented by $CaCl_2$, $MgCl_2$, $CaSO_4$ and $MgSO_4$, marine water type.

Ovitchinkov's graph (1963) is used for determining the origin of the studied groundwater samples (Fig. 6 & Table 4). The majority (61.3%) of groundwater samples lie in the triangles ( V, VI, VII & VIII), indicating marine water type, while 29.7% of the studied samples lie in the triangles (I, II, III & IV) indicating meteoric water origin.

From the previous representation of the collected groundwater samples, the Quaternary aquifer refers marine affinity, which may be due to leakage from the hydraulic connected Miocene aquifer (Abd El Samie *et al*., 2002 and Embaby & El-Haddad, 2007).

**VI. Evaluation of Groundwater Quality for Different Purposes**

Groundwater quality can be affected by both natural and anthropogenic activities. In aquifers unaffected by human activity, the quality of groundwater results from geochemical reactions between the water and rock matrix as the water moves along flow paths from areas of recharge to areas of discharge. In general, the longer groundwater remains in contact with soluble materials, the greater the concentrations of dissolved materials in the water. The quality of groundwater also can change as the result of the mixing of waters from different aquifers. In aquifers affected by human activity, the quality of water can be directly affected by the infiltration of anthropogenic compounds (USGS, 1998).

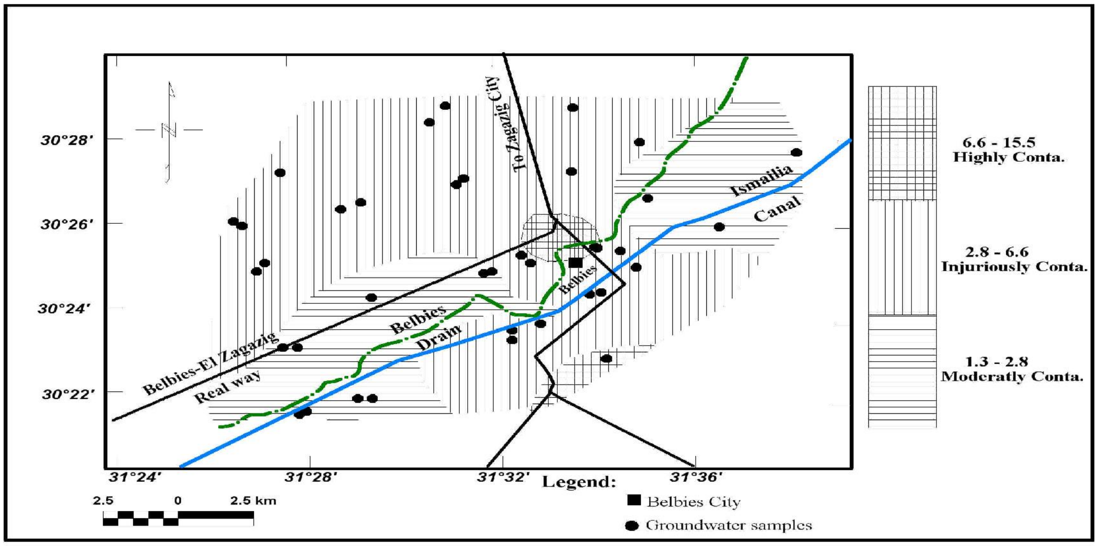


**Fig. (3): Zonation map of the (Cl/(HCO$_3$+CO$_3$) ratio of the Quaternary groundwater in Belbies district.**

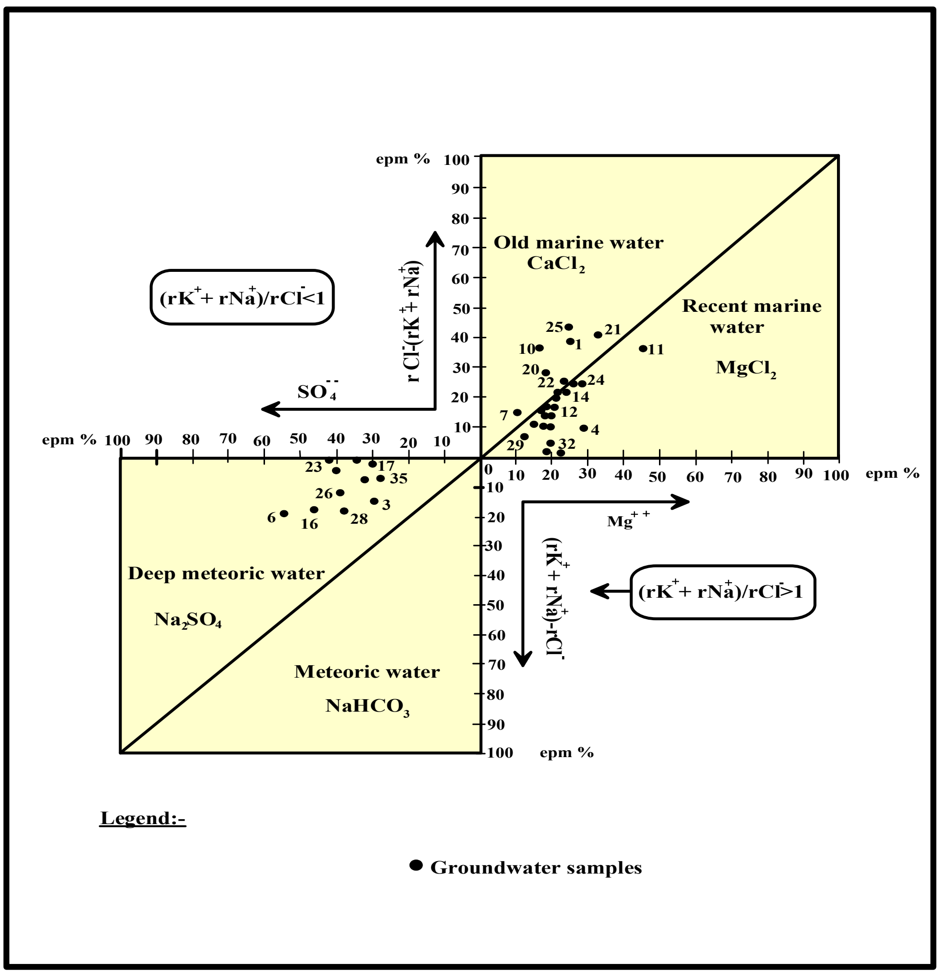


**Fig. (4): Sulin's graph (1948) for the studied groundwater samples in Belbies district.**

**Table (3): The hydrochemical coefficients (ratios) for the groundwater samples of the Quaternary aquifer in Belbies district.**

| Sample No. | Hydrochemical coefficients (ratios) | | | | | | | Sample No. | Hydrochemical coefficients (ratios) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $rNa^+/rCl^-$ | $rMg^{++}/rCl^-$ | $rCa^{++}/rCl^-$ | $rSO_4^{--}/rCl$ | $rCa^{++}/rMg^{++}$ | $r(Cl^- -Na^+)/rCl^-$ | $rCl^-/r(HCO_3^-+CO_3^-)$ | | $rNa^+/rCl^-$ | $rMg^{++}/rCl^-$ | $rCa^{++}/rCl^-$ | $rSO_4^{--}/rCl$ | $rCa^{++}/rMg^{++}$ | $r(Cl^- -Na^+)/rCl^-$ | $rCl^-/r(HCO_3^-+CO_3^-)$ |
| 1 | 0.32 | 0.40 | 0.80 | 0.48 | 2.00 | 0.68 | 2.50 | 21 | 0.38 | 0.44 | 0.47 | 0.13 | 1.05 | 0.62 | 4.50 |
| 2 | 0.64 | 0.36 | 1.09 | 0.95 | 3.00 | 0.36 | 5.50 | 22 | 0.54 | 0.38 | 0.50 | 0.36 | 1.33 | 0.46 | 8.00 |
| 3 | 1.26 | 0.20 | 0.22 | 0.46 | 1.10 | -0.26 | 5.00 | 23 | 1.02 | 0.33 | 0.67 | 0.87 | 2.00 | -0.02 | 6.00 |
| 4 | 0.70 | 0.50 | 0.55 | 0.30 | 1.10 | 0.30 | 2.00 | 24 | 0.64 | 0.40 | 0.42 | 0.24 | 1.05 | 0.36 | 5.00 |
| 5 | 0.60 | 0.40 | 0.80 | 0.48 | 2.00 | 0.40 | 2.50 | 25 | 0.28 | 0.40 | 0.80 | 0.12 | 2.00 | 0.72 | 2.50 |
| 6 | 1.60 | 0.67 | 1.33 | 2.07 | 2.00 | -0.60 | 1.50 | 26 | 1.23 | 0.29 | 0.57 | 0.86 | 2.00 | -0.23 | 3.50 |
| 7 | 0.79 | 0.13 | 0.26 | 0.08 | 2.00 | 0.21 | 7.80 | 27 | 0.64 | 0.36 | 0.38 | 0.16 | 1.05 | 0.36 | 5.50 |
| 8 | 0.88 | 0.40 | 0.80 | 0.76 | 2.00 | 0.12 | 2.50 | 28 | 1.47 | 0.67 | 0.73 | 1.13 | 1.10 | 0.47 | 1.50 |
| 9 | 0.76 | 0.40 | 0.44 | 0.20 | 1.10 | 0.24 | 2.50 | 29 | 0.78 | 0.36 | 1.27 | 1.25 | 3.50 | 0.22 | 5.50 |
| 10 | 0.40 | 0.25 | 0.75 | 0.20 | 3.00 | 0.60 | 4.00 | 30 | 0.76 | 0.29 | 0.71 | 0.64 | 2.50 | 0.24 | 7.00 |
| 11 | 0.26 | 0.40 | 0.60 | 0.10 | 1.50 | 0.74 | 5.00 | 31 | 0.80 | 0.29 | 0.31 | 0.11 | 1.10 | 0.20 | 3.50 |
| 12 | 0.64 | 0.40 | 0.80 | 0.52 | 2.00 | 0.36 | 2.50 | 32 | 0.84 | 0.44 | 0.89 | 1.00 | 2.00 | 0.16 | 4.50 |
| 13 | 1.15 | 0.50 | 0.55 | 0.65 | 1.10 | -0.15 | 2.00 | 33 | 1.00 | 0.40 | 0.44 | 0.44 | 1.10 | 0.00 | 2.50 |
| 14 | 0.56 | 0.40 | 0.80 | 0.40 | 2.00 | 0.44 | 2.50 | 34 | 0.69 | 0.29 | 0.57 | 0.31 | 2.00 | 0.31 | 3.50 |
| 15 | 0.56 | 0.40 | 0.80 | 0.32 | 2.00 | 0.44 | 2.50 | 35 | 1.11 | 0.18 | 0.36 | 0.47 | 2.00 | -0.11 | 5.50 |
| 16 | 1.50 | 1.00 | 1.10 | 1.70 | 1.10 | -0.50 | 1.00 | 36 | 0.66 | 0.40 | 1.00 | 0.90 | 2.50 | 0.34 | 5.00 |
| 17 | 1.00 | 0.67 | 0.73 | 0.73 | 1.10 | 0.00 | 1.50 | 37 | 0.72 | 0.33 | 0.83 | 0.75 | 2.50 | 0.28 | 6.00 |
| 18 | 0.98 | 0.44 | 0.47 | 0.64 | 1.05 | 0.02 | 4.50 | Min. | 0.26 | 0.13 | 0.22 | 0.10 | 1.05 | -0.60 | 1.00 |
| 19 | 1.00 | 0.44 | 0.47 | 0.67 | 1.05 | 0.00 | 4.50 | Max | 1.50 | 1.0 | 1.33 | 2.07 | 3.50 | 0.74 | 8.00 |
| 20 | 0.54 | 0.29 | 0.57 | 0.17 | 2.00 | 0.46 | 3.50 | Average | 0.80 | 0.40 | 0.68 | 0.58 | 1.75 | 0.24 | 3.90 |

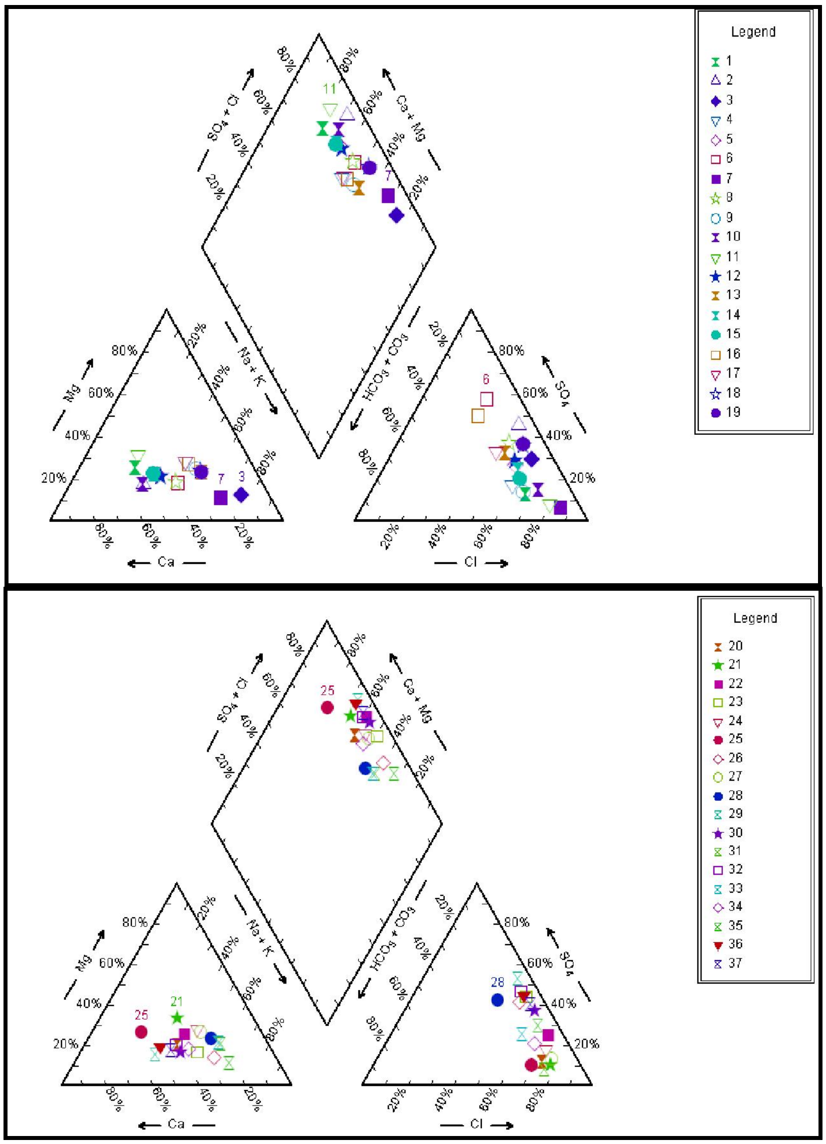


**Fig. (5): Plots of the analyzed groundwater samples of the Quaternary aquifer, Belbies district, on Piper trilinear diagram (1944).**

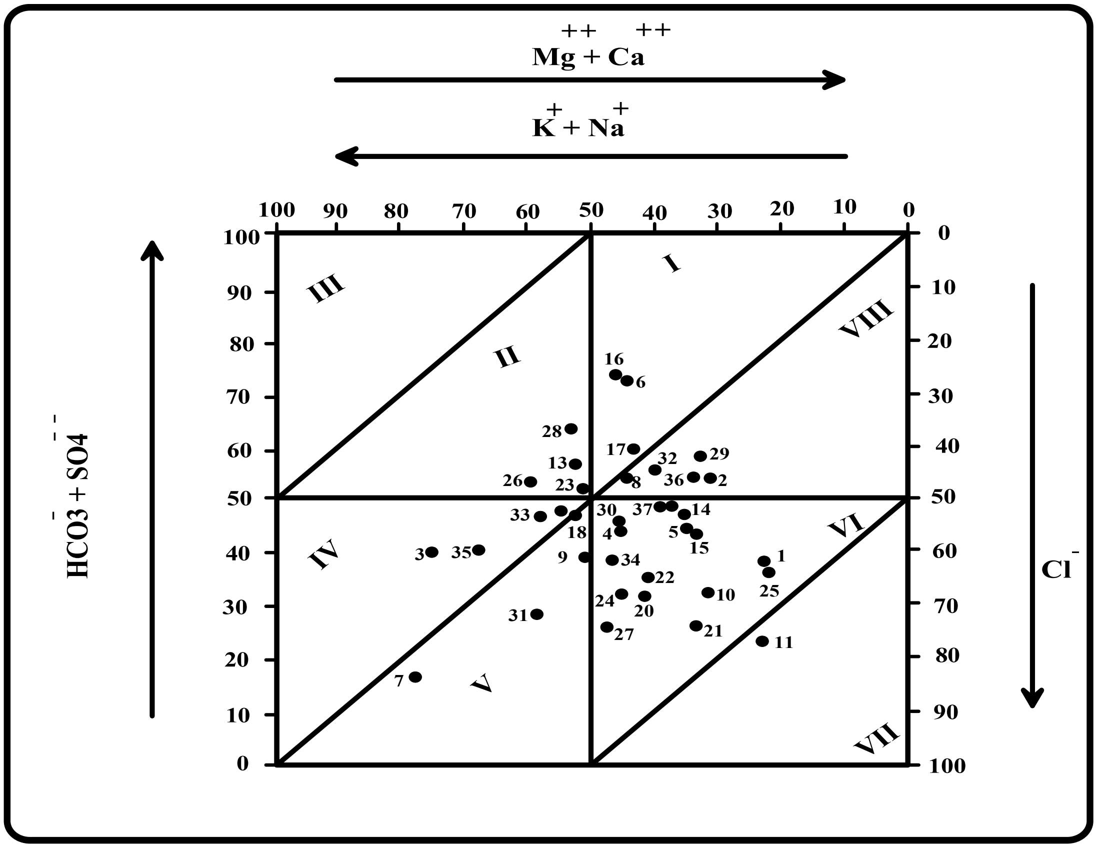


**Fig. (6): Ovitchinkov's classification of the Quaternary groundwater samples, Belbies district.**

**Table (4): Classification of water type based on Ovitchinkov's diagram (1963), Belbies district.**

| Water type | Triangle No. | Sample No. | % |
|---|---|---|---|
| **Meteoric water affinity** | **I** | 6, 16 & 17 | 8.1 |
| | **II** | 13, 23, 26 & 28 | 10.8 |
| | **III** | - | - |
| | **IV** | 3, 19, 33 & 35 | 10.8 |
| **Marine water affinity** | **V** | 7, 9, 18 & 31 | 10.8 |
| | **VI** | 1, 4, 5, 10, 12, 14, 15, 20, 21, 22, 24, 25, 27, 30, 34 & 37 | 43.3 |
| | **VII** | 13 | 2.7 |
| | **VIII** | 2, 8, 29, 32 & 36 | 13.5 |

**A). Evaluation for drinking purposes:**

Evaluation of groundwater for domestic purposes (drinking and household) depends mainly on its salinity, pH, the chemical and physical characters, odorless, colorless and tasteless as well as free of turbidity. High levels of total dissolved solids may impart an objectionable taste to drinking water. Sodium sulphate and magnesium sulphate levels above 250 mg/l in drinking water my produce a laxative effect (Bos, 1991). Assessment of the suitability for drinking consumption was evaluated by comparing the hydrochemical parameters of groundwater samples in Belbies district, with the prescribed specifications adopted by different organizations such as (Indian Drinking Water Specification "IDWS, 1992", Egyptian Ministry of Health "EMH, 1995"; Canadian Drinking Water Quality "CDWQ, 1996"; World Health Organization "WHO, 2011" and United States Environmental Protection Agency "U.S.EPA", 2012). By applying the standards of different organizations on the analyzed groundwater samples it is found that the drinking water risks include four categories, ranging from excellent to unsuitable (Table 5 & 6).

**Table (5): Drinking water standards of different organizations.**

| Category variable | IDWS (1992) | EMH (1995) | CDWQ (1996) | WHO (2011) | U.S.EPA (2012) |
|---|---|---|---|---|---|
| **Pollution indicators** | | | | | |
| **The pH range** | 6.5-8.5 | 6.5-9.5 | 6.5-8.5* | 6.5-8* | 6.5-8.5 |
| **Total Dissolved solids in mg/l** | 500 | 1200 | 500* | 600* | 500 |
| **Hardness as $CaCO_3$ in mg/l** | - | 500 | 200* | 500* | - |
| **Inorganic pollutants (major constituents) in mg/l** | | | | | |
| **Sodium** | - | 200 | 200* | 200* | - |
| **Magnesium** | 100 | 400 | - | - | - |
| **Calcium** | 250 | 200 | - | - | - |
| **Chloride** | - | 500 | 250* | 250* | 250 |
| **Sulphate** | 200 | 150 | 500* | 250* | 250 |
| **Nitrate-N(1)** | 45 | - | 10 | 10 | 10 |
| **Phosphates** | 5 | - | - | - | - |
| **Trace constituents in mg/l** | | | | | |
| **Copper(3)** | 1.50 | 1.00 | 1.00 | 2.00 | 1.300 |
| **Iron** | 0.30 | 1.00 | 0.30* | 0.30* | 0.300 |
| **Lead(2)** | 0.05 | 0.05 | 0.01 | 0.01 | 0.015 |
| **Manganese** | | 0.50 | 0.05* | 0.40 | 0.050 |
| **Zinc** | 5.00 | 3.00 | - | 5.00 | - |

**Table (6): The permissible limits of cations and anions in drinking water according to different organizations (IDWS 1992, EMH 1995, CDWQ 1996, WHO 2011 and US. EPA 2012).**

| Water characters | Class | Range | water samples No. | % |
|---|---|---|---|---|
| The pH value | Excellent | 6.5 – 8.5 | 1, 2, 6, 7, 12, 14, 15, 17, 21, 22, 23, 29, 32, 26 & 37 | 40 |
| | Unsuitable | <6.5 ->8.5 | 3, 4, 5, 8, 9, 10, 11, 13, 16, 18, 19, 20, 24, 25, 26, 27, 28, 30, 31, 33, 34 & 35 | 60 |
| TDS (mg/l) | Excellent | <500 | 1, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 24, 25, 26, 27, 28, 31, 33 &34 | 65 |
| | Permissible | 500-1000 | 2, 3, 7, 18, 19, 22, 23, 29, 30, 32, 35, 36 & 37 | 35 |
| | Excessive | 1000-1500 | - | - |
| | Unsuitable | >1500 | - | - |
| Hardness as ($CaCO_3$) | Excellent | <200 | 1, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 20, 25, 26, 28, 31, 33, 34 & 35 | 59 |
| | Permissible | 200-500 | 2, 10, 11, 18, 19, 21, 22, 23, 24, 27, 29, 30, 32, 36 & 37 | 41 |
| | Unsuitable | >500 | - | - |
| $Na^+$ (mg/l) | Excellent | <150 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 & 37 | 100 |
| | Permissible | 150-200 | - | - |
| | Unsuitable | >200 | - | - |
| $Mg^{++}$ (mg/l) | Excellent | <50 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 &37 | 100 |
| | Excessive | 50-150 | - | - |
| | Unsuitable | >150 | - | - |
| $Ca^{++}$ (mg/l) | Excellent | <75 | 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 24, 25, 26, 27, 28, 31, 33, 34 & 35 | 78 |
| | Excessive | 75-200 | 2, 22, 23, 29, 30, 32, 36 & 37 | 22 |
| | Unsuitable | >200 | - | - |
| $Cl^-$ (mg/l) | Excellent | <250 | 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 & 37 | 95 |
| | Permissible | 250-300 | 7 & 22 | 5 |
| | Excessive | 300-500 | - | - |
| | Unsuitable | >500 | - | - |
| $SO_4^{--}$ (mg/l) | Excellent | <250 | 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 35, 36 & 37 | 92 |
| | Permissible | 250-300 | 2 & 23 | 5 |
| | Excessive | 300-500 | 29 | 3 |
| | Unsuitable | >500 | - | - |

The results show that 60% of the studied groundwater samples have pH values within unsuitable limit (more than 8.5). With respect to salinity, all the groundwater samples are suitable for drinking purposes they falls in the permissible limit of TDS for drinking (500 – 1000 mg/l). Hardness levels in 59% of the studied Quaternary groundwater samples are in the excellent limit; less than 200 mg/l. Meanwhile 41% of the samples have slightly higher hardness (200-500 mg/l), which within the permissible limit for drinking. According to the concentration of sodium and magnesium, all the groundwater samples have concentrations under the limit of drinking water standards (Table 6). 78% of the total samples fall in the excellent evaluation class for calcium, also 22% of total groundwater samples fall in the excessive class limit for calcium.

All the groundwater samples falls in the excellent limit of chloride for drinking uses except sample No. 7 and 22 falls in permissible limit (250 – 300 mg/l) for drinking uses. The majority of the groundwater samples (92%) fall in the excellent class (> 250 mg/l) of sulphate for drinking purposes, 5% of the samples fall in the permissible limit (250 – 300 mg/l). Only sample 29 is excessive for use as drinking water because sulphate concentration is more than 300 mg/l. (Table 6).

Nitrate concentration are within the safe limit for drinking purpose (<44 mg/l) for the selected groundwater samples. The analyzed groundwater samples of Quaternary aquifer in Belbies district, classified into three water quality zones based on concentrations of nitrate (Fig 7); 1-Safe (≤ 10 mg $NO_3^-$/l) represented 72% of the selected groundwater samples, 2-Mildly problematic (> 10 & ≤25 mg/l) which represented by 22% of the samples and 3-Moderately problematic (> 25 & ≤ 50 mg/l) which represented by 6% of the samples (Kumar *et al*., 2002 and Thorburn *et al*., 2003).

According to the Indian Drinking Water Specification (IDWS, 1992), the standard limit of the total dissolved phosphates as (P) is 5 mg/l. All the selected groundwater samples in Belbies district fall in the unsuitable class which exceeds 5 mg/l, indicating pollution by phosphates.

Trace elements: Copper is an essential element in human metabolism, but can cause anemia, disorders of bone and connective tissues and liver damage at excessive levels. The toxicity of copper depends upon the hardness and pH of the water and therefore, it is more toxic in soft water and in water with low alkalinity (Jones, 1964). Regarding the concentrations of copper we found that all the analyzed samples falls in the excellent limit for drinking purposes "<1 mg/l" (Table 7).

The occurrence of iron in drinking water leads to a metallic taste. So, the recommended maximum concentration for drinking water is 0.3 mg/l (Hem, 1989).

The use of lead by humans tended to disperse the element widely through the environment. High lead concentrations in drinking water are very dangerous because it has poisoning effect. High lead level causes kidney disease and disturbances in the central nervous system (WHO, 2011). Regarding lead concentration, about 17% of the analyzed samples fall in excellent class (< 0.01 mg/l). The rest of the samples (83 %) fall in the unsuitable class (>0.05 mg/l), (Table 7 & Fig. 8).

The concentration of manganese content in the selected groundwater samples of the Quaternary aquifer ranges between 0.010 and 0.028 mg/l, which means excellent class, less than 0.05 mg/l. Also, the zinc contents fall in the excellent class < 3 mg/l for drinking purposes (Table 7).

**B). Evaluation for laundry purposes (water hardness):**

The proposed total hardness levels for human drinking water are differing to those of laundry use. The standards of the total hardness for laundry use are extremely stringent (Table 8). Total hardness of the studied samples calculated from the equation follows:

$TH = Ca^{++} \times 2.497 + Mg^{++} \times 4.116$ (mg/l)

Based on hardness classification for laundry uses according to (Durfer and Becker, 1964), 24% of the Quaternary groundwater samples at Belbies district are moderately hard; fall in the permissible class water. Meanwhile, 35% of the groundwater samples are hard; fall in the unsuitable class water and 41% of the samples fall in the very hard water (> 180); poor class water for laundry uses (Fig. 9). While, according to (Hem, 1989), 60% of the studied groundwater samples are moderately hard; fall in the permissible class water. Meanwhile, 24% of the groundwater samples are hard; fall in the unsuitable class water and 16% of the samples fall in the very hard water (> 300); poor class water for laundry uses.

**C). Evaluation for livestock production:**

Water used by animal is also subject to quality limitations. Animal tolerance also varies with species, age, water requirement, season, and physiological condition (Boyles *et al.*, 1988; Kober, 1993 & Bagley *et al.*, 1997). With respect to pH criteria, about 40% of the analyzed groundwater samples within the safe limit (5.5-8.5) while about 60% of the samples fall in the unsuitable limit (> 8.5). As the total dissolved solids (TDS) of water increase, the animals refuse to drink. Depressed water intake is accompanied by depressed feed intake (Bagley *et al.*, 1997). It is clearly that all the groundwater samples can be used for livestock and poultry. Sulphate and nitrate concentrations are below the risky level (less than 1500 mg/l and 100 mg/l respectively) in all groundwater samples (Table 9).

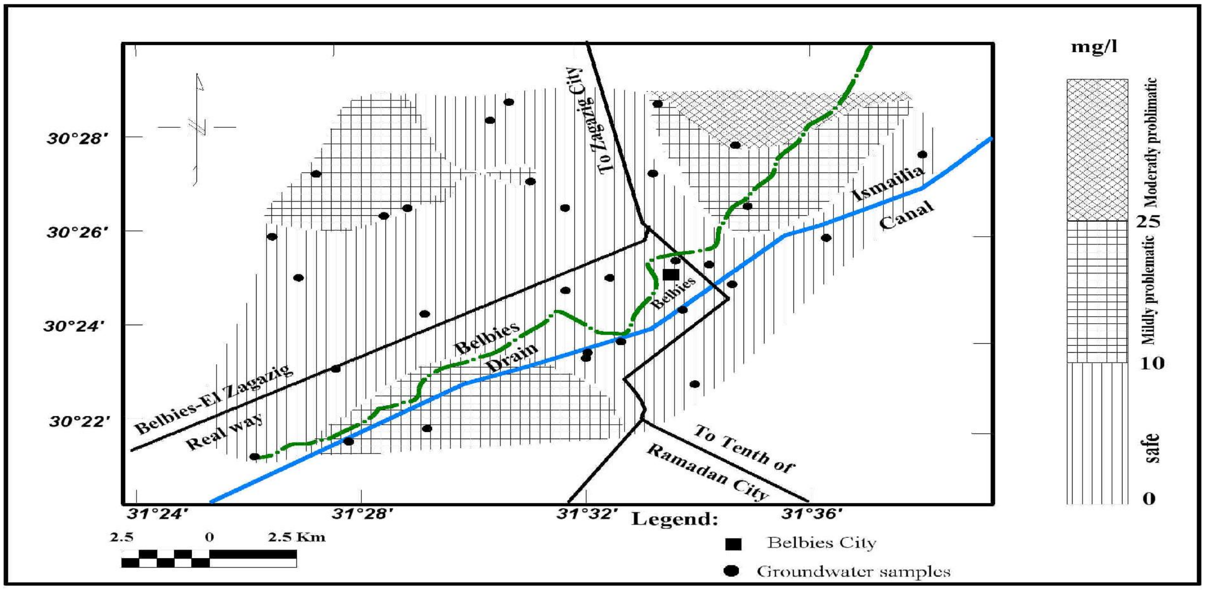


**Fig. (7): Nitrate ($NO_3^-$) zonation map of the Quaternary aquifer samples at Belbies district, categories classified for drinking uses according to Kumar *et al*. (2002) and Thorburn *et al*. (2003).**

**Table (7): Evaluation of the selected groundwater samples for drinking purposes on the basis of trace constituents (in mg/l) for the Quaternary aquifer in Belbies district.**

| Sample No. | Cu | Fe | Mn | Pb | Zn |
|---|---|---|---|---|---|
| **1** | 0.040 (A) | 0.033 (A) | 0.020 (A) | 0.113 (D) | 0.001 (A) |
| **7** | 0.032 (A) | 0.135 (A) | 0.019 (A) | 0.103 (D) | 0.008 (A) |
| **8** | 0.040 (A) | 0.132 (A) | 0.015 (A) | 0.009 (A) | 0.020 (A) |
| **12** | 0.037 (A) | 0.177 (A) | 0.022 (A) | 0.003 (A) | 0.002 (A) |
| **13** | 0.034 (A) | 0.178 (A) | 0.019 (A) | 0.129 (D) | 0.009 (A) |
| **18** | 0.038 (A) | 0.124 (A) | 0.028 (A) | 0.007 (A) | 0.007 (A) |
| **22** | 0.030 (A) | 0.234 (A) | 0.025 (A) | 0.122 (D) | 0.005 (A) |
| **23** | 0.057 (B) | 0.196 (A) | 0.010 (A) | 0.102 (D) | 0.009 (A) |
| **24** | 0.036 (A) | 0.210 (A) | 0.019 (A) | 0.127 (D) | 0.001 (A) |
| **25** | 0.044 (A) | 0.222 (A) | 0.021 (A) | 0.132 (D) | 0.020 (A) |
| **26** | 0.033 (A) | 0.186 (A) | 0.028 (A) | 0.121 (D) | 0.004 (A) |
| **29** | 0.035 (A) | 0.282 (A) | 0.024 (A) | 0.123 (D) | 0.011 (A) |
| **31** | 0.032 (A) | 0.135 (A) | 0.013 (A) | 0.106 (D) | 0.012 (A) |
| **32** | 0.030 (A) | 0.276 (A) | 0.026 (A) | 0.128 (D) | 0.006 (A) |
| **33** | 0.043 (A) | 0.244 (A) | 0.020(A) | 0.138 (D) | 0.018 (A) |
| **34** | 0.043 (A) | 0.200 (A) | 0.022 (A) | 0.125 (D) | 0.016 (A) |
| **36** | 0.031 (A) | 0.293 (A) | 0.028 (A) | 0.122 (D) | 0.022 (A) |
| **37** | 0.039 (A) | 0.401 (B) | 0.024 (A) | 0.128 (D) | 0.200 (A) |
| **Minimum** | 0.030 | 0.033 | 0.010 | 0.003 | 0.001 |
| **Maximum** | 0.057 | 0.401 | 0.028 | 0.138 | 0.200 |

**(A): Evaluation classes; (A)= Excellent, (B)= Permissible, (C)= Excessive, and (D)= Unsuitable.**

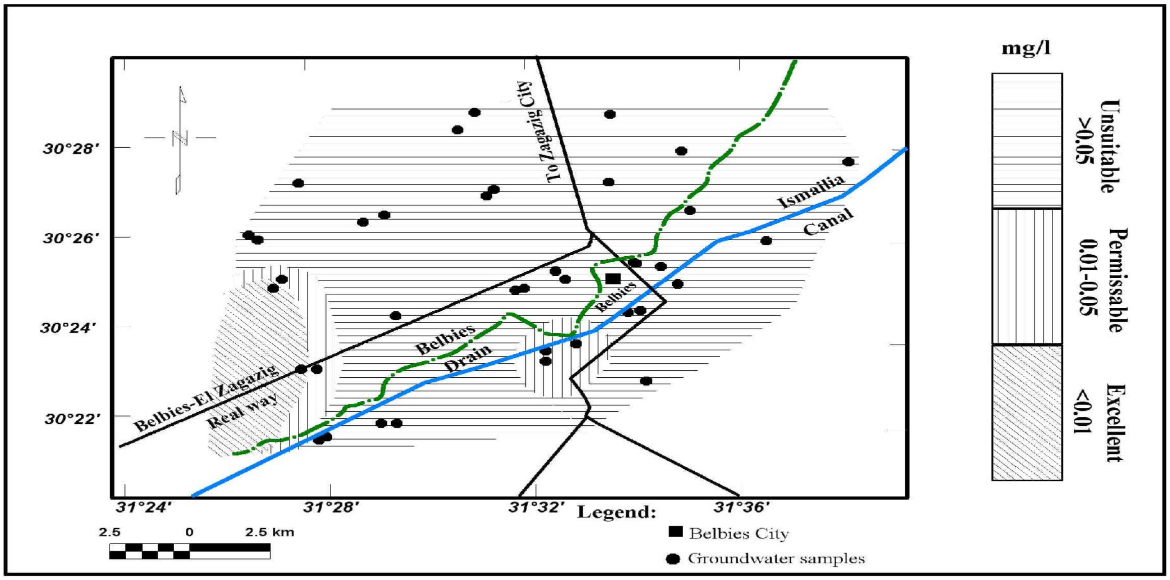


**Fig. (8): Lead (Pb) zonation map of the Quaternary groundwater samples, Belbies district, for drinking uses (categories classified according to WHO, 2011).**

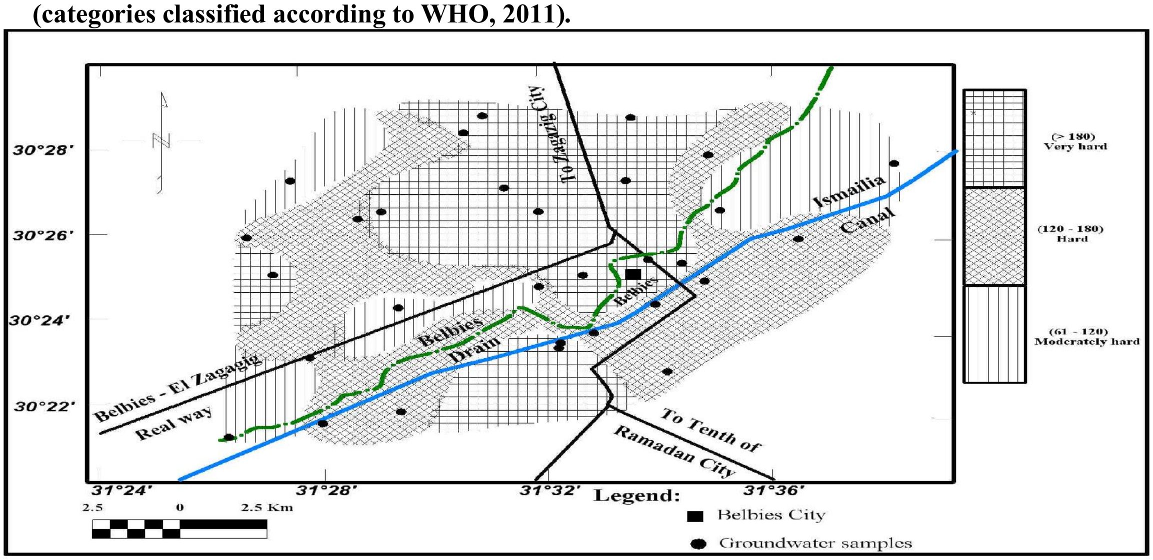


**Fig. (9): Total Hardness (TH) zonation map of the Quaternary aquifer samples, Belbies district, categories classified for laundry uses according to Durfer and Becker (1964).**

**Table (8): Hardness of the studied Quaternary groundwater samples in Belbies district, for laundry uses (after Durfer & Becker 1964 and Hem 1989).**

| Water Classes | Evaluation for laundry use | Hardness ranges ($CaCO_3$) mg/l after Durfer and Becker (1964) | Samples No. | % | Hardness ranges ($CaCO_3$) mg/l after Hem (1989) | Samples No. | % |
|---|---|---|---|---|---|---|---|
| Soft | Excellent | 0-60 | - | - | 0-75 | - | |
| Moderately Hard | Permissible | 61-120 | 3, 4, 9, 13, 16, 17, 28, 31& 33 | 24 | >75-150 | 1, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 20, 25, 26, 28, 31, 33, 34 & 35 | 60 |
| Hard | Unsuitable | 121-180 | 1, 5, 6, 7, 8, 12, 14, 15, 20, 25, 26, 34 & 35 | 35 | >150-300 | 10, 11, 18, 19, 21, 23, 24, 27 & 32 | 24 |
| Very hard | Poor | >180 | 2, 10, 11, 18, 19, 21, 22, 23, 24, 27, 29, 30, 32, 36& 37 | 41 | >300 | 2, 22, 29, 30, 36 & 37 | 16 |

**D). Evaluation for irrigation purposes:**

The suitability of groundwater for irrigation is dependent on the effects of mineral constituents in the water on both the plant and the soil (Khodapanah *et al.,* 2009). Soil scientists use the following parameters to describe irrigation water effects on crop production and soil quality (Bauder *et al.,* 2004): 1- Salinity content (T.D.S); 2- Soluble Sodium percent SSP (Na %); 3- Specific ions such as: Sodium, chloride, phosphate, and nitrate-nitrogen.

Other potential irrigation water contaminants that may affect suitability for agricultural use include heavy metals and microbial contaminants. Parameters such as salinity, sodium adsorption ratio (SAR), residual sodium carbonate (RSC), and hardness have been used to assess the suitability of the Quaternary aquifer in Belbies district for irrigation purposes.

In fact, the suitability of groundwater for irrigation in arid and semi-arid region depends on the effects of constituent minerals of water on both the plant and soil. The high salt content in irrigation water causes an increase in soil solution osmotic pressure. The chemical composition is directly affecting either the growth of plants and disrupts their metabolism. Also, it affects soil structure, permeability and aeration which indirectly affect plant growth (Ben Alaya, *et al.,* 2014).

In the present study, the groundwater samples were classified for irrigation purposes according to the following principles:

***1). Classification according to salinity content (TDS):***

Salinity may reduce the yields of crops by as much as 25% without visible symptoms (Rhoades, 1990). Forage crops are generally the most resident to salinity, followed by field crops, vegetable crops and fruit crops, which are generally the most sensitive (Ayers and Westcot, 1976). According to the classification of irrigation water after Fipps (1996), about 67% of the analyzed groundwater samples at Belbies district, have salinity values in range (175 – 525 mg/l), which are good for irrigation for many crops (Table 10) and 33% are in range of (525 – 1400 mg/l of TDS) which are permissible for irrigation purposes.

***2). Classification according to soluble sodium percent (SSP, Na%):***

Water for irrigation purposes must have Na% for groundwater in the studied samples (Table 10) is calculated using the equation:

Na% = (Na+K) / (Ca+Mg+Na+K) epm x100

High percentage of sodium with respect to ($Ca^{++}$, $Mg^{++}$ and $Na^{+}$) in irrigation water, causes deflocculating and impairing of soil permeability (Singh *et al*., 2008). Water with a SSP greater than 60% may cause sodium accumulations that will cause a breakdown in the physical properties of soil (Fipps, 1996).

In the studied groundwater samples of the Quaternary aquifer at Belbies district, the SSP (Na%) ranges from 22 to 76.3 (Table 10), where 92% of the analyzed groundwater samples fall in the good and permissible classes and only 8% fall in doubtful class (Table 11).

***3). Classification according to sodium adsorption ratio (SAR):***

Sodium adsorption ratio (SAR) is a relative percentage of sodium to other cations. This ratio is often important toxic to plants especially fruits and it frequently causes different problems in soil structure, infiltration and permeability rates (U. S. Salinity Laboratory Staff, 1954).

High salt content (high EC) in water leads to formation of saline soil, while high sodium content (SAR) leads to development of an alkaline soil. Irrigation with $Na^{+}$ enriched water results in ion exchange reactions: uptake of $Na^{+}$ and release of $Ca^{++}$ and $Mg^{++}$ causing soil aggregates to disperse, reducing its permeability (Tijani, 1994).

The sodium adsorption ratio (SAR) for studied groundwater samples in the investigated area is calculated using the following equation:

**Table (9): Recommended level of some pollutant in water for drinking of livestock after different authors indicators.**

| Pollutants | Class | Range | Comments | Samples | % |
|---|---|---|---|---|---|
| **pH value Bagley *et al.* (1997)** | Excellent | 6-8 | For dairy animals. | - | - |
| | | 5.5-8.5 | For other livestock. | 1, 2, 6, 7, 12, 14, 15, 17, 21, 22, 23, 29, 32, 36 & 37 | 40 |
| | Unsuitable | <5.5 or >8.5 | Highly alkaline waters may cause digestive upsets, diarrhea, poor feed conversion and reduced water/feed intake. | 3, 4, 5, 8, 9, 10, 11, 13, 16, 18, 19, 20, 24, 25, 26, 27, 28, 30, 31, 33, 34 & 35 | 60 |
| **Total dissolved solid (T.D.S) in mg/l NAS (1974) and Ayers & Westcot (1985)** | Excellent | < 1000 mg/l | For all livestock and poultry kinds. | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 & 37 | 100 |
| | Very satisfactory | 1000 – 2999 mg/l | - | - | - |
| | Unfit for poultry | 3000 – 4999 mg/l | Satisfactory for livestock and unfit for poultry | - | - |
| | Limited use | 5000 – 6999 mg/l | Limited use for livestock and unfit for poultry | - | - |
| | Unfit | 7000 – 10000 mg/l | Unfit for poultry and probably for swine | - | - |
| | Unsuitable | > 10000 mg/l | Can't be recommended for use under any conditions. | - | - |
| **Sulphate ($SO_4^{--}$) in mg/l Kober (1993)** | Excellent | <500-1000 | <500 for calves and <1000 for adult cattle. | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 & 37 | 100 |
| | Permissible | 1000-1500 | Produce slight effects on livestock. | - | - |
| | Excessive | 1500-2500 | Produce temporary diarrhea. | - | - |
| | Unsuitable | >2500 | Should not be used. | - | - |
| **Nitrate-N* in mg/l Boyles *et al.* (1988)** | Suitable | 0-100 | Considered safe. | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 & 37 | 100 |
| | Excessive | 100-300 | Exercise caution. Consider additive effect of nitrate in feed. | | |
| | Unsuitable | >300 | Potentially toxic. | | |

* 1 mg/l of nitrate-N is equivalent to 4.4 mg/l of nitrate-$NO_3$ (100 mg/l nitrate-N= 440 mg/l Nitrate-$NO_3$).

**Table (10): Results of some calculated parameters for groundwater samples, Belbies district.**

| Sample No. | TH (mg/l) | $Na^+$ (%) | SAR (epm) | RSC (epm) | Sample No. | TH (mg/l) | $Na^+$ (%) | SAR (epm) | RSC (epm) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 150 | 24.4 | 12.0 | -1.99 | **21** | 200 | 34.2 | 1.0 | -2.99 |
| **2** | 400 | 31.8 | 2.0 | -6.99 | **22** | 350 | 41.2 | 4.1 | -5.99 |
| **3** | 100 | 76.3 | 1.6 | -0.99 | **23** | 300 | 51.0 | 2.8 | -4.99 |
| **4** | 100 | 44.1 | 1.7 | -0.99 | **24** | 200 | 45.3 | 2.0 | -2.99 |
| **5** | 150 | 35.8 | 0.77 | -1.99 | **25** | 150 | 22.0 | 2.0 | -1.99 |
| **6** | 150 | 46.1 | 1.2 | -1.99 | **26** | 150 | 60.0 | 1.1 | -1.99 |
| **7** | 150 | 68.0 | 3.7 | -1.99 | **27** | 200 | 47.7 | 1.1 | -2.99 |
| **8** | 150 | 44.8 | 1.6 | -1.99 | **28** | 100 | 53.6 | 1.8 | -0.99 |
| **9** | 100 | 50.4 | 1.7 | -0.99 | **29** | 450 | 33.4 | 2.1 | -7.99 |
| **10** | 200 | 31.2 | 1.8 | -2.99 | **30** | 350 | 44.0 | 2.9 | -5.99 |
| **11** | 250 | 22.6 | 1.0 | -3.99 | **31** | 100 | 59.0 | 0.94 | -0.99 |
| **12** | 150 | 37.2 | 1.0 | -1.99 | **32** | 300 | 40.1 | 1.6 | -4.99 |
| **13** | 100 | 53.8 | 1.5 | -0.99 | **33** | 100 | 58.0 | 1.7 | -0.99 |
| **14** | 150 | 34.0 | 1.1 | -1.99 | **34** | 150 | 46.7 | 2.3 | -1.99 |
| **15** | 150 | 33.3 | 1.1 | -1.99 | **35** | 150 | 67.3 | 1.4 | -1.99 |
| **16** | 100 | 46.4 | 1.2 | -0.99 | **36** | 350 | 33.5 | 2.5 | -5.99 |
| **17** | 100 | 44.7 | 1.5 | -0.99 | **37** | 350 | 39.2 | 3.0 | -5.99 |
| **18** | 200 | 53.2 | 1.1 | -2.99 | **Min.** | 100 | 22.0 | 0.77 | -7.99 |
| **19** | 250 | 53.6 | 0.88 | -2.99 | **Max.** | 450 | 67.3 | 12.0 | -0.99 |
| **20** | 150 | 40.8 | 1.2 | -1.99 | **Average** | 300 | 45.0 | 6.5 | -4.50 |

$$SAR = \frac{[Na^+]}{\sqrt{\frac{1}{2}([Ca^{2+}]+[Mg^{2+}])}}$$

SAR of the groundwater samples in Belbies district ranges between 0.77 and 12 (Table 10); excellent to good grades. The relation between SAR and salinity (Fig. 10) for the analyzed groundwater samples reveals the following classes:

**1). Water of medium salinity and low SAR (C2S1);** This class includes about 65% of the groundwater samples at Belbies district, which is excellent for irrigation of most plants and suits for all soil texture.

**2). Water of high salinity and low SAR (C3S1);** This class contains about 35% of the total groundwater samples. This water category is satisfactory if only used for plants having moderate salt tolerance and soil of moderate permeability. Irrigation by this type of water requires regular leaching and special management.

***4). Specific ions:***

***a). Sodium hazard:***

Sodium in irrigation water can cause toxicity problems for some crops, especially when sprinkler irrigation is applied (Bauder *et al*., 2004). The susceptibility of crops to foliar injury from spray irrigation with water containing sodium is proposed by Maas (1990). Symptoms of excess sodium include necrotic areas on the tips, margins, or interveneal areas. Incipient injury is indicated by a mottled or chlorotic condition (Rhoades, 1990).

About 87% of the groundwater samples of Quaternary aquifer at Belbies district have sodium concentration less than 115 mg/l which causing foliar injury for almond, apricot, citrus and plum crops (Table 11). Also, 13% of the samples have sodium concentration ranges from (115 and 230 mg/l), which cause foliar injury for some crops especially grape, pepper, potato and tomato according to Maas (1990).

***b). Excess chloride:***

The concern with chloride is the possibility of excessive foliar absorption under overhead irrigation or leaf edge burn caused by excessive root uptake in sensitive plants. Excess chloride deposited on leaves cause foliar burn (Hopkins *et al*., 2007). About 40% of the analyzed groundwater samples have $Cl^-$ concentration between (142- 335 mg/l) and 60% have $Cl^-$ concentration less than 142 mg/l which show no chloride toxicity according to Ayers (1975).

Hazards of high-chloride in irrigation water can be minimized by planting less sensitive crops; avoiding foliar injury by using furrow, flood, or drip irrigation (Hopkins *et al*., 2007). About 68% of the samples have chloride concentration less than 175 mg/l, which cause foliar injury from spray irrigation for almond, apricot, citrus and plum, while 32% of the analyzed groundwater samples have chloride ranges between (175 and 350 mg/l) which cause foliar injury for grapes, pepper, potato, and tomato (Table 11).

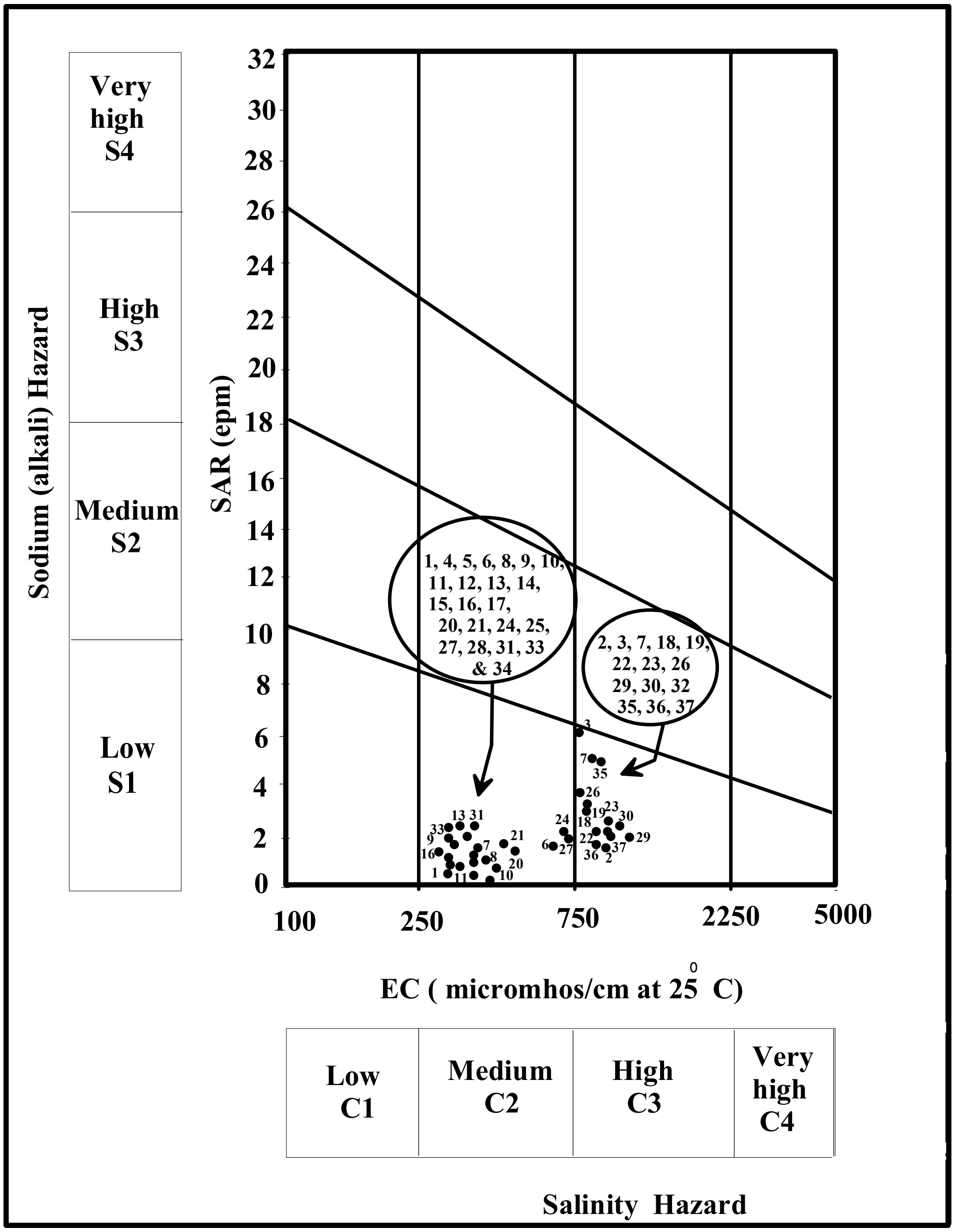


**Fig. (10): Classification of the studied groundwater samples for irrigation, Belbies district (based on U.S. Salinity Laboratory Staff, 1954).**

***c). Nitrogen ($NO_3^-$):***

Nitrogen in irrigation water (N) is largely a fertility issue, especially nitrate-nitrogen ($NO_3$- N), which often occurs at higher concentrations than ammonia in irrigation water and causes quality problems in crops such as barley and sugar beets and excessive vegetative growth in some vegetables (Bauder *et al.*, 2004). However, these problems can usually be overcome by good fertilizer and irrigation management. Regardless of the crop, nitrate should be credited toward the fertilizer rate especially when the concentration exceeds 10 mg/l $NO_3$-N (44 mg/l $NO_3^-$), Bauder *et al.* (2004). In Belbies district, all the selected groundwater samples are within the safe limit; less than 44 mg/l (Table 12).

***d). Phosphate ($P^{-3}$):***

Plants generally need phosphorus (P) early in their life cycle, which makes P an important pre-plant amendment if already deficient in the soil, but later-stage application of P via fertigation is adopted if P deficiency symptoms appear in plants any time during the growing season (Fares and Abbas, 2009).

The acceptable limit for phosphate concentrations in irrigation water is between 0-2 mg/l (Shahinasi and Kashuta, 2008). All the selected groundwater samples fall in the unsuitable class of phosphate, which exceed 2 mg/l, indicating aquifer pollution (Table 12).

**Table (11): Recommended level of some pollutant in water for irrigation purposes after different authors indicators.**

| Pollutants | Class | Range | | samples | % |
|---|---|---|---|---|---|
| **Total dissolved solid (T.D.S) & EC in mg/l Fipps (1996)** | | **E.C** | **T.D.S** | | |
| | Excellent | <250 | <175 | Not Recorded | - |
| | Good | 250 -750 | 175 - 525 | 1, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 24, 25, 26, 27, 28, 31, 33 &34 | **67.5** |
| | Permissible | 750 - 2000 | 525 – 1400 | 2, 7, 18, 19, 22, 23, 29, 30, 32, 35, 36 & 37 | **32.5** |
| | Doubtful | 2000 - 3000 | 1400 – 2100 | Not Recorded | - |
| | Unsuitable | >3000 | >2100 | Not Recorded | - |
| **Sodium concentration ($Na^+$) causing foliar injury* Maas (1990)** | | **Range** | **Crops** | | |
| | 1 | <115 mg/l | Almond, Apricot, Citrus & Plum. | 1, 2, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34, 36 &37 | **86.5** |
| | 2 | 115 - 230 mg/l | Grape, Pepper, Potato & Tomato | 3, 7, 23, 30 & 35 | **13.5** |
| | 3 | 230 - 460 mg/l | Alfalfa, Barely, Corn, Cucumber, Safflower, Sesame & Sorghum. | Not Recorded | - |
| | 4 | >460 mg/l | Cauliflower, Cotton, Sugar beat & Sunflower. | Not Recorded | - |
| **Soluble sodium percent (SSP) Wilcox (1955) and Todd (1980)** | Excellent | <20 | | Not Recorded | - |
| | Good | 20 – 40 | | 1, 2, 5, 10, 11, 12, 14, 15, 21, 25, 29, 26 & 37 | **35** |
| | Permissible | 40 – 60 | | 4, 6, 8, 9, 13, 16, 17, 18, 19, 20, 22, 23, 24, 26, 27, 28, 30, 31, 32, 33 & 34 | **57** |
| | Doubtful | 60 – 80 | | 3, 7 & 35 | **8** |
| | Unsuitable | >80 | | | |
| **Chloride concentration ($Cl^-$) causing foliar injury* Tanji (1990)** | | **Range** | **Crops** | | |
| | 1 | <175 mg/l | Almond, Apricot, Citrus & Plum | 1, 2, 4, 5, 6, 8, 9,10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 31, 32, 33, 34, 36 & 37 | **86.5** |
| | 2 | 175 – 350 mg/l | Grape, Pepper, Potato & Tomato. | 3, 7, 23, 30 & 35 | **13.5** |
| | 3 | 350 – 700 mg/l | Alfalfa, Barely, Corn, Cucumber, Safflower, Sesame & Sorghum. | - | - |
| | 4 | >700 mg/l | Cauliflower, Cotton, Sugar beat & Sunflower. | - | - |

* Foliar injury is influenced by cultural and environmental conditions. These data are presented only as general guidelines for day time irrigation .

**Table (12) Evaluation of the selected groundwater samples of Quaternary aquifer, Belbies district, for irrigation purposes, on the basis of nitrates and phosphates content (in mg/l).**

| Samples | $NO_3^-$ | Evaluation | $P^{-3}$ | Evaluation |
|---|---|---|---|---|
| **1** | 23.10 | Suitable (excellent) <44 mg/l | 6.67 | Unsuitable (> 2 mg/l) |
| **7** | 6.52 | | 8.75 | |
| **8** | 1.41 | | 7.92 | |
| **12** | 7.30 | | 6.46 | |
| **13** | 6.30 | | 7.92 | |
| **18** | 4.30 | | 8.33 | |
| **22** | 8.40 | | 8.75 | |
| **23** | 6.05 | | 9.79 | |
| **24** | 6.00 | | 9.37 | |
| **25** | 7.10 | | 5.21 | |
| **26** | 9.82 | | 9.58 | |
| **29** | 10.80 | | 8.12 | |
| **31** | 18.60 | | 8.75 | |
| **32** | 5.15 | | 7.50 | |
| **33** | 1.00 | | 8.33 | |
| **34** | 25.00 | | 8.33 | |
| **36** | 2.53 | | 7.21 | |
| **37** | 10.50 | | 7.92 | |

**Evaluation classes ($NO_3^-$) Suitable= <44 mg/l and Unsuitable= >44 mg/l.**
**Evaluation classes ($P^{-3}$) Suitable= 0-2 mg/l and Unsuitable= >2 mg/l.**

***e). Trace elements:***

The accumulation of trace elements in plants causes subsequent contamination of the animal food chain and hence high toxicity to animals. Pratt and Suarez (1990) set guidelines for evaluating the maximum permissible concentrations of trace elements in irrigation water for production of plant growth as well as potential toxicity to animals (Table 13). The concentrations of all trace elements (Cu, Fe, Mn, Pb and Zn) in the selected groundwater samples of the Quaternary aquifer in Belbies district are below the permissible limit and are suitable for irrigation purposes.

**Table (13): Recommended maximum concentrations of some trace elements in irrigation water for long-term protection of plants and animals (Pratt and Suarez, 1990), Belbies district.**

| Sample No. | Cu | Fe | Mn | Pb | Zn |
|---|---|---|---|---|---|
| 1 | 0.040 | 0.033 | 0.020 | 0.113 | 0.001 |
| 7 | 0.032 | 0.135 | 0.019 | 0.103 | 0.008 |
| 8 | 0.040 | 0.132 | 0.015 | 0.009 | 0.020 |
| 12 | 0.037 | 0.177 | 0.022 | 0.003 | 0.002 |
| 13 | 0.034 | 0.178 | 0.019 | 0.129 | 0.009 |
| 18 | 0.038 | 0.124 | 0.028 | 0.007 | 0.007 |
| 22 | 0.030 | 0.234 | 0.025 | 0.122 | 0.005 |
| 23 | 0.057 | 0.196 | 0.010 | 0.102 | 0.009 |
| 24 | 0.036 | 0.210 | 0.019 | 0.127 | 0.001 |
| 25 | 0.044 | 0.222 | 0.021 | 0.132 | 0.020 |
| 26 | 0.033 | 0.186 | 0.028 | 0.121 | 0.004 |
| 29 | 0.035 | 0.282 | 0.024 | 0.123 | 0.011 |
| 31 | 0.032 | 0.135 | 0.013 | 0.106 | 0.012 |
| 32 | 0.030 | 0.276 | 0.026 | 0.128 | 0.006 |
| 33 | 0.043 | 0.244 | 0.020 | 0.138 | 0.018 |
| 34 | 0.043 | 0.200 | 0.022 | 0.125 | 0.016 |
| 36 | 0.031 | 0.293 | 0.028 | 0.122 | 0.022 |
| 37 | 0.039 | 0.401 | 0.024 | 0.128 | 0.200 |
| **Minimum** | 0.030 | 0.033 | 0.010 | 0.003 | 0.200 |
| **Maximum** | 0.057 | 0.401 | 0.028 | 0.149 | 0.001 |
| **Maximum recommended concentration (mg/l)** | **0.200** | **5.000** | **5.000** | **0.200** | **0.500** |

## Summary And Conclusion

The Quaternary aquifer is the most important source of water in Belbies district, south El Sharkia Governorate, Egypt for drinking and agricultural purposes. The source and amount of recharge, type of sediment, and groundwater flow are mainly affecting the geochemical characteristics of the Quaternary aquifer in Belbies district. The Quaternary groundwater is mainly fresh in character, with TDS range from 224 to 855 mg/l. The groundwater belongs to three main water types; $CaCl_2$, $MgCl_2$ reflecting the marine affinity, which may be due to leakage through the genuine hydraulically connected system of Quaternary and Miocene aquifers, and $Na_2SO_4$ water type which reflecting meteoric water affinity. The majority of the analyzed groundwater samples are suitable for drinking purposes, except some samples which contain phosphate and lead ions. While in irrigation water the majority of samples are suitable under normal condition. About 65% of the samples is excellent for irrigation of most plants and suits for all soil texture. About 35% of the total groundwater samples used only for plants having moderate salt tolerance and soil of moderate permeability. Irrigation by such water requires regular leaching and special management.

## Acknowledgements

The authors are greatly indebted to the stuff members of the Geology Department, Faculty of Science, Damietta University, and the Nuclear Materials Authority Laboratories, Anshas, Egypt for their valuable assistances, scientific and technical remarks and faithful helps.

**Corresponding author:**
Abd-Alrahman A.A. Embaby
Geology Department, Faculty of Science, Damietta University, Egypt
embaby@du.edu.eg

## References

**Abd El Samie, S. G.; Sadek, M. A. and Mahmoud, N. S. (2002):** Assessment of groundwater pollution from the oxidation ponds in Tenth of Ramadan City, using isotopic techniques and hydrogeological modeling", Arab J. of Nuclear Sci. and Applications, Vol. 35, No 2, pp: 35-47.

**American Public Health Association** "APHA" **(1985):** Standard methods for the examination of water and wastewater 16th ed., Washington D.C., 1268 p.

**Attia, F.A.R. (1985):** Management of water systems in Upper Egypt. Ph.D. Thesis, Fac. Eng., Cairo Univ., Cairo, Egypt, 355p.

**Attia, F.A.R. and Hefny, K. (1993):** Groundwater salinity and groundwater reuse in the Delta. In the Proceedings of the Regional Seminar of Fresh-Water Quality and Efficiency in the Arab Region, Center for Environ.

Development of the Arab Region and Europe "CEDARE", Cairo, Egypt, pp: 17-18.

**Ayers, R.S. (1975):** Quality of water for irrigation. Proc. J. Irrigation and drainage Division, Specially Conf., American Society of Civil Engineers, Utah, Vol. 8, pp: 24-56.

**Ayers, R.S. and Westcot, D.W. (1976)**: Water quality for agriculture. Food and Agriculture Organization (FAO), Irrigation and Drainage Paper No. 29, United Nations, Rome, Italy, 97p.

**Ayers, R.S. and Westcot, D.W. (1985):** Water quality for agriculture. Food and Agriculture Organization (FAO), Irrigation and Drainage Paper Pub. (Rev. 1 FAO), United Nations, Rome, Italy, 176p.

**Babiker. I. S.; Mohamed, M. A. A.; Terao, H.; Hato, K. and Ohta, K. (2004):** Assessment of groundwater contamination by nitrate leaching from intensive vegetable cultivation using geographical information system. Environ. Int., Vol. 29, pp: 1009-1017.

**Bagley, C.V.; Amacher, J.K. and Poe, K.F. (1997):** Analysis of water quality for livestock. Animal Health Fact Sheet, Utah State Univ. Cooperative Extension, pp: 2-7.

**Bauder, T.A.; Waskom, R.M. and Davis, J.G. (2004):** Irrigation water quality criteria. Colorado State Univ., Cooperative Extension, Fact Sheet No. 0.506, pp: 1-5.

**Ben Alaya, M.; Salwa, S.; Zemni, T. and Zargouni, F. (2014):** Suitability assessment of deep groundwater for drinking and irrigation use in the Djeffara aquifers (Northern Gabes, south-eastern Tunisia). Environ. Earth Sci., Vol. 71, pp: 3387–3421.

**Bos, R. (1991):** Water quality, disease and human health. Paper presented at the Water Quality Conf., Bratislava.

**Boyles, S.; Wohlgemuth, K.; Fisher, G.; Lundstrom, D. and Johnson, L. (1988):** Livestock and Water. Extension Service Bulletin AS-954. North Dakota State Univ., Fargo, ND, USA.

**Canadian Drinking Water Quality "CDWQ" (1996):** Guidelines for Canadian drinking water quality. Canada Communication Group, Ottawa, Canada K1A 0S9, 90p.

**Custodio, E. and Bruggeman, G.A. (1987):** Groundwater problems in coastal areas. UNESCO Publications; Studies and reports in hydrology 45, Imprimerie Bietlot Frères, Fleurus, Belgium, 596p.

**Diab, M.S. (1982):** Groundwater pollution in the Quaternary aquifer under the Nile Delta, Egypt. J. Geol, Special Vol., Part 2, pp: 135-144.

**Durfer, C.N. and Becker, L. (1964)**: Public water supplies of the 100 largest cities in the United States. U.S. Geol. Survey, Water Supply Paper 1812, 364p.

**Egyptian Environmental Affairs Agency "EEAA" (1992):** Environmental Action Plan. The Egyptian Affairs Agency. Cabinet of Ministers, Cairo, Egypt, pp: 127.

**Egyptian Meteorological Authority "EMA" (1996):** Climatic atlas of Egypt. Published report, Ministry of Transport, Cairo, Egypt.

**Egyptian Ministry of Health "EMH" (1995):** Standards and specifications of water quality for drinking and domestic uses. Internal report, 8p.

**Elewa, H.H; Shohaib, R.E; Qaddah, A.A. and Nousir, A.M. (2013):** Determining groundwater protection zones for the Quaternary aquifer of northeastern Nile Delta using GIS-based vulnerability mapping. Environ. Earth Sci., Vol. 68, pp: 313–331.

**El Haddad, I.M. (2002):** Hydrogeological studies and their environmental impact on future management and sustainable development of the new communities and their surroundings, east of the Nile Delta, Egypt. Ph.D. Thesis, Fac. Sci., Mansoura Univ., Egypt. 435p.

**El Shamy, I. Z. and Mohammed, S. M. (1999):** Hydrogeochemical investigations for the groundwater at Cairo-Belbies district. $4^{th}$ Intern. Conf. on Geochemistry, Alex. Univ., pp: 335-351.

**Embaby, A. A. and Dawoud, I. A. (2009):** Health and environmental risks of water resources consumption south of Dakahlia Governorate, Egypt. The $4^{th}$ International Conf., under the Theme "Environment, Industry and Development." New Damietta City, Marsh $30^{th}$ –April $1^{st}$,10p.

**Embaby, A. A. and El Haddad, I. M. (2007):** Environmental impact of wastewater on soil and groundwater at the Tenth of Ramadan City area, Egypt", Mans. J. of Geol. and Geophysics, Vol. 34 (2), pp: 25-56.

**Fares, A. and Abbas, F. (2009)**: Irrigation systems and nutrient source for irrigation. Soil and Crop Management. College of Tropical Agriculture. and Human Resources, Univ. of Hawii, Manoa, Hawaii, USA, SCM-25, 4p.

**Farid, M.S. (1985):** Management of groundwater systems of the Nile Delta. Ph. D. Thesis, Fac. Eng., Cairo Univ., Cairo, Egypt, 202p.

**Fipps, G. (1996)**: Irrigation water quality standards and salinity management. Texas Agricultural Extension Services, Vol. 1667(B), 19p.

**Fields, S. (2004):** Global nitrogen: cycling out of control. Environ. Health Perspective, Vol. 112(A), pp: 557-563.

**Hach, E. (1990):** Chemical procedures explained. Hach Technical Center for Applied Analytical Chemistry, Colorado, USA, 48p.

**Hem, J.D. (1970):** Study and interpretation of the chemical characteristics of natural water, $2^{nd}$ ed. U. S. Geological Survey Water Supply. Paper 1473, 363p.

**Hem, J. D. (1989):** Study and interpretation of the chemical characteristics of natural water. U. S. Geological Survey, Water Supply, Paper 2254, 264p.

**Hopkins, B.G.; Horneck, D.A.; Stevens, R.G.; Ellsworth, J.W. and Sullivan, D.M. (2007):** Managing irrigation water quality for crop production in the Pacific Northwest. Oregon State Univ., PNW 597-E, 24p.

**Indian Drinking Water Specification "IDWS" (1992):** General standards for discharge of environmental pollutants.

**Jones, J.R.E. (1964):** Fish and river pollution. Butterworth & Company, London, 66p.

**Ketata, M.; Hamzaoui, F.; Gueddari, M.; Bouhlila, R. and Ribeiro, L. (2011):** Hydrochemical and statistical study of groundwaters in Gabes south deep aquifer (southeastern Tunisia). J. Phys. Chem. Earth Vol. 36, pp: 187–196.

**Khodapanah, L.; Sulaiman, W.N. and Khodapanah, N. (2009):** Groundwater quality assessment for different purposes in Eshtehard district, Tehran, Iran. European J. Sci. Research, Vol. 36, No. 4, pp: 543-553.

**Kober, J.A. (1993)**: Water: The most limiting nutrient. Agric. Practice 14, pp: 39-42.

**Kotb, A.M. (1988):** Geological, hydrogeological and geoelectrical studies on the eastern portion of Delta. M.Sc. Thesis, Fac. Sci., Al-Azhar Univ., Cairo, Egypt, 120p.

**Kumar, S.; Gupta, A.B. and Gupta, S. (2002):** Need for revision of nitrates standards for drinking water: a case study of Rajasthan. Indian. J. Environ. Health, Vol. 44(2), pp: 168-172.

**Lennaerts, B.M.; Attia, F.A.R. and De Jong, S.J. (1988):** Forecasting the suitability of pumped groundwater for irrigation in the Nile Valley. Agricultural Water Management, Vol. 14, pp: 525-535.

**Maas, E.V. (1990)**: Crop salt tolerance. In: Agricultural salinity and assessment management (K.K. Tanji, Editor). American Society of Civil Engineers (ASCE), Manuals and Reports on Engineering No. 71, New York, pp: 262-304.

**McLay, C.D.A.; Dragten, R.; Sparling, G. and Sclvarajain, N. (2001):** Predicting groundwater concentrations in a region of mixed agricultural lands use: a comparison of three approaches. Environ. Pollut., Vol. 115, pp: 191-204.

**National Academy of Sciences "NAS" (1974)**: Nutrients and toxic substances in water for livestock and poultry. Washington, DC, 93p.

**Ovitchinkov, A. M. (1963):** National water, Gosgeolitchizdat, Moscow, U.S.S.R., 375p. (In Russian).

**Piper, A. M. (1944):** A graphic procedure in the geochemical interpretation of water analysis. J. American Geophysics Union Trans., V. 25, pp: 914-923.

**Pratt, P.F. and Suarez, D.L. (1990):** Irrigation water quality assessments. In Agricultural salinity assessment and management, (K.K. Tanji, Editor). American Society of Civil Engineers (ASCE), Manuals and Reports on Engineering Practice No. 71, New York, pp: 220-236.

**Research Institute for Groundwater "RIGW" (1980):** Safe yield studies for groundwater in Nile Delta and Upper Egypt". Cairo, (Arabic).

**Rhoades, J.D. (1990)**: Overview Diagnosis of salinity problems and selection of control practices. In Agricultural salinity assessment and management (K.K. Tanji, Editor). American Society of Civil Engineers (ASCE), Manuals and Reports on Engineering Practice No. 71, New York. pp: 18-41.

**Shahinasi, E. and Kashuta, V. (2008)**: Irrigation water quality and its effects upon soil. BALWOIS 2008 – Ohrid, Republic of Macedonia, 6p.

12/11/2014

**Shehata, M. and El Sabrouty, M.N. (2014):** Applications of hydrogeochemical modeling to assessment geochemical evolution the Quaternary aquifer system in Belbies area, east Nile Delta, Egypt". J. of Biology and Earth Sci., Vol. 4(1): E34-E47.

**Simpson, T.R. (1946):** Salinas basin investigation. Bull. 52, Calif. Div. Water Resources, Sacramento, 230p.

**Singh, A.K.; Mondal, G.C.; Kumar, S.; Singh, T.B.; Tewary, B. K. and Sinha, A., (2008):** Major ion chemistry, weathering processes and water quality assessment in upper catchment of Damodar River basin, India. Environ. Geol. J., Vol. 54, pp: 745-758.

**Spaliding, R.F. and Exner, M.E. (1993):** Occurrence of nitrate in groundwater a review. J. Environ. Qual., Vol. 22, pp: 392-402**.**

**Sulin, V.A. (1948):** Condition of formation, principles of classification and constituents of natural waters, particularly water of petroleum accumulation. Leningard Acad. Sci., Moscow, USSR, 215p (In Russian).

**Tanji, K.K. (1990):** Agricultural salinity assessment and management. American Society of Civil Engineers (ASCE), Manuals and Reports on Engineering Practice No. 71, New York, 619p.

**Thorburn, P.J; Biggs, J.S; Weier, K.L. and Keating, B.A. (2003):** Nitrate in groundwater of intensive agricultural areas in coastal northeastern Australia. Agri. Ecosys. Environ., Vol. 94, pp: 49-58.

**Tijani, M.N. (1994):** Hydrochemical assessment of groundwater in Moro area, Kwara State, Nigeria. Environ. Geol. J., Vol. 24, pp: 194–202.

**Todd, D. K. (1980):** Groundwater hydrology. John Willy and Sons. Inc. New York. U.S.A., 335p.

**Tripathy, J.K. and Sahu, K.C. (2005)**: Seasonal hydrochemistry of groundwater in the barrier spit system of the Chilika Lagoon, India. J. Environ. Hydrology, Vol. 13, pp: 3-9.

**United States Salinity Laboratory Staff "USSLs" (1954):** Diagnosis and improvement of saline and alkali soils. U. S. Dept. Agric., Handbook, Washington, DC, Vol. 60, pp: 1-60.

**United States Environmental Protection Agency "U.S. EPA" (2012):** Drinking Water Standards and Health Advisories. Washington, DC, EPA 822-S-12-001, 12p**.**

**United States Geological Survey "USGS" (1998):** Overview of Middle East water resources", U.S. Geological Survey for Middle East Water Data Banks Project, pp: 2-44.

**Wilcox, L.V. (1955):** Classification and uses of irrigation waters. U.S. Dept. Agric. Circular (969), Washington D.C., 19p.

**World Health Organization "WHO" (2011)**: Guidelines for Drinking Water Quality, 4th ed., WHO, Geneva, Switzerland, 541p.