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RESEARCH ARTICLE

Effect of surface water system on groundwater composition using geochemical modeling and geostatistical techniques, East Nile Delta (Case study)

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Abstract

El Gabal Al Asfar and El Adelya areas are parts of the East Nile Delta; where development is constrained by the amount of good groundwater quality that can be withdrawal sustainably. In these two areas, the Quaternary aquifer represents the main source for groundwater; where seepage from Nile drainages and irrigation canals consider the main recharge sources. Unfortunately; the groundwater in such aquifer has been heavily polluted by heavy metals and biological activity due to seepage from sewage and agricultural drains. Geochemical modeling (NETPATH) determined the sources, mixing and delineates the recharge areas within the Quaternary aquifer. The results showed that the groundwater salinity is controlled by dissolution of minerals and salts in the aquifers matrix along flow paths and mixing of chemically different waters. The geochemical model output shows high potential recharge for the Quaternary aquifer at El Gabal Al Asfar area along the drains. The surface water-groundwater interactions have been evaluated; where the maximum mixing percent ratio attains 79% from surface water to 21% from groundwater. To effectively manage groundwater in El Gabal Al Asfar area, Future groundwater pumping must be closely monitored to limit these effects. R-mode factor have been calculated for twenty variables. The results show that; five principal factors were obtained in El Gabal Al Asfar area and four principal factors were obtained in El Adelya area. Finally hierarchical clusters were constructed; most of the groundwater samples are clustered around the surface water samples confirming the effect of surface water system on the groundwater composition.

1-Introduction

The application of domestic waste water for agriculture purposes has increasingly gained importance in the various countries of the arid and semi-arid Middle East Region as water is becoming a scarce commodity and enormous sandy areas initially poor of nutrients available. Egypt has planned to reclaim large areas of desert with the use of sewage effluent from Greater Cairo. These areas are particularly located in both the Eastern and Western fringes of the Nile Delta floodplain, where sandy soils are present which are initially poor of nutrients. Since vulnerability to groundwater pollution in these areas is generally high, a negative impact on groundwater quality may be expected. El Gabal Al Asfar area is located approximately 25 km north east of Cairo near the eastern desert area at the fringes of the Delta floodplain. The use of sewage effluent irrigation in this area was initiated in 1915. After primary treatment the effluent is now used to cultivate an area of 3,000 acre feddan. Unfortunately, the amount of sewage effluent reaching the farm has increased to such amount an amount that the excess sewage effluent is not treated and used as raw sewage. In El Gabal Al Asfar farm cultivation depend on the sewage effluent present in a large net of drains but the cultivated area surrounding it is irrigated by groundwater. In addition most of the people depend on groundwater for drinking, domestic and poultry purposes and this reflect bad health and some diseases.

As a major diagnostic tool in groundwater hydrology, hydrogeochemical data have been used to identify recharge zones and flow patterns, calculate recharge rate or mixing ratios, and to discern hydraulic connections between aquifers (Hem, 1989; Mayo et al., 1992; Mazor et al., 1993; Panno et al., 1994; Wang and Khaustove, 1997).

Geostatistical analysis of geochemical data can often give some insights into the underlying factors controlling hydrogeochemical processes. For instance, Kriging has been found to be especially useful for analyzing regional scale hydrochemical data (Goovaerts et al., 1993)

The area under study lies within the eastern boundary of the Nile flood plain (Fig. 1). It is limited by Latitudes 30˚ 10′ & 30˚ 25′ N and Longitudes 31˚ 10′ &31˚ 50′ E It is occupied by sedimentary rocks belonging to Tertiary and Quaternary periods. The stratigraphic succession in the study areas includes sediments ranging in age from Eocene up to Pleistocene- Holocene (Shendi, 1995)
(Fig.2). The Quaternary aquifer represents the main groundwater resource in the study area; the Quaternary aquifer is mainly recharged from the main Nile Delta aquifer, seepage from Damietta branch, El Ismailia canal and from the irrigation canals system. Groundwater movement is mainly northeast wards with regional hydraulic gradient ranges between 50 and 60 cm/km (Taha et al., 1997).

The main objectives of the present study are: (1) to characterize the hydrogeochemical features of the groundwater in some locality in East Nile Delta (2) to show the effectiveness of combining geostatistical analysis and geochemical modeling techniques to extract hydrological information about the groundwater in the study area (3) investigate the extend of surface water effect on the quality of groundwater in the Pleistocene aquifer in the study area by measuring the mixing ratios using geochemical modeling technique and (4) testing water corrosivity.

2-Experimental

2.1. Sampling and hydrochemical measurements

In May 2012, 53 groundwater samples were collected, 31 groundwater samples from El Gabal Al Asfar area and 22 groundwater samples from El Adelya area. Also 5 surface water samples representing El Ismailia canal, El Belbasy drain, El Gabal Al Asfar drain and Mixed drain in El Gabal Al Asfar area and El Adelya canal in El Adelya area (fig.1). Three samples were taken from each water point as the following, the first is about one liter to measure the major and minor elements, the second is about 100 ml acidified with nitric acid where pH< 2 for analysis the trace element using ICP instrument, the third to measure COD and BOD. Electrical conductance (EC, micro mhos/cm), pH and temperature (°C) were measured immediately after sampling; also longitude and latitude were detected. The complete chemical analyses were performed in the Hydrogeochemistry Department of Desert Research Center (DRC) according to the methods adopted by the United States Geological Survey, (Rainwater and Thatcher, 1960), methods of determination for inorganic substance in water and fluvial sediments (Fishman and Friendman, 1985 and American Society for Testing Materials ASTM, 2002) and the results are tabulated (Table 1)

2.2. Geochemical modeling

The software package NETBATH for windows, (El Kadi et al, 2010) is a computer program that can be used to compute the mixing proportion of two to five initial waters and net geochemical reactions accounting for the observed composition of final water, also it is used to perform a variety of aqueous geochemical calculations including the saturation indices (SI) of the major minerals phases by WATEQF which included in the software (Plummer, 1992). The saturation indices of relevant mineral (SI) is determined according to the following equation:
$SI = \text{Log}(IAP/KT)$
Where, IAP is the ion activity products, and KT is the solubility product of the minerals. For $SI = 0$, there is an equilibrium between the mineral and the solution; $SI < 0$ reflects sub-saturation and dissolution of mineral and $SI > 0$ indicates super-saturation and precipitation of mineral (Appello and Postama, 1993)

2.3. Geostatistical method

The software SPSS for windows (Statistical Package for the Social Sciences), The Pearson correlation coefficient matrix are obtained, we also calculate the scores for principal factors using R-mode factor analysis of the chemical composition of the groundwater, each of the principal factors is influenced both by regional hydrogeochemical conditions and by local geology and hydrogeology. Thus, these factors are regarded as regionalized variables. We also obtain the Dendrogram (cluster analysis). The purpose of cluster analysis is to identify groups or clusters of similar sites on the basis of similarity within a class and dissimilarities between different classes (Vega et.al. 1998), (Sparks, 2000) and (Panda, et. al., 2006).

3. Result and discussion

3.1. Geochemical modeling

3.1.1 Saturation State with Respect to Minerals

From the results of Saturation Index calculation using WATEQF contained in NETPATH we deduce that, in El Gabal Al Asfar area, 12 minerals were recognized in the groundwater samples (Calcite, Aragonite, Dolomite, Siderite, Rodochorosite, Strontite, Gibbs, Hematite, Goethite, $Fe(OH)_3$, Hydroxape and Viviante). The saturation indices of these minerals are tabulated and illustrated (Table 2 &Fig.3a), and the following could be deduced:

All groundwater samples are super-saturated with respect to carbonate minerals (Calcite, Aragonite and Dolomite) (SI>0), this is clear where the pH values reflect slightly alkaline character (pH range from 7.9 to 9.1). The main source of CO_2 in this aquifer is atmosphere when reacts with rainwater to form bicarbonate ion in addition to leaching and dissolution of carbonate material. 28 samples are super saturated with respect to Rodochorosite, 20 samples are slightly saturated with respect to strontite. 30 samples are saturated with respect to Gibbs, 23 samples are super-saturated with respect to iron minerals (Hematite, Goethite, Siderite and $Fe(OH)_3$) (Fig.1), except samples Nos. 14 and 19 are under saturation with respect to siderite, such minerals reflect the sensitivity of iron to oxidation even in low concentrations (Mahmoud, 2005) 21 samples are super-saturated with respect to Hydroxape, 8 samples are super-saturated with respect to Viviante, presence of phosphate minerals are concentrated in El Gabal Al Asfar farm (Fig. 1) this may be due to pollution of groundwater by agriculture waste water infiltration from the irrigation canals (Hem,1989).

In El Adelya area, 10 minerals were detected in the groundwater samples (Calcite, Aragonite, Dolomite, Siderite, Gibbs, Hematite, Goethite, $Fe(OH)_3$, Hydroxape and Viviante) the saturation indices of these minerals are tabulated and illustrated (Table 3 & Fig.3b), and the following could be deduced: All water samples are super-saturated with respect to Calcite, Aragonite and Dolomite, 15 samples are saturated with respect to Gibbs, 14 samples are super-saturated with respect to iron minerals (Hematite, Goethite, siderite and $Fe(OH)_3$), except samples Nos. 36 and 39 are under saturation with respect to siderite, 2 samples (Nos.32 & 38) are super-saturated with respect to Hydroxape, only one sample (No.32) is saturated with respect to Viviante.

Results of saturation indices using WATEQF contained in NETPATH are plotted (Figures 4, 5 and 6). From these isograms, it is clear that the trends of variation in the saturation indices of different minerals were nearly similar. The values of the indices are smaller in the recharge area if compared with those in the downgradient area. Those isograms provide information on the recharge and resident time (water-minerals reaction time) of groundwater (Wang et al., 1998; Gomaa et al. 2012).

3.1.2. Corrosivity and scale formation:

Corrosion is a complex series of reactions between water and metal surfaces as well as materials in which the water is stored or transported. The corrosion process is an oxidation/reduction reaction that returns refined or processed metals to their more stable ore state. The primary concerns of the corrosion potential of water include the potential presence of toxic metals as lead and copper, deterioration and damage of the household plumbing as well as aesthetic problems such as; stained laundry, bitter taste, and greenish-blue stains around basins and drains. In soft water, corrosion occurs due to the lack of dissolved cations such as calcium and magnesium; while in hard water a precipitate or coating of calcium or magnesium carbonate accumulate on the internal wall of pipes. This coating can inhibit the corrosion of the pipe, because it acts as a barrier, but it can also clog the pipe. Water with high levels of sodium, chloride, or other ions will increase water conductivity and promoting corrosion (W.U., C.E.G, G.S.E. Dept., 2002). Saturation indices were used as an indicator of water corrosivity or scale formation. Table (4) presents a typical range of SI of calcite that may be encountered in a drinking water and a description of the nature of the water as well as the general recommendations regarding treatment (W.U., C.E.G, G.S.E. Dept., 2002).

According to the saturation indices of calcite mineral in the investigated groundwater samples in El Gabal El Asfar area (Table 2) as indicator of water corrosivity or scale forming , it is clear that all the samples are mild scale forming Except samples (Nos. 1 and 8) are some faint coating.

In El Adelya area, the majority of the groundwater samples are some faint coating except samples (Nos. 37 and 38) are mild scale forming in samples (Nos. 32, 35 and 36) treatment typically not needed.

3.1.3. Mixing proportions of two or more initial waters

The **NETPATH** program has been used to calculate the mixing ratio at the final water between two up to five initial waters, we selected the constraints (carbon, calcium, sulfur, magnesium, sodium and chloride) and phases (calcite, dolomite, exchange, pyrite, NaCl, gypsum, Montmorillonite , Illite, CO_2 and CH_2O) (Ezz El-Deen et al., 2005).

In El Gabal Al Asfar area the first initial water is sample No. 14 which represents the Quaternary aquifer, the second initial water is Ismailia canal, the third initial water is Belbaisy drain, the forth initial water is El Gabal Al

Asfar drain and the fifth initial water is the mixed drain. The final water is the sample which we need to estimate the mixing ratio between the initial waters in it.

From (Table 5) we can conclude that samples Nos.1 to 12 inclusive have considerable mixing from Ismailia canal and Belbasy drain only (range from 26% to 79%, except sample No.3 have no mixing from surface water), while the farm wells (wells Nos. 13 to 31 inclusive) have no mixing from Ismailia canal (except samples Nos. 17, 20 and 22). The total mixing from the surface water range from 17.5% to 63% (Except sample Nos.26, 31 are highly affected from surface water), while samples Nos. 18, 19, 23, 28 and 30 have no mixing from the surface waters.

From plotting groundwater samples of quaternary aquifer in El Gabal El Asfar area on trilinear diagram (Fig 7), most of groundwater samples are clustered around surface water, indicating the effect of leakage on their chemistry (Wang et al., 2001. Gomaa et al., 2012). In addition most of the samples have water type (HCO_3-Na). Such similarity between samples reflects high degree of mixing between various sources of waters (Koh et al., 2012).

In El Adelya area the first initial water is sample No. 53 which represents the Quaternary aquifer, the second initial water is El Adelya canal and the final water is the sample which we need to estimate the mixing ratio between the initial waters in it.

From (Table 6) we can conclude that all ground water samples have mixing from El Adelya canal especially samples Nos.32 to 44 inclusive which locate near to El Adelya canal (range from 51% to 99%) the rest of the samples have lower mixing from Adelya canal (range from 10% to 46%).

3.2. Statistical analysis

3.2.1. Pearson Correlation Coefficients

The close inspection of correlation matrix was useful because it can point out associations between variables that can show the overall coherence of the data set and indicate the participation of the individual chemical parameters in several influence factors, a fact which commonly occurred in hydrochemistry (Helena et al., 2000).

In El Gabal Al Asfar area, the Pearson correlation coefficient matrix for El Gabal Al Asfar area is given in the Table (7). The variables having coefficient value (r) >0.5 are considered significant. pH show significant correlation with phosphate, electric conductance (EC) show significant correlation with Ca^{2+}, Na^{+}, SO_4^{2-}, Cl^{-}, NO_3^{-} and Sr which reveals that conductance of water is mainly due to these ions, salinity of water samples is strongly correlated with permanent hardness, Ca^{2+}, Na^{+}, SO_4^{2-}, Cl^{-}, NO_3^{-} and Sr indicating that these elements are the main component of salinity (the strong correlation between salinity and permanent hardness is mainly attributed to the effect of leaching and dissolution of soluble salts which lead to the increase of hardness with particular importance to the effect of NaCl on increasing solubility of Ca^{2+} and Mg^{2+} in water) (Freeze and Cherry, 1979& Hem, 1989), total hardness is strongly correlated with Ca^{2+}, Mg^{2+}, SO_4^{2-} , NO_3^{-} , Al^{3+}, Sr^{2+} and Fe^{3+}. This indicates that water hardness is mainly due to calcium, magnesium and strontium salts, permanent hardness shows significant correlation with Ca^{2+}, Mg^{2+}, SO_4^{2-} , NO_3^{-} , Sr^{2+} and Fe^{3+}. It indicates that permanent hardness is mainly due to calcium, magnesium, strontium and ferrous sulfate & nitrate. In El Adelya area**,** from the correlation matrix (Table 8) we can conclude that, electric conductance shows significant correlation with Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, NO_3^{-} and Sr which reveals that conductance of water is mainly due to these ions, salinity of the samples is strongly correlated with Ca^{2}, Mg^{2+}, Na^{+}, Cl^{-}, NO_3^{-} and Sr, total hardness is strongly correlated with Ca^{2+}, Mg^{2+},Na+, Cl^{-} , NO_3^{-} ,Sr^{2+} and permanent hardness. This indicates that the water hardness is mainly due to calcium, magnesium and strontium salts and permanent hardness exceeds the temporary hardness, permanent hardness is strongly correlated with Ca^{2+}, Mg^{2+}, Cl^{-} and Sr^{2+}. This may indicate that permanent hardness is mainly due to CaCl, MgCl and SrCl.

3.2.2. Factor Analysis

Factor analysis is a statistical approach that can be used to analyze interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (factors). The statistical approach involving finding a way of condensing the information contained in a number of original variables into a smaller set of dimensions (factors) with a minimum loss of information. In groundwater quality management, it is important to relate the spatial distribution of different chemical parameters to different possible sources, which have different chemical signatures.

In El Gabal Al Asfar area, R-mode factor analysis was made on twenty variables (pH, EC, TDS, TH, alkalinity, permanent hardness, Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-}, PO_4^{3-}, Al^{3+}, Sr^{2+}, Fe^{3+}. Mn^{2+}, COD and BOD) for the investigated 31 samples. The two Eigen values of R are: r1= 5.79, r2= 1.41, calculated by the program, with a cumulative percentage variables contribution of 90.15 %. Correspondingly, five principal factors were obtained (Table 9). The first factor usually represents the most important process or mix of processes controlling the hydrochemistry. It has the highest Eigen value and accounts for the highest variance among the factors. F1 has positive loadings for EC, TDS, TH,Ca^{2+}, Mg^{2+}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-}, Al^{3+}, Sr^{2+} and Fe^{3+}. (> +0.5), (Fig.8.a). This factor refers to leaching and dissolution processes from the aquifer matrix. F2 has positive loadings for pH, Na^{+}, NO_3^{-}, PO_4^{3-} and Mn^{2+}. This may be due to groundwater pollution by agriculture waste water infiltration from the irrigation canals. F3 has positive loadings for alkalinity and HCO_3^- this should be an indicator of the hydrochemical effect of recharge from Ismailia canal. F4 has positive loadings for COD this may be due to the effect of the drains on the groundwater. F5 has positive loadings for Al^{3+}. this may be due to dissolution of lithogenic materials.

In El Adelya area**,** R-mode factor analysis was made on twenty variables (the same variables mentioned before) for the investigated 11 samples, four principal factors were obtained (Table 10 & Fig 8.b) F1 has positive loadings for EC, TDS, TH, permanent hardness, Ca^{2+}, Mg^{2+}, Na^+, Cl^-, NO_3^- and Sr^{2+}. This factor refers to leaching and dissolution processes from the aquifer matrix. F2 has positive loadings for PO_4^{3-} and COD. This may be due to groundwater pollution by agriculture waste water infiltration from the irrigation canals. F3 has positive loadings for alkalinity, HCO_3^-, SO_4^{2-} and Mn^{2+}. These refer to the dilution effect of El Adelya canal. F4 has positive loadings for Fe^{2+}. This is mainly due to dissolution of lithogenic material.

3.2.3. Cluster Analysis

The purpose of cluster analysis is to identify groups or clusters of similar sites on the basis of similarity within a class and dissimilarities between different classes (Sparks, 2000). In hierarchical cluster analysis the distance between samples is used as a measure of similarity (Vega et.al., 1998). In order to classify the objects of the system into categories or clusters based on their nearness or similarity (Panda, et. al., 2006). Agglomerative hierarchical clusters are formed sequentially, by starting with the most similar pair of objects and forming higher cluster step by step.

One of the main purposes of cluster analysis in this study is to identify samples affected by recharge from El Ismaylia canal, irrigation canals and drains.

In El Gabal Al Asfar area**,** to detect spatial similarity among groups, cluster analysis (CA) was applied on 31 groundwater samples and 4 surface water samples (El Ismailia canal, Belbays drain, El Gabal Al Asfar drain and mixed drain). The 31 groundwater samples fell into 3 major clusters (Fig. 9-a).

Cluster No.1 (C1) represents the major cluster. It consists of 25 groundwater samples, which is affected by El Gabal Al Asfar drain and mixed drain. The majority of these samples are the farm samples (17 samples) which are located adjacent to such two drains and less affected by El Ismailya canal and this is in agreement with mixing ratios (Table 5)

Cluster No.2 (C2) represents the most samples affected by El Ismailia canal samples Nos 7 & 8 which record the highest mixing ratio from Ismailia canal (77% & 72% respectively) and sample No.1, which is located directly on it.

Cluster No.3 (C3) represents 2 samples No.10 & 12 which are greatly affected by Belbays drain and this is confirmed by the mixing ratio (80% & 60% respectively)

Sample No. 30 is independent sample (dissimilar with respect to any of surface water and also it has no mixing from any of them).

In El Adelya area**,** to detect spatial similarity among groups, cluster analysis (CA) was applied on 22 groundwater samples and 1 surface water sample (El Adelya canal), 22 groundwater samples located into 2 main clusters (fig. 9-b). Cluster 1 (C1) includes 13 groundwater samples which is more affected by El Adelya canal and all of them have the lowest TDS values (range from 506 ppm to 1344 ppm)

Cluster 2 (C2) includes 8 samples which is less affected by El Adelya canal and have higher values of TDS (range from 1676 ppm to 2574 ppm)

Sample No. 44 is independent sample and has the highest TDS value equal 3425 ppm.

4- Conclusion

The results obtained in the present study show that coupling hydrogeochemical modeling (using software package NETPATH for windows) with geostatistical techniques (using software SPSS for windows) is an effective approach to detect the effect of surface water system on groundwater composition of the Quaternary aquifer in the study area. To achieve the main target of this article, fifty three groundwater samples (thirty one groundwater samples from El Gabal Al Asfar area and twenty two groundwater samples from El Adelya area) and five surface water samples (Ismaylia Canal, El Belbaisy drain, El Gabal Al Asfar drain and Mixed drain in El Gabal Al Asfar area and El Adelya Canal in El Adelya area). The major conclusions of the study are as follows:

- All the groundwater samples are supersaturated with respect to the main carbonate minerals (Calcite, Aragonite, Dolomite and Rhodochor), which reflect slightly alkaline character to groundwater.
- Most of groundwater are supersaturated with respect to iron minerals phases (Hematite, Goethite, Siderite and $Fe(OH)_3$ such minerals reflect the sensitivity of iron to oxidation even in low concentrations
- Few groundwater samples are supersaturated with respect to phosphate minerals (Hydroxap and Viviante) which concentrated in El Gabal Al Asfar farm; this is due to agricultural activities in this area.
- Most of groundwater samples are supersaturated with respect to Gibbs.

- The majority of groundwater samples in El Gabal Al Asfar area are mild scale forming and in El Adelya area the majority of the groundwater samples are some faint coating.
- In El Gabal Al Asfar area there are mixing in groundwater samples Nos. 1 to 12 inclusive from Ismailia canal and El Belbasy drain rang from low to high
- In El Gabal Al Asfar area there are mixing in groundwater samples Nos. 13 to 31 inclusive from El Belbasy drain, El Gabal Al Asfar drain and the mixed drain rang from low to moderate.
- On trilinear diagram most of groundwater samples are clustered around surface water, indicating the effect of leakage on their chemistry
- In El Adelya area there are mixing in all groundwater samples from El Adelya canal, samples Nos. 32 to 44 inclusive range from moderate to very high the rest of the samples have low mixing.
- Pearson Correlation Coefficients were calculated for twenty variables (pH, EC, TDS, total hardness, alkalinity, permanent hardness, Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-}, PO_4^{3-}, Al, Sr, Fe, Mn, COD and BOD)
- R-mode factor analysis was made on the same twenty variables, five principal factors were obtained for groundwater in El Gabal Al Asfar area
  - a- F1 factor is composed of EC, TDS, total hardness, Ca^{2+}, Mg^{2+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-}, Al, Sr, and Fe.
  - b- F2 is composed of pH, Na^{+}, NO_3^{-}, PO_4^{-3} and Mn.
  - c- F3 is composed of alkalinity and HCO_3^{-}.
  - d- F4 is composed of COD
  - e- F5 is composed of Al
- Four principal factors were obtained for groundwater in El Adelya area
  - a- F1 is composed of EC, TDS, total hardness, Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, NO_3^{-} and Sr.
  - b- F2 is composed of PO_4^{-3} and COD
  - c- F3 is composed of HCO_3^{-}, SO_4^{2-} and Mn.
  - d- F4 is composed of Fe.
- Finally hierarchical clusters (Dendrogram) were constructed; most of groundwater samples are clustered around the surface water samples confirming the effect of surface water system on the groundwater and the data is in agreement with the mixing ratio (Table 4)

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Table (1): Major constituents of groundwater and surface water samples in mg/l.

Sample No.	pH	T°C	EC	TDS	Ca^{2+}	Mg^{2+}	Na^{+} + K^{+}	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^-	PO_4^{3-}	Fe^{3+}	Al^{3+}	Sr^{2+}
El Gabal Al Asfar area															
1	8.4	25	428	350	47	49	28	164	160	58	8	ND	0.2385	0.0487	0.295
2	8.3	25	961	730	129	40	78	343	200	100	2	ND	0.4645	0.0813	1.092
3	8.3	25	1370	1018	106	31	217	489	320	75	8	ND	0.2157	0.0712	1.217
4	8.2	25	1248	656	78	48	121	512	70	65	5	ND	0.8209	0.8637	1.666
5	8.4	25	961	610	78	38	103	329	125	95	4	ND	0.0734	0.1026	1.943
6	8.5	28	1280	759	81	49	132	301	160	163	ND	1.0	0.1355	0.0956	2.507
7	8.6	27	777	375	45	29	66	231	45	62	3	ND	0.5171	0.0933	0.7611
8	8.5	26	734	402	39	34	66	211	72	74	5	ND	0	0.1243	1.89
9	8.3	25	1000	645	110	52	51	343	106	150	30	ND	1.005	0.5009	2.398
10	7.9	25	1765	986	208	76	24	384	300	175	22	ND	1.39	0.2735	5.848
11	8.2	25	988	630	98	31	84	306	180	75	3	ND	1.578	0.1304	0.5912
12	8.6	25	1967	1274	98	38	321	311	400	250	32	1.4	0.2889	0.0794	1.531
13	8.6	25	1173	688	71	29	161	348	180	75	24	2.3	0.1031	<0.01	1.175
14	8.8	25	1144	600	99	26	103	331	70	108	8	2.0	0.0447	0.1735	1.203
15	8.9	25	1097	561	89	23	93	284	96	94	4	3.0	0	0.1387	0.8517
16	8.9	26	1090	577	79	30	97	288	120	84	8	3.0	0.597	0.1486	0.9041
17	8.9	25	1070	545	85	29	88	294	84	89	10	2.0	0	0.1097	0.714
18	8.8	25	1070	532	71	29	98	254	89	98	18	5.0	0	0.2188	0.6697
19	8.9	24	1000	534	65	35	99	261	70	110	7	4.0	0.0623	0.1931	0.6349
20	8.8	26	994	502	69	25	96	237	70	100	7	4.0	0	0.1485	0.6442
21	8.9	26	1256	655	102	40	100	304	95	142	8	2.0	0	0.1393	0.8484
22	8.9	30	1178	579	79	26	106	314	88	96	8	3.0	0	0.1489	0.809
23	9.1	25	1080	603	91	29	107	311	90	110	12	2.0	0	0.1621	0.8438
24	8.5	25	1437	903	125	31	168	288	250	180	22	0.4	1.353	0.2608	2.788
25	8.4	25	1028	628	90	24	105	279	180	85	22	3.4	0.1049	0.1306	0.7069
26	8.4	25	1009	608	94	26	100	279	150	90	16	3.1	0.5759	0.3792	1.075
27	8.3	25	1120	691	118	24	116	352	140	110	22	2.6	0.4065	0.3201	1.203
28	8.6	25	1447	964	114	35	184	297	360	100	29	2.5	0.0876	0.1288	1.556
29	8.4	25	1477	757	100	37	142	329	140	155	32	2.4	0.6176	0.3883	1.894
30	8.5	25	2350	1456	237	64	181	348	660	140	40	1.0	0.8968	0.9393	3.494
31	8.5	25	1230	793	118	33	125	338	240	90	31	1.6	0.1888	0.1321	0.9753
Ismailia Canal	8.20	25	480.00	204.49	31.36	16.6698	28.62	150.675	20	32.5	3.766	0	2.512	3.119	0.311
El Belbasy	7.50	25	2190.00	1275.46	148.96	47.628	268	411.75	350	255	23.972	1.9	ND	ND	ND

D.															
El Gabal Al Asfar Drain	8.20	25	1237.00	737.21	78.4	23.814	163.17	283.65	180	150	27.705	2.86	0.5115	0.641	1.233
Mixed Drain	8.54	25	1185.00	680.93	56.84	49.7421	127	150.7	220	152	60	3	3.157	1.785	0.9085
El Adelya area															
32	8.2	27.2	1980	845	16	8	304	201	120	288	12	1	0.3891	0.1299	0.3711
33	8.33	27	1775	910	51	32	241	191	210	276	6	ND	0	0.0367	1.485
34	8.44	27	780	527	35	16	141	157	55	194	ND	ND	0.7381	0.0979	1.003
35	8.72	27.2	1050	520	6	6	185	211	64	144	ND	ND	0.3823	0	0.1632
36	8.6	31	1200	536	12	7	182	174	90	144	ND	ND	0.114	0.1238	0.128
37	8.75	29.5	1900	868	24	14	296	268	30	360	ND	ND	1.617	0.0572	0.486
38	8.4	31.5	4556	2485	106	35	787	204	100	1344	18	10	0	0.0351	1.873
39	8.24	29.5	3160	1676	90	35	508	191	100	840	8	ND	0.0794	0	1.929
40	8.8	30	1126	506	14	7	171	194	35	168	ND	ND	0	0.148	0.2361
41	8.25	30.5	3200	2161	133	63	612	171	180	1080	8	ND	0.5622	0.4598	3.177
42	8.08	29.2	3600	1901	139	56	510	188	180	912	8	ND	0	0	2.575
43	8.21	28.2	3600	2024	114	48	573	201	100	1080	8	ND	0.2148	0	2.504
44	7.99	28.5	5900	3425	277	99	888	164	40	2030	18	ND	0	0.0592	5.47
45	8.42	26.9	1845	888	57	30	249	211	110	330	12	ND	0.1162	0.0719	1.078
46	8.15	27.3	3420	1876	91	37	541	184	290	816	3	ND	1.256	0	1.696
47	8.08	28	4500	2574	134	44	806	164	200	1296	18	ND	0	0.0331	2.294
48	8.4	27	1461	669	24	12	224	201	30	270	ND	ND	0.1207	0.0699	0.5186
49	8.4	27	2690	1344	69	20	414	191	240	498	26	ND	0.0998	0.1584	1.065
50	8	27.5	2330	1240	53	30	377	245	290	360	6	ND	0.2419	0.2907	1.13
51	8.02	27	3380	1716	104	37	506	208	200	756	12	ND	0	0.0404	1.983
52	8	27	2250	1195	77	20	316	228	370	288	5	ND	0	0.1536	1.165
53	8.42	27	2420	1332	57	26	387	235	350	390	5	ND	0.5353	0.0534	0.9915
Adelya Canal	8.79	29.9	444	222	33	14	37	151	26	29	0	0	0.685	0.569	0.3184

Table (2) Saturation indices for present minerals in groundwater of Quaternary aquifer El Gabal Al Asfar area.

	Calcite	Aragonite	Dolomite	Siderite	Rhodochor	Strontite	Gibbs	Hematite	Geothite	$Fe(OH)_3$	Hydroxap	Viviante
1	0.76	0.62	1.88	0.48	0.59	-0.9	0.39	16.68	7.34	1.44	-	-
2	1.37	1.2	2.52	0.88	1.04	-0.3	0.68	16.47	7.23	1.34	-	-
3	1.37	1.23	2.56	0.63	1.14	-0.1	0.63	15.64	6.82	0.93	-	-
4	1.23	1.08	2.6	1.19	1.02	0.01	1.8	16.28	7.14	1.25	-	-
5	1.22	1.08	2.48	0.12	0.59	0.08	0.68	15.37	6.68	0.78	-	-
6	1.31	1.63	2.77	0.35	0.67	0.25	0.45	16.4	7	1.21	7.2	-1
7	1.12	0.98	2.44	0.83	0.94	-0.2	0.35	18	7.86	2.04	-	-
8	0.92	0.77	2.15	-	0.16	0.06	0.62	-	-	-	-	-
9	1.26	1.01	2.56	1.23	0.84	0.06	1.5	17.28	7.63	1.74	-	-
10	1.55	1.01	2.22	1.09	0.96	0.06	1.6	15.24	6.62	0.72	-	-
11	1.1	0.95	2.05	1.35	0.6	-0.7	0.99	17	7.54	1.65	-	-
12	1.36	1.2	2.67	0.64	0.62	0.03	0.37	17.35	7.67	1.78	8	0.2
13	1.33	1.2	2.62	0.24	-	0.03	-	16.52	7.26	1.36	8.5	-0.5
14	1.67	1.53	3.13	-0.3	0.75	0.24	0.55	16.1	7	1.15	9.46	-2.5
15	1.65	1.5	3.06	-	0.62	0.12	0.37	-	-	-	10.1	-
16	1.64	1.5	3.23	0.48	0.61	0.18	0.3	18.48	8.2	2.33	10	0.02
17	1.69	1.54	3.27	-	0.26	0.1	0.19	-	-	-	9.6	-
18	1.44	1.3	2.85	-	0.39	-0.1	0.63	-	-	-	10.2	-
19	1.52	1.37	3.13	-0.43	0.31	0.005	0.47	16.55	7.32	1.4	9.93	-2.3
20	1.44	1.29	2.8	-	0.45	-0.1	0.42	-	-	-	9.99	-
21	1.76	1.62	3.5	-	0.78	0.17	0.22	-	-	-	9.79	-
22	1.72	1.58	3.38	-	0.14	0.2	0.12	-	-	-	10.3	-
23	1.82	1.68	3.52	-	0.7	0.29	0.2	-	-	-	10	-
24	1.39	1.24	2.52	1.32	-0.05	0.2	0.99	18.4	8.19	2.3	6.88	1.46
25	1.18	1.04	2.14	0.22	0.25	-0.5	0.82	15.8	6.9	1.01	8.9	0.19
26	1.21	1.07	2.22	0.96	0.53	-0.3	1.26	17.24	7.62	1.73	8.8	2.27
27	1.3	1.16	2.26	0.83	0.5	-0.2	1.29	16.39	7.2	1.3	8.6	1.52
28	1.46	1.32	2.76	0.13	0.31	0.07	0.59	16.34	7.16	1.27	9.2	-0.8
29	1.31	1.17	2.54	1.04	0.57	0.06	1.28	17.26	7.63	1.74	8.5	2
30	1.6	1.46	2.98	1.12	0.63	0.23	1.53	17.95	7.97	2.1	8.5	1.3
31	1.46	1.32	2.73	0.54	0.74	0.15	0.7	16.67	7.33	1.44	8.4	0.1

Table (3) Saturation indices for present minerals in groundwater of Quaternary aquifer El Adelya area.

Sample No.	**calcite**	**aragonite**	**Dolomite**	**Siderite**	**Gibbs**	**Hematite**	**Geothite**	**$Fe(OH)_3$**	**Hydroxap**	**Viviante**
32	0.19	0.04	0.44	0.64	0.88	16.2	6.93	1.12	3.57	1.2
33	0.74	0.59	1.65	-	0.2	-	-	-	-	-
34	0.71	0.57	1.45	0.95	0.54	18	7.83	2	-	-
35	0.33	0.18	1.04	0.52	-	18	7.84	2.02	-	-
36	0.49	0.36	1.18	-0.1	0.29	16.8	6.96	1.28	-	-
37	1	0.87	2.2	1.02	-0.1	19.2	8.27	2.54	-	-
38	1.07	0.93	2.08	-	-0.1	-	-	-	10.4	-
39	0.9	0.76	1.8	-0.1	-	15.2	6.27	0.54	-	-
40	0.78	0.64	1.68	-	0.23	-	-	-	-	-
41	0.99	0.85	2.06	0.68	1.19	17	7.11	1.14	-	-

42	0.9	0.76	1.8	-	-	-	-	-	-	-
43	0.95	0.81	1.92	0.32	-	15.8	6.66	0.88	-	-
44	0.96	0.82	1.88	-	0.65	-	-	-	-	
45	0.93	0.79	1.96	0.19	0.41	16.2	6.9	1.11	-	-
46	0.74	0.6	1.47	1	-	16.9	7.28	1.47	-	-
47	0.79	0.65	1.49	-	0.33	-	-	-	-	
48	0.6	0.46	1.27	0.23	0.4	16.1	6.9	1.1	-	-
49	0.9	0.76	1.64	0.06	0.77	15.9	6.8	0.99	-	-
50	0.5	0.37	1.16	0.31	1.4	14.6	6.11	0.3	-	-
51	0.75	0.6	1.4	-	0.54	-	-	-	-	-
52	0.64	0.5	1.1	-	1.16	-	-	-	-	-
53	0.89	0.75	1.8	0.8	0.28	17.4	7.56	1.74	-	-

Table (4) Classification of water corrosion potential based on the calcite saturation indices values and recommended treatments

Saturation indices (SI)	Description	General recommendations	Saturation indices (SI)	Description	General recommendations
-5	Severe corrosion	Treatment recommended	0.5	Some faint coating	Treatment typically not needed
-4	Moderate corrosion	Treatment recommended	1	Mild scale forming	Some aesthetic problems
-3	Moderate corrosion	Treatment recommended	2	Mild scale forming	Some aesthetic – considered
-2	Moderate corrosion	Treatment should be considered	3	Moderate scale forming	Treatment should be considered
-1	Mild corrosion	Treatment should be considered	4	Severe scale forming	Treatment probably required
-0.5	Mild corrosion	Treatment probably not needed	5	Severe scale forming	Treatment required
0	Balanced	Treatment typically not needed	-	-	-

Table (5) Mixing Ratio for El Gabal Al Asfar area

SN	Sample No. 14	Ismailia Canal	El Belbasy drain	El Gabal Al Asfar drain	Mixed drain	The total mixing from surface water	Mixing degree
1	61	9	30	0	0	39	Low
2	21	57	22	0	0	79	High
4	74	21	5	0	0	26	Low
5	34	49	17	0	0	66	Moderate
6	65	2	33	0	0	35	Low
7	32	65	3	0	0	68	Moderate
8	31	60	9	0	0	69	Moderate
9	21	58	21	0	0	79	High
10	57	2	41	0	0	43	Low
11	70	14	16	0	0	30	Low
12	42	54	4	0	0	58	Moderate
13	59	0	32	0	9	41	Low
15	82	0	2	4	12	18	Low
16	60	0	2	25	13	40	Low
17	49	26	0.6	23	1.4	51	Moderate
20	45	35	2	12	6	55	Moderate
21	82.5	0	2.5	0	15	17.5	Low
22	58	7.5	5.2	27.15	2.15	42	Low
24	37	4	51	0	8	63	Moderate
25	44.6	0	18.4	0	37	55.4	Moderate
26	22	6	5	65	2	78	High
27	69	0	17	0	14	31	Low
29	63	0	11	0	26	37	Low
31	7	0	33	51	9	93	Very High

Table (6) Mixing Ratio for El Adelya area

No.	Sample No.53	El Adelya canal	the total mixing from surface water	Mixing degree
32	29	71	71	High
33	57	43	43	Moderate
34	9	91	91	Very High
35	11	89	89	Very High
36	20	80	80	Very High
37	1	99	99	Very High
38	22	78	78	High
39	23	77	77	High
40	2	98	98	Very High
41	49	51	51	Moderate
42	49	51	51	Moderate
43	22	78	78	High
44	4	96	96	Very High
45	74	26	74	Low
46	81	19	19	Low
47	55	45	45	Low
48	90	10	10	Low
49	65	35	35	Low
50	84	16	16	Low
51	55	45	45	Low
52	54	46	46	Low

Mixing Ratio from surface water < 50% Low mixing
From 50% - 70% Moderate mixing
From 70% - 80% High mixing
From 80% - 100% Very high mixing

Table (7) the Pearson correlation coefficient matrix for El Gabal Al Asfar area

	pH	EC	TDS	TH	Alk	PerH	Ca	Mg	Na	HCO_3^{2-}	SO_4^{2-}	Cl	NO_3^{1-}	PO_4^{3-}	Al^{3+}	Sr^{2+}	Fe^{3+}	Mn^{2+}	COD	BOD
pH	1.00																			
EC	-0.14	1.00																		
TDS	-0.30	0.93	1.00																	
TH	-0.47	0.75	0.76	1.00																
Alk	-0.25	0.42	0.39	0.32	1.00															
PerH	-0.43	0.62	0.66	0.93	-0.03	1.00														
Ca^{2+}	-0.38	0.79	0.79	0.96	0.35	0.87	1.00													
Mg^{2+}	-0.52	0.46	0.49	0.81	0.19	0.80	0.61	1.00												
Na^{+}	0.07	0.66	0.72	0.11	0.32	0.00	0.20	-0.11	1.00											
HCO_3^{-}	-0.41	0.47	0.47	0.43	0.97	0.10	0.45	0.28	0.32	1.00										
SO_4^{2-}	-0.33	0.80	0.93	0.74	0.16	0.74	0.77	0.49	0.59	0.26	1.00									
Cl	-0.08	0.68	0.63	0.47	0.06	0.46	0.45	0.39	0.51	0.10	0.42	1.00								
NO_3^{-}	-0.21	0.65	0.66	0.55	0.02	0.57	0.60	0.30	0.43	0.12	0.65	0.52	1.00							
PO_4^{3-}	0.62	-0.02	-0.20	-0.33	-0.20	-0.29	-0.19	-0.52	0.07	-0.31	-0.23	-0.04	0.11	1.00						
Al^{3+}	-0.29	0.47	0.38	0.54	0.36	0.45	0.50	0.46	0.08	0.46	0.33	0.11	0.43	-0.10	1.00					
Sr^{2+}	-0.54	0.62	0.57	0.82	0.25	0.77	0.72	0.79	0.02	0.35	0.50	0.55	0.40	-0.41	0.42	1.00				
Fe^{3+}	-0.64	0.31	0.34	0.55	0.15	0.54	0.51	0.48	-0.1	0.29	0.33	0.25	0.27	-0.49	0.45	0.55	1.00			
Mn^{2+}	-0.60	0.16	0.23	0.46	0.56	0.30	0.35	0.55	-0.1	0.61	0.16	0.03	-0.16	-0.58	0.19	0.45	0.42	1.00		
COD	0.25	0.00	0.01	0.02	0.12	-0.04	0.05	-0.05	0.0	0.09	0.02	-0.13	-0.03	-0.11	-0.06	-0.09	0.12	0.04	1.00	
BOD	0.06	-0.43	-0.39	-0.29	-0.44	-0.14	-0.34	-0.11	-0.3	-0.47	-0.29	-0.15	-0.20	0.01	-0.35	-0.02	-0.22	-0.19	-0.30	1

Table (8). the Pearson correlation coefficient matrix for El Adelya area

	pH	EC	TDS	TH	Alk	PerH	Ca	Mg	Na	HCO_3^{2-}	SO_4^{2-}	Cl	NO_3^{1-}	PO_4^{3-}	Al^{3+}	Sr^{2+}	Fe^{3+}	Mn^{2+}	COD	BOD
pH	1																			
EC	-0.6	1.0																		
TDS	-0.6	1.0	1.0																	
TH	-0.6	0.9	0.9	1.0																
Alk	0.2	-0.3	-0.3	-0.4	1.0															
PerH	-0.6	0.9	0.9	1.0	-0.5	1.0														
Ca	-0.7	0.9	0.9	1.0	-0.4	1.0	1.0													
Mg	-0.6	0.9	0.9	1.0	-0.4	1.0	1.0	1.0												
Na	-0.6	1.0	1.0	0.9	-0.3	0.8	0.9	0.8	1.0											
HCO3	0.2	-0.3	-0.3	-0.4	1.0	-0.5	-0.4	-0.4	-0.3	1.0										
SO4	-0.5	0.1	0.1	0.1	0.2	-0.1	0.1	0.1	0.1	0.2	1.0									
Cl	-0.5	1.0	1.0	0.9	-0.4	0.9	0.9	0.9	1.0	-0.4	-0.1	1.0								
NO3	-0.4	0.7	0.6	0.5	-0.3	0.5	0.6	0.5	0.7	-0.2	0.2	0.6	1.0							
PO4	0.1	0.3	0.3	0.1	0.1	0.0	0.1	0.0	0.4	0.0	-0.1	0.3	0.3	1.0						
Al	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.2	-0.1	0.0	-0.1	1.0					
Sr	-0.6	0.9	0.9	1.0	-0.5	1.0	1.0	1.0	0.8	-0.4	0.0	0.9	0.5	0.0	0.0	1.0				
Fe	0.3	-0.2	-0.2	-0.2	0.3	-0.2	-0.3	-0.2	-0.2	0.3	0.0	-0.2	-0.4	-0.1	0.0	-0.2	1.0			
Mn	0.0	-0.3	-0.3	-0.3	0.3	-0.3	-0.3	-0.2	-0.3	0.3	0.3	-0.4	-0.3	-0.2	0.4	-0.3	0.4	1.0		
COD	0.1	0.3	0.3	0.3	0.1	0.4	0.3	0.3	0.3	0.1	-0.4	0.4	0.0	0.3	-0.1	0.3	0.2	###	1.0	
BOD	-0.3	0.0	0.1	0.2	-0.2	0.2	0.2	0.2	0.0	-0.2	0.1	0.0	0.2	-0.2	0.3	0.2	-0.1	###	0.0	1.0

Table (9): Component matrix of El Gabal Al Asfar

	F1	F2	F3	F4	F5
pH	-0.551	0.57	0.08	0.29	-0.02
EC	0.848	0.45	0.12	-0.04	0.02
TDS	0.878	0.39	0.10	-0.13	-0.16
TH	0.941	-0.07	-0.17	0.14	0.06
Alkalinity	0.446	-0.18	0.81	-0.13	0.16
Per. H.	0.833	-0.03	-0.48	0.19	0.01
Ca^{2+}	0.904	0.08	-0.09	0.18	0.08
Mg^{2+}	0.757	-0.36	-0.29	0.02	0.00
Na^{+}	0.358	0.68	0.40	-0.35	-0.25
HCO_3^-	0.569	-0.23	0.74	-0.12	0.16
SO_4^{2-}	0.808	0.34	-0.09	-0.02	-0.21
Cl^-	0.570	0.41	-0.19	-0.29	-0.17
NO_3^-	0.619	0.50	-0.22	0.09	0.16
PO_4^{3-}	-0.389	0.63	0.00	0.16	0.47
Al^{3+}	0.586	-0.07	0.11	0.27	0.58
Sr^{2+}	0.809	-0.22	-0.29	-0.11	0.03
Fe^{3+}	0.608	-0.40	-0.13	0.21	-0.07
Mn^{2+}	0.484	-0.67	0.29	-0.15	-0.11
COD	0.004	-0.01	0.29	0.72	-0.54
BOD	-0.389	-0.2	-0.56	-0.40	0.00

Table (10): Component matrix of El Adelya

	1	2	3	4
pH	-0.657	0.442	-0.353	0.17
EC	0.949	0.165	0.189	-0.127
TDS	0.968	0.11	0.167	-0.039
TH	0.974	-0.045	0.063	0.153
Alkalinity	-0.473	0.395	0.692	-0.064
Per. H.	0.957	-0.002	-0.056	0.216
Ca^{2+}	0.981	-0.029	0.052	0.108
Mg^{2+}	0.939	-0.072	0.087	0.226
Na^{+}	0.927	0.179	0.18	-0.113
HCO_3^-	-0.458	0.338	0.725	-0.046
SO_4^{2-}	0.056	-0.512	0.664	-0.306
Cl^-	0.969	0.201	0.017	0.031
NO_3^-	0.65	-0.046	0.053	-0.5
PO_4^{3-}	0.192	0.562	0.037	-0.468
Al^{3+}	-0.049	-0.454	0.253	0.297
Sr^{2+}	0.963	-0.058	0.015	0.214
Fe^{3+}	-0.296	0.273	0.305	0.604
Mn^{2+}	-0.364	-0.239	0.562	0.313
COD	0.315	0.684	-0.015	0.389
BOD	0.168	-0.517	-0.117	0.179

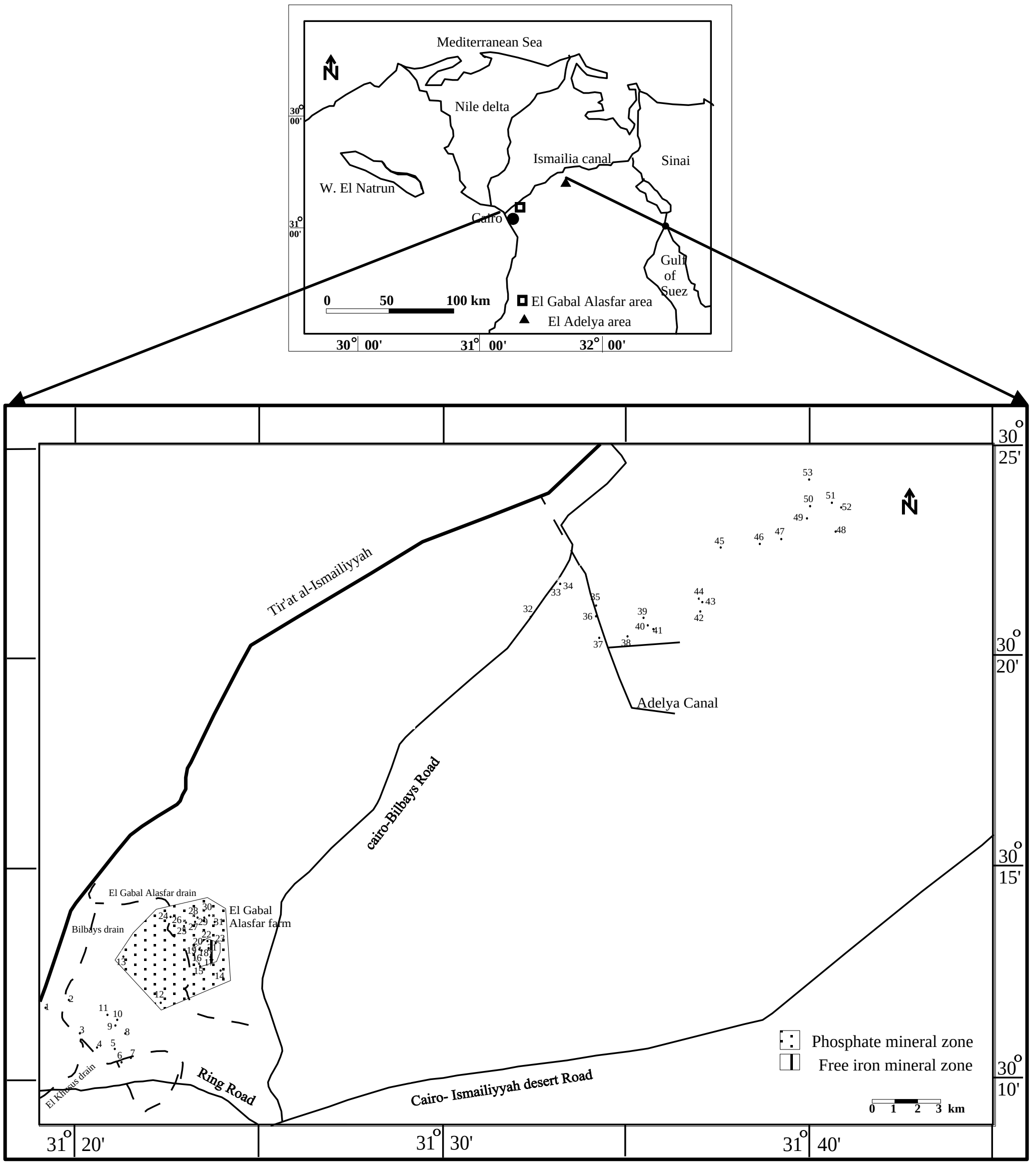


Fig. (1): Wells' location map.

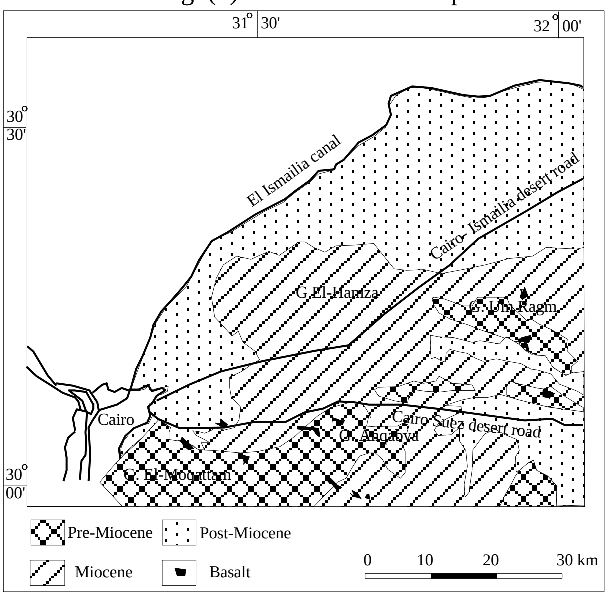
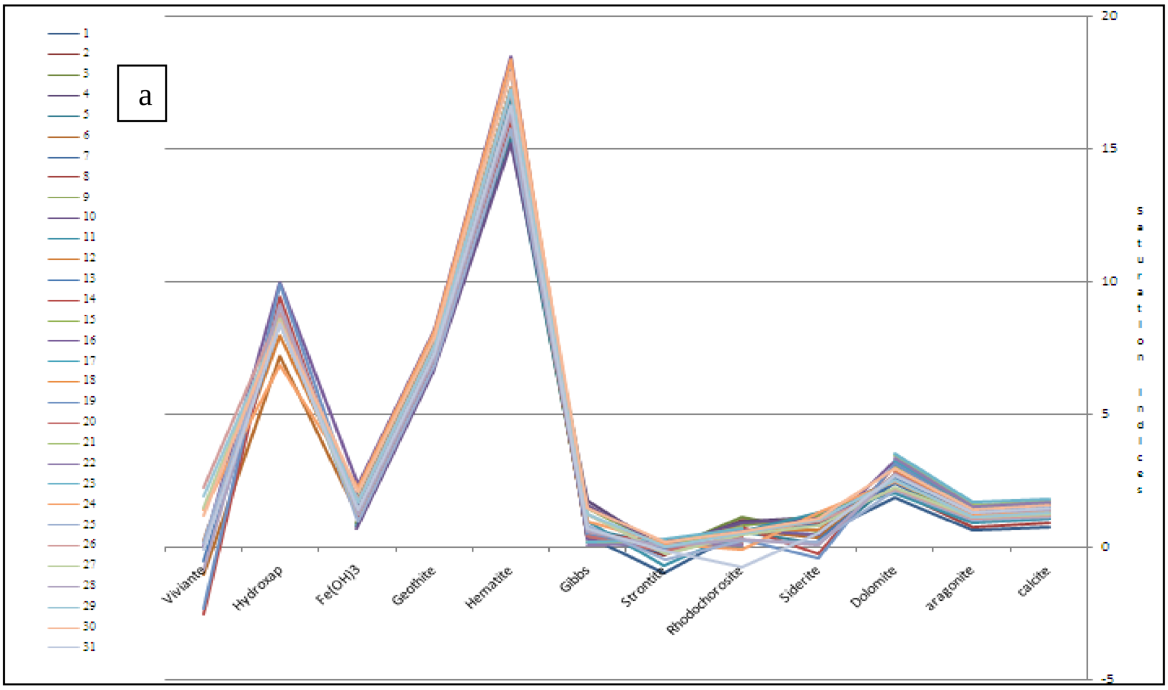


Fig. (2): Geological map (Modified after Conoco, 1987).



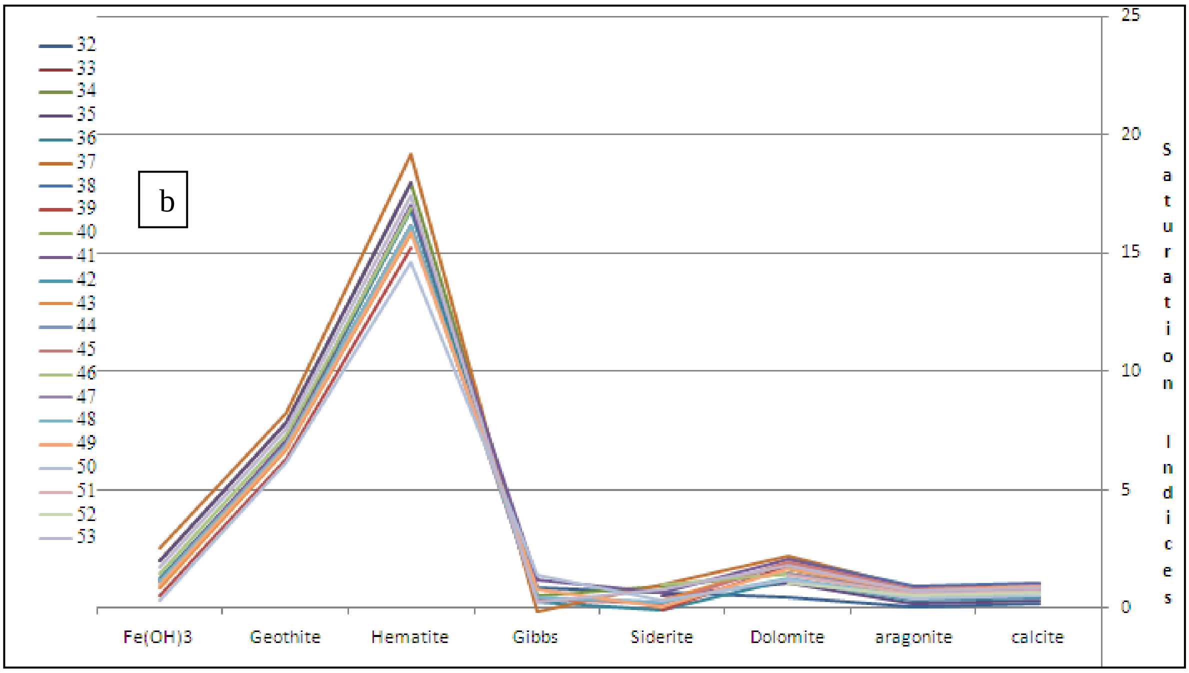


Fig (3) mineral distribution bar of a- El Gabal Al Asfar area b- El Adelya area

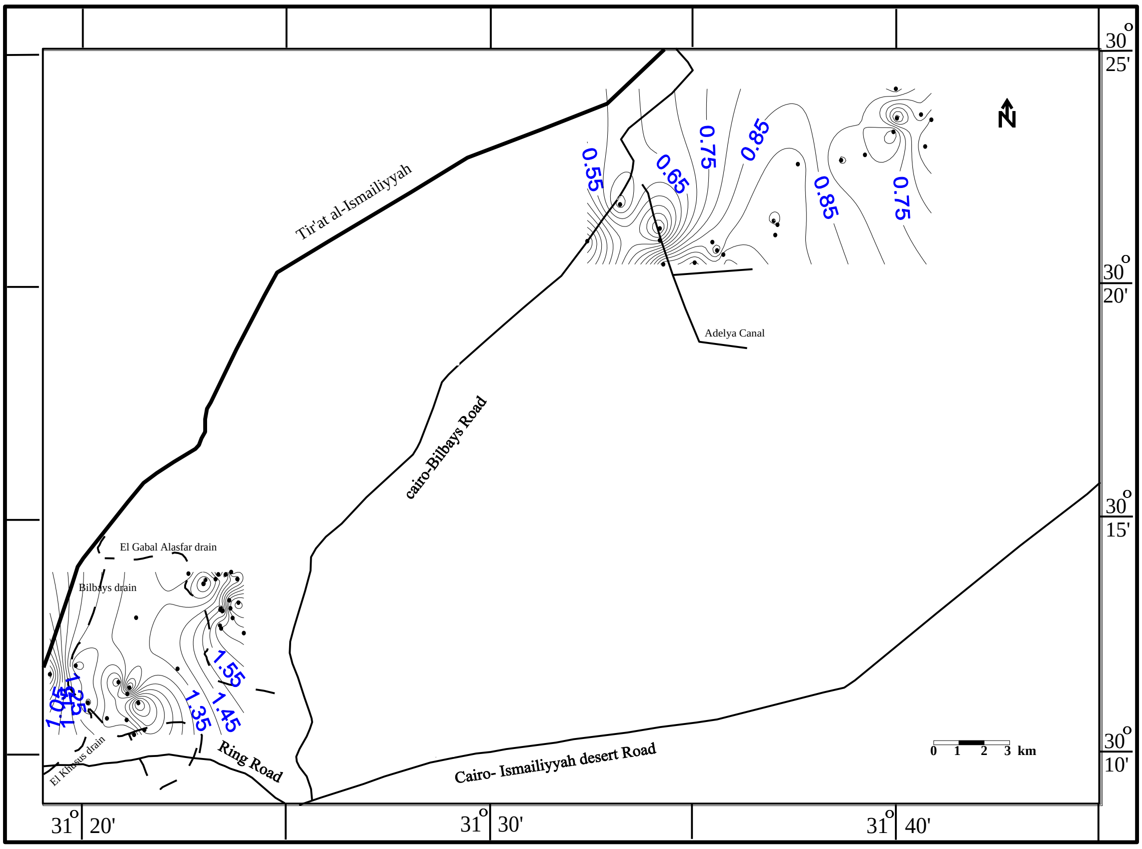


Fig. 4: Isogram of SI of Calcite in the study area

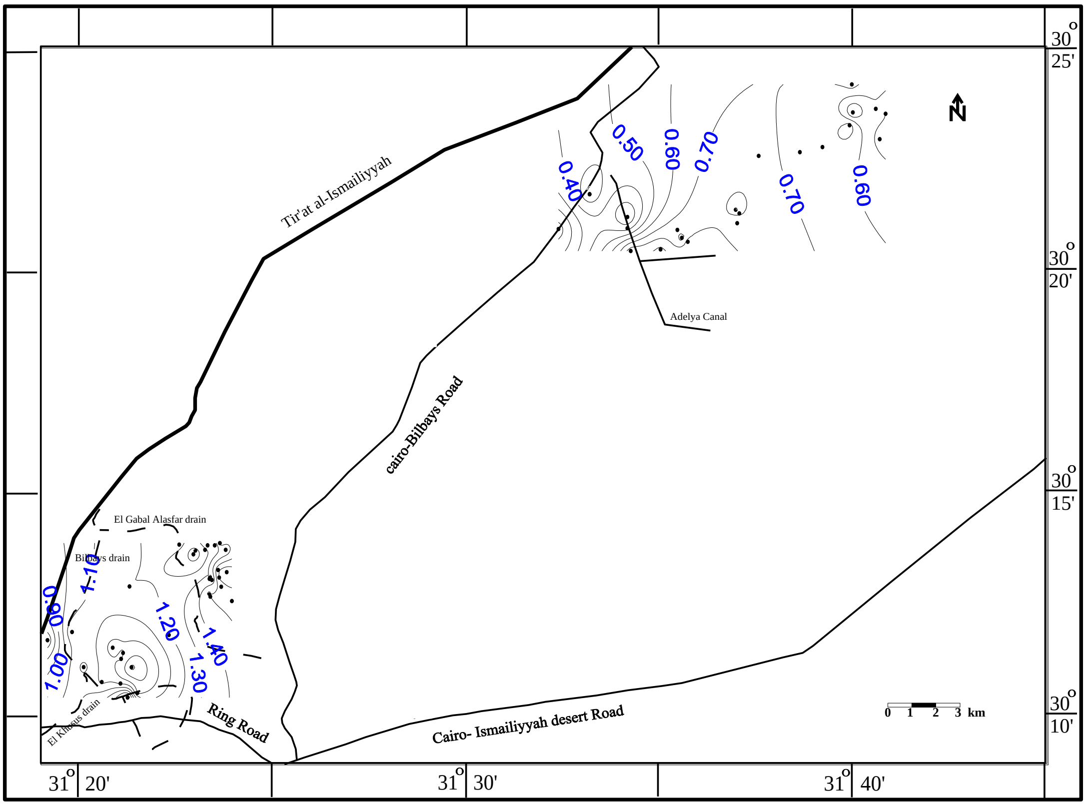


Fig. 5: Isogram of SI of Aragonite in the study area

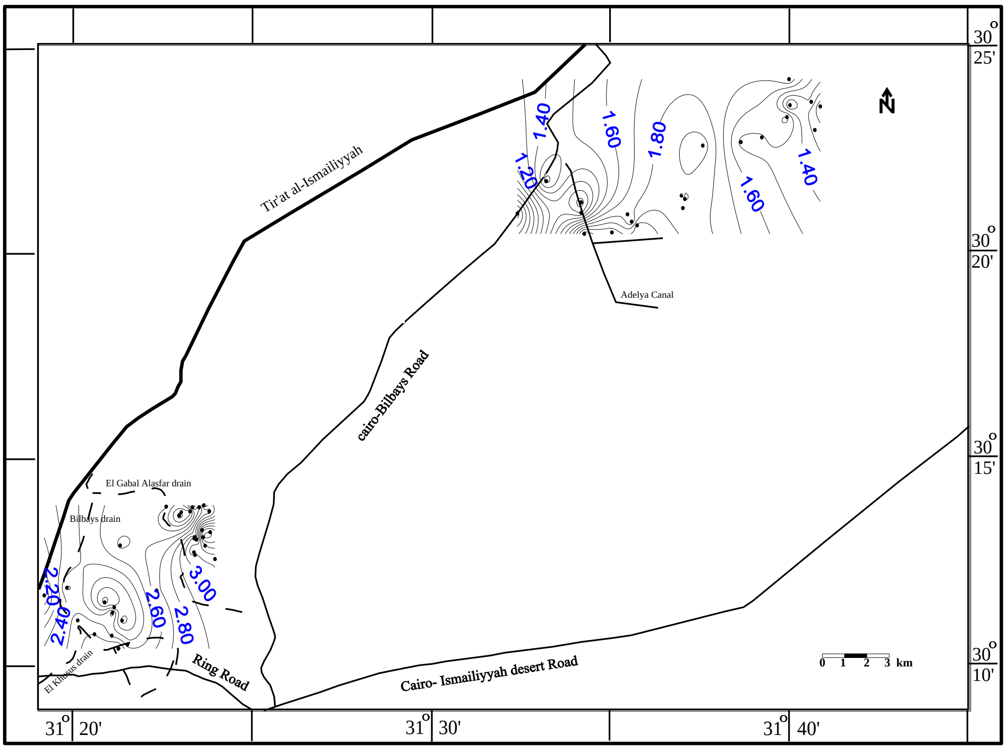


Fig. 6: Isogram of SI of Dolomite in the study area

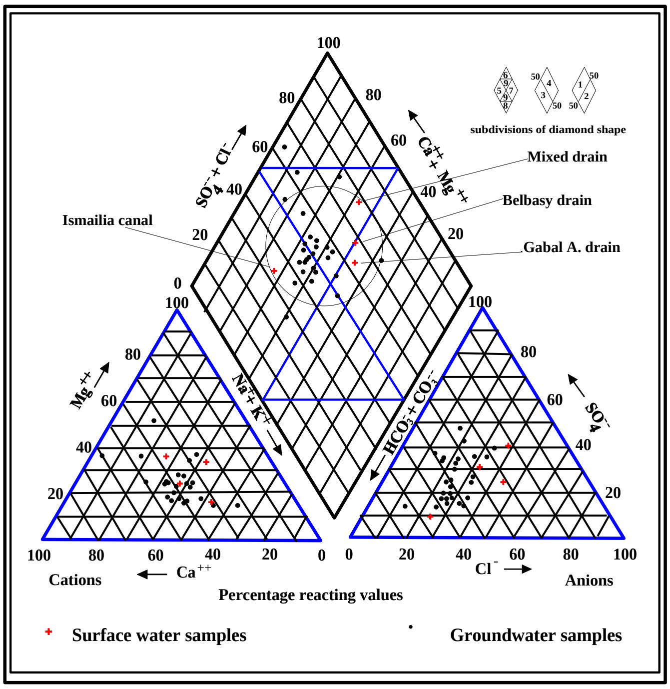
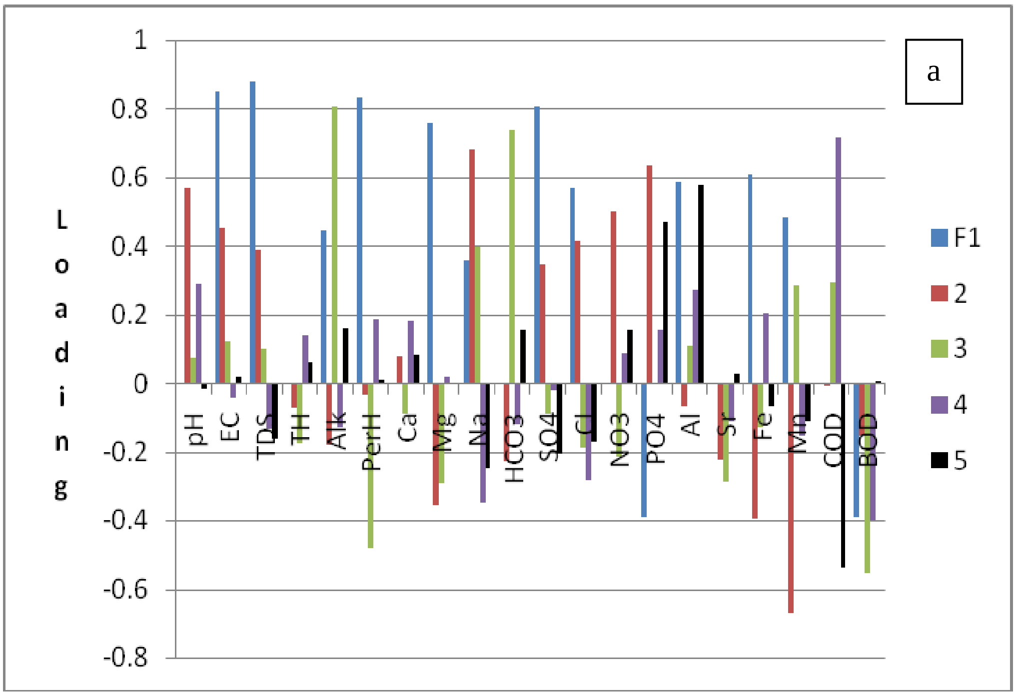
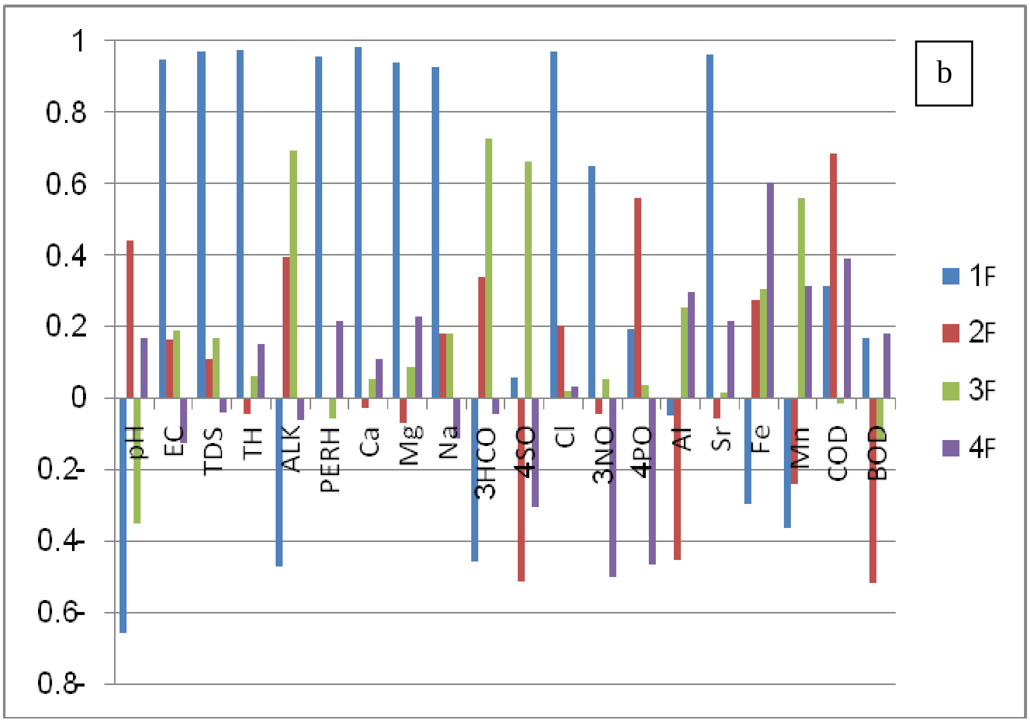


Fig (7): Trilinear diagram of groundwater samples in El Gabal El Asfar area.





Fig(8): loading of the factor with variable in a- El Gabal Al Asfar area b- El Adelya area

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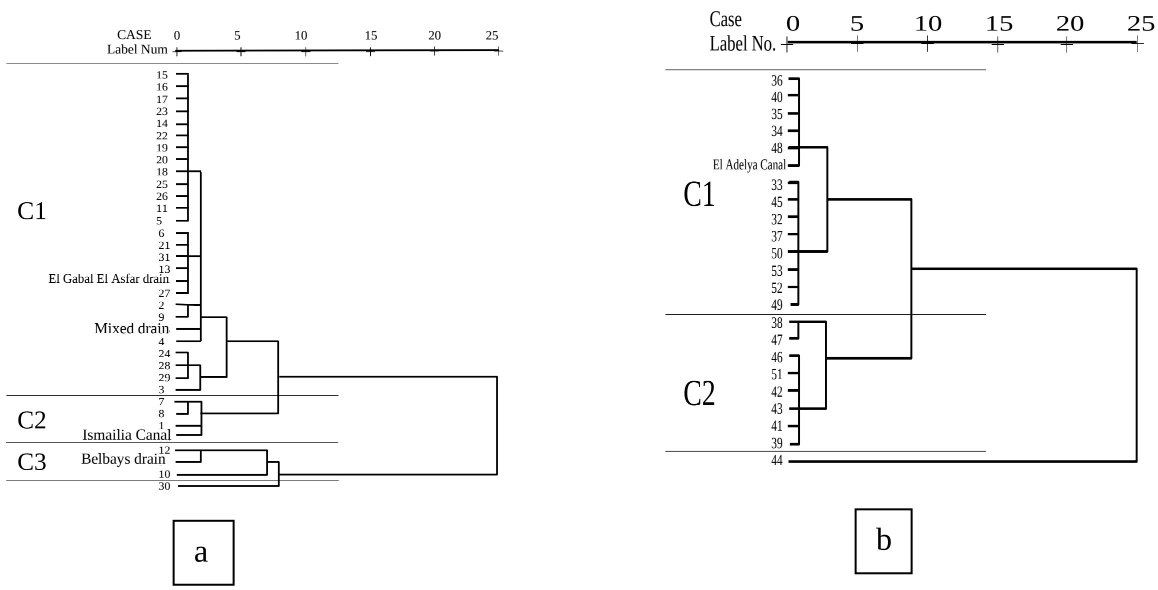

Fig (9): Dendrogram of cluster analysis of a- El Gabal Al Asfar area. b- El Adelya area.