Environmental impact of anthropogenic activity on surface and groundwater systems in the western part of the River Nile, between EL-Edwa - Der Mawas area, El Minia Governorate, Upper Egypt

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Abstract: The aim of this dissertation is to investigate the Environmental impact of anthropogenic activity on the surface and ground-waters systems in the western part of the River Nile, Minia Governorate, Upper Egypt. The situation is further complicated by contamination with lithogenic and anthropogenic (agricultural and sewage wastewaters) sources and low plan exploitation techniques. The Pleistocene aquifer is composed of sand and gravel of different sizes, with some clay intercalation. The semi confined condition was around the River Nile shifted to unconfined outside the floodplain. The groundwater flow generally from south to north and diverts towards the western part and the River Nile**.** Ninety-six and twenty-one water samples were collected from Pleistocene aquifer and surface irrigated waters (Ibrahimia canal, River Nile, and Bahr Youssef) and El Moheet drain. The detail chemical analyses with respect to major and trace elements were accomplished for hydrogeochemical evaluation. The total dissolve solids (TDS) of the surface irrigated water are below 500 ppm which is suitable for drinking and irrigating uses. The As and Ni content of surface water makes it unsuitable for drinking but suitable for irrigation. The River Nile in the study area with respect to the Cd content is inappropriate for drinking and irrigation purposes due to the agricultural activity and inflow from the groundwater (the River Nile is a discharge zone). The Pb and Se concentrations in surface irrigated water are higher than the drinking standards and lower than the irrigation standards The Zn and F concentrations in surface irrigated water are lower than the drinking and irrigation standards. The dissolved oxygen (DO) concentration is more or less equal in surface irrigated water and decline in El Moheet drain by increase in organic wastewaters (BOD and COD) in the drain. The COD and BOD in surface irrigated water are higher than the drinking standards. The B and Cu concentrations in surface irrigated water are lower than drinking and irrigation standards**.** The TDS concentration in groundwater increases generally from southern to northern part of the study area, with groundwater flow. The TDS anomalous areas (800 to 1400 ppm) are attributed to lithogenic, and anthropogenic (agricultural) impact. The B concentration anomalous areas are located due to the western zone that exceed the drinking water standard. The contamination with respect to Cu and Ni is out the aquifer system. The Cd concentration was below the drinking water standard of 0.003 mg/l, therefore no pollution with respect to Cd concentration. The NO2 and Cr concentrations shows no impact on the groundwater quality. The Ba, Fe, Mn, and Pb concentrations impact on the groundwater environment with respect to drinking purpose while it can use in irrigation. The cluster analysis was distinguished into four clusters which subdivided into six sub clusters (A-F). The average concentrations of each sub cluster was determined and correlated with the geographic position. The principal component analysis was established and classified into six factors.

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1. Introduction.

Since groundwater moves through rocks and subsurface soil, it has the opportunity to dissolve substances and pollutants of different sources. Furthermore, they are widely distributed as an anthropogenic pollutant (Rangsivek and Jekel 2005). Heavy metals are encountered in various emission sources related to industrial, transportation, and urban activities and agricultural practices (Brantley and Townsend 1999; Romic and Romic 2003), which have environmental adverse effects. Land disposal of municipal and industrial wastes and application of fertilizers and pesticides for agriculture have contributed to a continuous accumulation of heavy metals in soils (Alloway and Jackson 1991). There is an increased concern regarding the environmental impacts of agricultural practices on the bioavailability and leaching of heavy metals. Fertilizers are usually not sufficiently purified during the processes of manufacture; for economic reasons, they usually contain several impurities, among them heavy metals, (Santos et al 2002; Tanji and Valoppi 1989). Also heavy metals often form a part of the active compounds of pesticides. Surpluses of heavy metals in soils are frequently caused by the use of fertilizers, metallo-pesticides and sewage sludge. Among the fertilizers that are being used in farmlands super phosphate contains the highest concentrations of Cd, Cu, and Zn as impurities. Copper sulphate and iron sulphate have the highest contents of Pb and Ni (Eugenia et al 1996). With sufficient surface water infiltration, soil contaminants, such as heavy metals, can leach to underlying groundwater. Unconfined aquifers with shallow water tables, overlain by permeable soils or another aquifer are especially vulnerable to various contaminants. The anthropogenic developments and the fact that most contaminants penetrate into soils or aquifer and eventually groundwater have caused pollution increase, all acting as a threat to today's world. Cd is a heavy metal with chemical properties similar to Zn, but is much less common in the environment than Zn. Cd occurs in igneous rocks and some sedimentary rocks, which is generally associated with Zn ore minerals like sphalerite and with a range of Cu ore minerals (Picker et al. 1992; Pogotto et al. 2001). Cd is often present in artificial fertilizers and these heavy metals may accumulate in soils in areas that have been used for agriculture for long period (Rattan et al. 2005; Mahvi et al. 2005; Nouri et al. 2006). Recently, attention has been paid to development and rehabilitation in Upper Egypt beyond the overpopulated areas to the north of the country . El-Minia district is a target for many of these activity where it lies in the center of upper Egypt and has a good access through many highways and transportation means. The main water resources in El-Minia district are the River Nile and irrigation canals. Groundwater is used as an auxillary source for irrigation , domestic and industrial purposes in the flood plain and desert. Information on the quality of water sources is of great importance in water quality management of water supplied fields. Some countries have set tolerance limits on the addition of heavy metals to soils because of their long term effects on human, animals, and plants. The major and toxic heavy elements concentrations (Al, As, Ba, Cd, Cr, Cu, Sn, Pb, Hg, Ni, Se, Mn, Fe, NO2, and NH4) in groundwater system, River Nile, Ibrahimia canal, Bahr Youssef, and El Moheet drain in the area between EL-Edwa-Der Mawas, El Minia district **(Fig. 1)** are determined. Dissolved oxygen, COD, and BOD are determined in case of surface water.

2. Geology and hydrogeology.

The River Nile passes through high eastern and western calcareous plateaus with a general slope from south to north about 0.1 m/km (Korany et al 2006). The Nile tends to represent the eastern part of the Valley; therefore, the cultivated area is wider in western part than in the eastern. The investigated area land feature is the young alluvial plain, which is composed of modern Nile silt and clay sediments. It is bounded in both sides by old alluvial plain underlain by mixed sands, gravels, and rock fragments / and structural plateau of limestone layer (Sadek 2001). The surface of the old alluvial plain and structural plateau is dissected by a complex drainage pattern of wadis which represented the inactive shed area. The stratigraphic succession in El Minia area is essentially represented by sedimentary rocks (Tertiary and Quaternary). The distribution of the different rock units was indicated in (Said 1981). The stratigraphic sequence is built up of from base to top as follows (Tamer et al., 1974); Middle Eocene limestone intercalated with shale; Pliocene undifferentiated sands, clays, and conglomerates; Plio-Pleistocene sand and gravel with clay and shale lenses; Pleistocene sand and gravel with clay lenses; and Holocene silt and clay. The study area is highly affected by faulting mainly in NW-SE direction**.** (Sadek 2001). The Nile Valley is essentially of structural origin (Beadnell 1900; Ball 1909; Sandford and Arakell 1934; Attia 1954; Said 1962, 1981, 1993). The area is arid to semi arid, hot climate, dry, rainless in summer and mild with rare precipitation in winter. The rainfall average value for 15 y ranged from 23.05-33.15 mm/y, evapotranspiration in El Minia is 4897.91 mm/y (Korany 1980 and 2008).

The min. and max. temperature are 4.5 (January) to 20.5°C (August) and 20.7 (January) to 36.7 °C, respectively. The mean monthly relative humidity during daytime ranged from 36 % in May to 62 % in December (Korany 1984). The water logging problem is common in Nile Valley, and affect plant growth and soil degradation. Therefore, the groundwater degradation resulted from water logging, lithogenic, and anthropogenic impact. The groundwater exists in different aquifers; Pre-Tertiary Nubian sandstone; Eocene limestone; and Quaternary. The present investigated aquifer is the Pleistocene, the main aquifer in Delta and Nile Valley, which composed of sand and gravel of different sizes **(Fig. 2)**, with some clay intercalation. The thickness of the aquifer ranged from 25 to 300 m, from desert fringes to central Nile valley, respectively (Sadek 2001). The aquifer overlain and underlain by semi pervious silt and clay **(Fig. 2)** and Pliocene clay, respectively. The semi confined bed (1-15 m thickness) is missed outside the floodplain and the aquifer become unconfined. The topography is generally decreased due the northern part of the study area **(Fig. 3A)**. The ground surface in the southern part of the study area slopes from west (55 m) to the vicinity of the River Nile (43 m) **(Fig. 3A)**. The groundwater flows generally from the southern part to the northern part of the study area **(Fig. 3C)**. Locally, the groundwater flows towards the River Nile in the northern part, accordingly the River Nile is considered as discharge zone. While in the southern part of the study area, the groundwater flows from the center outwards in all directions **(Fig. 3C)**, therefore the River Nile is also a discharge zone. The aquifer is recharged by Nile water, irrigation system, drains, agricultural wastewater, vertical upward; leakage from the deeper saline aquifers (Korany 1984).

3. Materials and methods.

Ninety-six groundwater samples were collected from the Pleistocene aquifer, twenty-one water samples from irrigated surface water (Ibrahimia canal, River Nile, and Bahr Youssef) and El Moheet drain between EL-Edwa -Der Mawas area, El Minia district. Water analyses were completed during winter season (2010). The groundwater samples were taken by means of well pumps after a pumping period of at least 1 hr. The location site is determined by GPS instrument (model: Garmin eTrex Summit®). Pre-rinsed polypropylene bottles were filled with the samples, sealed tightly. pH, electrical conductivity, and temperature are measured in situ using portable field kite (Ultrameter ^{tm} 6p). Cl, HCO_3, Ca, and Mg were measured by titration, while SO_4 is estimated by turbidity, and Na and K were analyzed by flame photometer. The samples were acidified with ultra pure nitric acid, after filtration, to avoid complexation and adsorption. The acidification was accomplished in situ and in case of toxic metals determination. Then the samples transported to laboratory and then stored in a refrigerator at approximately – 20 ^{0}C to prevent change in volume due to evaporation The toxic metals (Al, As, Ba, Cd, Cr, Cu, Sn, Pb, Hg, Ni, Se, Mn, Fe, NO2, and NH4) were determined by the ICP (Inductive Couples Plasma)-AES (Optima 3000; Perkin Elmer). The dissolved oxygen (DO) was measured by azide modification, the chemical oxygen demand (COD) estimated by potassium dichromate oxidation, and the biochemical oxygen demand (BOD) determined by incubation 5 days. The water table is accomplished by sounder instrument method. The results of laboratory and field measurements were within 10% and therefore a significant alteration of the alkalinity during storage and transport can be excluded. The analyses were carried out at Environmental monitoring in Embaba.

4. Results and discussion.

4.1. Surface water.

The total dissolved solids (TDS) concentration in Ibrahimia canal, River Nile, and Bahr Youssef are lower than the WHO 2006, 2007 of 500 ppm and Egypt 1995, 2007 of 1000 ppm standards **(Fig. 4)**. The TDS concentration is increased in El Moheet drain due to agricultural, industrial, and sanitary wastewaters that dump in the drain. The As, Hg, and Ni concentrations are increased due the El Moheet drain **(Fig. 5A, B, and C)** due to agricultural, industrial, and sanitary wastewaters that dump in the drain. The As concentration in Ibrahimia canal, River Nile, more or less Bahr Youssef, and El Moheet drain is higher than drinking standards (WHO 2006, 2007 Egypt 1995, 2007) and lower than irrigation standards **(Fig. 5A)**. The Hg concentration in Ibrahimia canal, River Nile, and Bahr Youssef is equal or lower than the drinking standards **(Fig. 5B)**. The Ni concentration in surface water is fluctuated above and below the drinking standards **(Fig. 6C)**, but it is lower than irrigation standards except El Moheet drain **(Fig. 5C)**. With respect to As and Ni, the surface water are not suitable for drinking but suitable for irrigation, while El Moheet drain is not suitable for drinking neither irrigation purposes. The Cd and Cr concentrations are below the drinking standards in Ibrahimia canal and Bahr Youssef, while they fluctuated above and below the drinking and irrigation standards in the River Nile **(Fig. 5D and E)**. The River Nile with respect to the Cd content is not suitable for drinking and irrigation purposes in the study area due to the agricultural activity and inflow from the groundwater (the River Nile is a discharge zone). The Pb concentration in surface water is higher than the drinking standards and lower than the irrigation standards **(Fig. 6A)**. The Sn concentration is increased in the River Nile than other surface water **(Fig. 6B)**. The Se concentration is higher than drinking standard and lower than the irrigation standards in surface water except El Moheet drain which has Se concentration higher than drinking and irrigation standards **(Fig. 6C)**. The Zn and F concentrations in surface water are lower than the drinking and irrigation standards **(Fig. 6D and E)**. The dissolved oxygen (DO) concentration is more or less equal in surface water and decline in El Mohhet drain **(Fig. 7A)**. It is attributed to the consumption of the oxygen concentration by organic wastewaters. The BOD and COD concentrations are increased in El Moheet drain **(Fig. 7B and C)** that consumes the oxygen concentration **(Fig. 7A)**. The COD and BOD in surface water are higher than the drinking standards **(Fig. 7B and C)**. The B concentration in surface water is lower than drinking and irrigation standards **(Fig. 7D)**. The Cu concentration is more or less equal or lower than drinking and irrigation standards **(Fig. 7E)**.

4.2. Groundwater.

4.2.1. Total dissolved solids (TDS).

Although pH values are in the usual ranges of natural water (Hem 1985) **(Fig. 8B)**. The spatial changes in the groundwater quality is illustrated in **Fig. 8C**. The TDS concentration distribution map shows variations between 300 and 1400 ppm in general **(Fig. 8C)**. An anomalous areas that has values greater than 500 ppm occurs in the central zone of the southern part of the study area and western zone of the northern part of the study area **(Fig. 8C)**. The northern TDS anomaly (1400 ppm) is attributed to reverse match with groundwater flow **(Fig. 8C)**. The lack match, in northern part of the study area, between hydrogeology (groundwater flow, **Fig. 3C**) and hydrogeochemistry (TDS concentration, **Fig. 8C**) is obvious. It is caused by vertical changes in hydraulic conductivity especially upward increase that enhance the dilution in the vicinity of the River Nile (eastern zone of the northern part of the study area). The recharge from River Nile, neighboring aquifers, and surface irrigation canals can dilute the groundwater salinity in the eastern zone of the northern part of the study area. The TDS concentration trend didn't match with groundwater flow in the southern part of the study area, also attributed to the same phenomenon in the northern part. Generally, the hydrogeology (groundwater flow, **Fig. 3C**) match with hydrogeochemistry (TDS concentration, **Fig. 8C**). The TDS concentration increases generally from southern to northern part of the study area, with groundwater flow. The TDS anomalous areas are attributed to lithogenic, anthropogenic (agricultural) impact. The spatial distribution of Na concentration **(Fig. 9A)** is similar to TDS concentration. An anomalous area occurs in the western zone of the northern part of the study area **(Fig. 9A)**. This anomaly is characterized by relatively high Na concentration (210 mg/l). It conforms the dissolution of the aquitard Holocene deposits by leakage of agricultural and industrial wastewaters. The Ca and Mg concentrations **(Fig. 9B and C)** shows a high degree of conformability with TDS distribution map. The anomaly areas of Ca and Mg concentrations are located in the western zone of the northern part of the study area about 125 and 70 mg/l, respectively. They are because of dissolution of Eocene limestone distributed in the study area and agricultural fertilizers. The K concentration is rather different **(Fig. 9D)**, it has low values and more or less of an even distribution. The HCO3 concentration is linked to recent recharge coming through lateral flow from the River Nile in the study area. In the vicinity of the River Nile, it reaches 450 mg/l and far from the River Nile it reaches 120 mg/l **(Fig. 10A)**. The Cl concentration map **(Fig. 10B)** is different from TDS concentration. The Cl concentration anomalous areas are located in the eastern zone of the northern and southern part of the study area, i.e. beside the River Nile **(Fig. 10B)**. The hydrogeology (groundwater flow, **Fig. 3C**) match with Cl concentration either in the northern or the southern part of the study area **(Fig. 10B)**, i.e. with groundwater flow, the Cl concentration increases. It is thus accordance with the subsurface influx and the water table distribution heads. The SO4 concentration **(Fig. 10C)** is resemble to the TDS concentration map. Thus it is evident that recent recharge is taking place from southern part towards the northern part of the study area. Local groundwater flow is in the eastern part in both northern and southern part of the study area.

4.2.2. Heavy metals.

The B, Cu, and Ni concentrations in groundwater are low **(Fig. 11** and generally decreases in the River Nile zone, resulted from recharge from the River Nile and surrounding aquifers. The B concentration anomaly area is in the western zone of the southern part of the study area **(Fig. 11A)**. The B concentration is increased in the western zone of the study area, attributed to agricultural activity especially fertilizers and pesticides. The B concentration anomalous areas are located due the western zone that exceed the drinking water standard (WHO 2006, 2007 Egypt 1995, 2007). The Cu and Ni distribution maps **(Fig. 11B and C)** are below drinking water standard of 2 and 0.02 mg/l, respectively. The contamination with respect to Cu and Ni is out the aquifer system. The Cd concentration is detected only in the northwestern part **(Fig. 12A)** and the rest map was below the detection limit (< 0.001 mg/l). The Cd concentration was below the drinking water standard of 0.003 mg/l (WHO 2006, 2007 Egypt 1995, 2007), therefore no pollution with respect to Cd content. The NO2 and Cr concentrations are below the drinking water standard of 0.3 and 0.05 mg/l, respectively **(Fig. 12B and C)** in the study area. The NO2 and Cr concentrations shows no impact on the groundwater quality. The Ba, Fe, Mn, and Pb concentrations in groundwater are exceeded the drinking water standard of 0.7, 0.3, 0.4, and 0.01 mg/l, respectively **(Fig. 13)**. The high concentration of these last metals are close to the vicinity of the River Nile and decreased away from it **(Fig. 13)**. They are attributed to leakage of El Moheet drain and other agricultural and industrial wastewaters. The Ba, Fe, Mn, and Pb concentrations impact on the groundwater environment with respect to drinking purpose while it can use in irrigation purpose.

4.2.3. Statistical analyses.

4.2.3.1. Hierarchical Cluster Analysis (HCA).

In this study a cluster analysis has been performed on a hierarchical amalgamate technique based on the Euclidean distance between the samples in a n-dimensional space. Prior to statistical analysis, data were standardized by means of: **Kij = (Xij-X) / Sic**

Where Kij is the standardized value for Xij, the ith variable for the jth sample, X is the mean value of the ith variable and Sic is its standard deviation. The adopted procedure gives equal weight to each variable. The measure of similarity was simply the distance as defined in Euclidean space (Eriksson 1985) . The resulting dendrogram **(Fig. 14A)** was interpreted to have classified the samples into four main clusters which subdivided into six sub clusters (A-F). The average concentrations of the sub clusters identified by HCA was shown in **Fig. 14B**. The relationship of the defined sub clusters of samples to geographic location was tested with **Fig. 1**. Cluster analysis is a simple approach of classifying groundwater quality and it should be taken into consideration that hydrochemical systems are usually complex and difficult to analyze.

4.2.3.2. Principle Component Analysis.

Factor analysis is used here as a numerical method of discovering variables that are more important than others for representing parameter variation and identifying hydrochemical process. The principal component analysis approach started by extracting Eigenvalues and Eigenfactors of the correlation matrix and then discarding the less important of these (Davis 1986). Eigenfactors were then transformed to the factor of the data set. The amount of variable retained in the factors or communalities is obtained by squaring the elements in the factor matrix and summing the total within each variable. The magnitude of communalities is dependent upon the number of factors retained. This type of analysis is called R- mode factor analysis. Varimax rotation was then adopted. The results of the factor analysis are summarized in **Fig. 15**. When dealing with all samples collected from the study area, six factors were found to be responsible for the variation of groundwater quality. Factor 1 accounts about 31 % of the total variance. It includes high values of TDS, Ca, Mg, K, Na, SO4, and Cl with positive loadings. It is attributed to evaporation, dissolution, and agricultural impact. Factor 1 is called lithogenic and anthropogenic sources. Factor 2 represent 13 % of the total variance. It contain positive loadings of turbidity, topography, and water table. It is caused by high discharge rate that enhance the suspended particulate matter inside the borehole during pumping process. Factor 2 is negatively loaded with pH and Cu, confirm the impact of pH. Factor 2 is named pumping rate. Factor 3 is positive loadings with Cr and Ni, which attributed to sanitary wastewaters, therefore it is a sanitary wastewater dump factor. Factor 4 is composed of HCO3, topography, and B with positive loadings. It is because of the impact of surface water on groundwater quality especially with respect to B concentration which may derived from agricultural wastewaters. Factor 5 is consisted of Pb with negative loading, which reflect the unique character of the Pb in groundwater system. Factor 6 is indicated by B in positive loading and Al in negative loading. It indicate two different sources for both may agricultural for the former and lithogeic for the latter. The relation among the first three factors was shown in **Fig. 16.** Factor analysis seems to confirms the cluster analysis. In conclusion, the six factors seem to control the groundwater chemistry in the study area, and are positively correlated with the overall mineralization of groundwater.

5. Conclusion and recommendation.

The Pleistocene aquifer is the main aquifer in Delta and Nile Valley, which composed of sand and gravel of different sizes, with some clay intercalation. The groundwater flows generally from the southern part to the northern part of the study area. Locally, the groundwater flows towards the River Nile in the northern part. The total dissolved solids (TDS) concentration in Ibrahimia canal, River Nile, and Bahr Youssef are lower than the WHO and Egypt standards. With respect to As and Ni, the surface water are not suitable for drinking but suitable for irrigation. The River Nile with respect to the Cd content is not suitable for drinking and irrigation. The Zn and F concentrations in surface water are lower than the drinking and irrigation standards. The BOD and COD concentrations are increased in El Moheet drain that consumes the oxygen concentration. In groundwater, the TDS concentration shows variations between 300 and 1400 ppm in general. The B, Cu, and Ni concentrations in groundwater are low and generally decreases in the River Nile zone. The Ba, Fe, Mn, and Pb concentrations impact on the groundwater environment with respect to drinking purpose while it can use in irrigation purpose. The toxic metal concentrations should estimated periodically and evaluated to sustain the aquifer system.

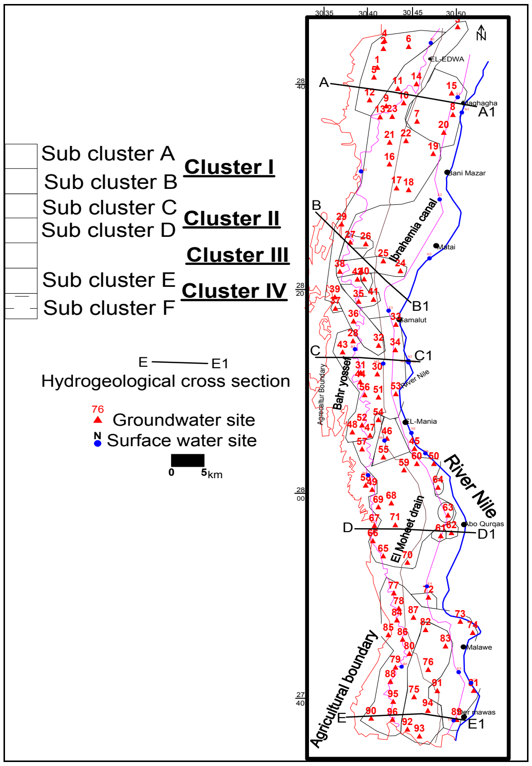


Fig. 1

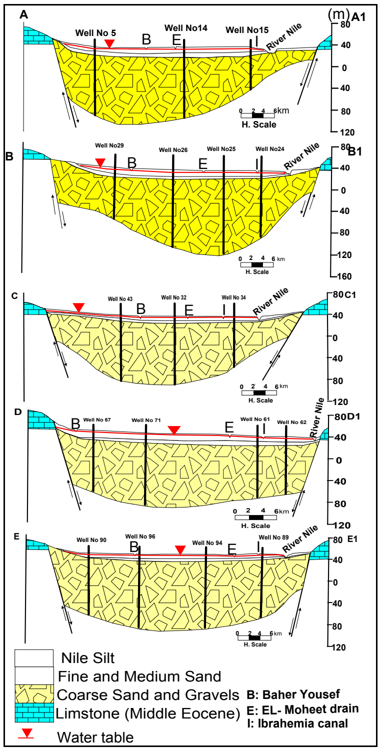
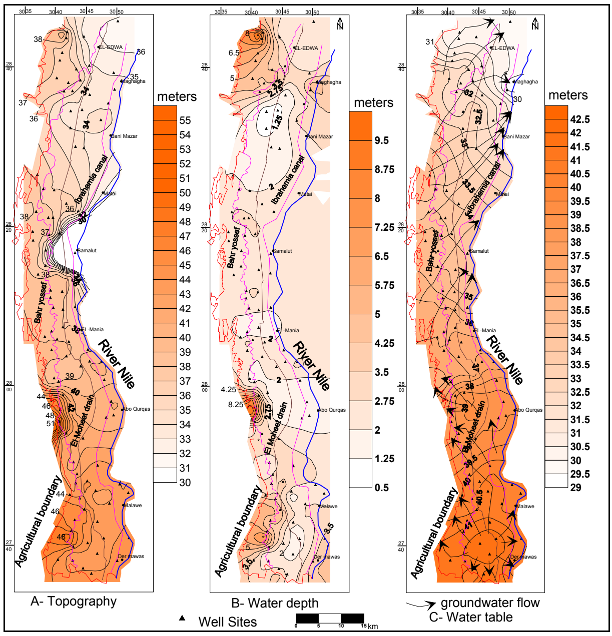


Fig. 2



A- Topography

B- Water depth

C- Water table

Fig. 3

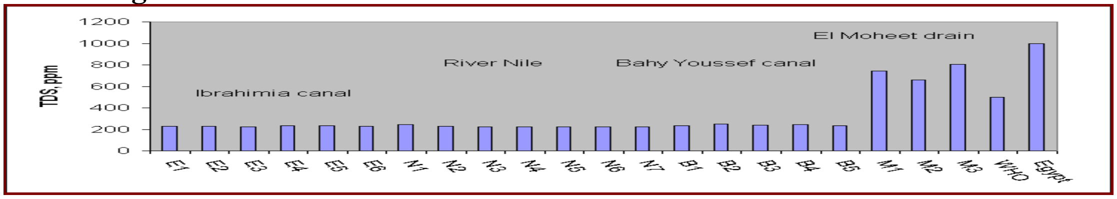


Fig. 4

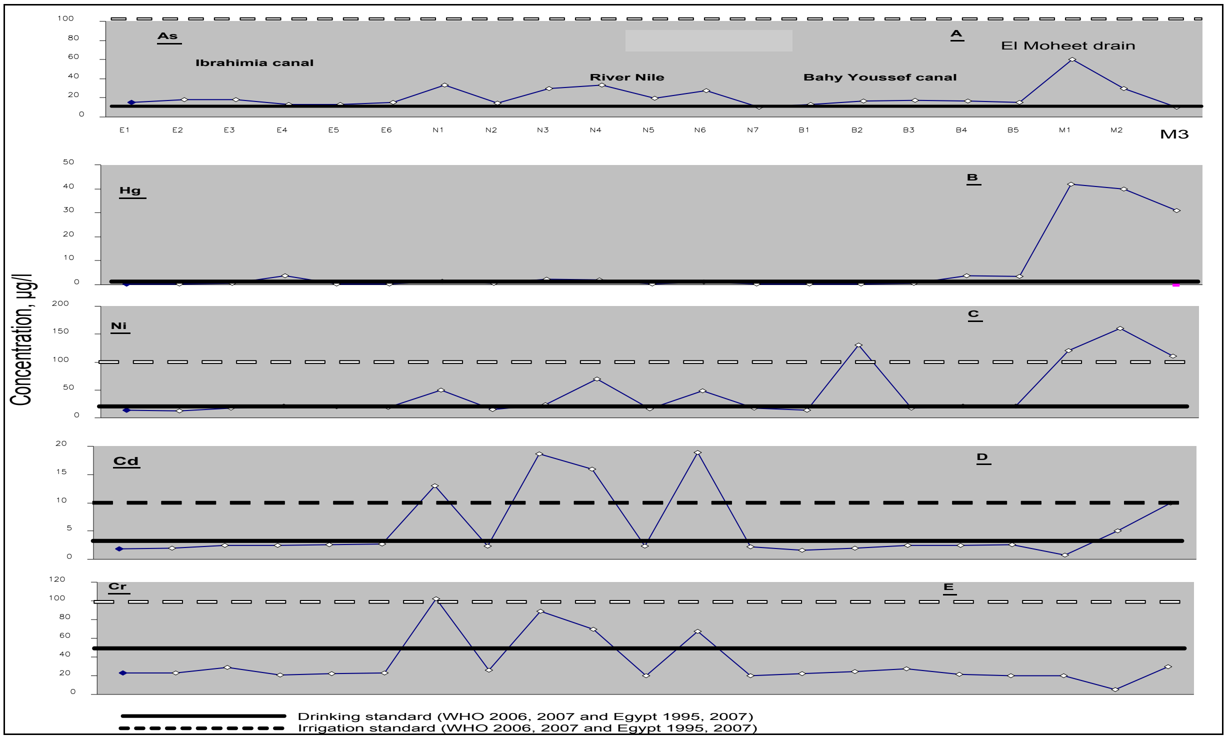


Fig. 5 As, Hg, Ni, Cd, and Cr concentrations in surface water.

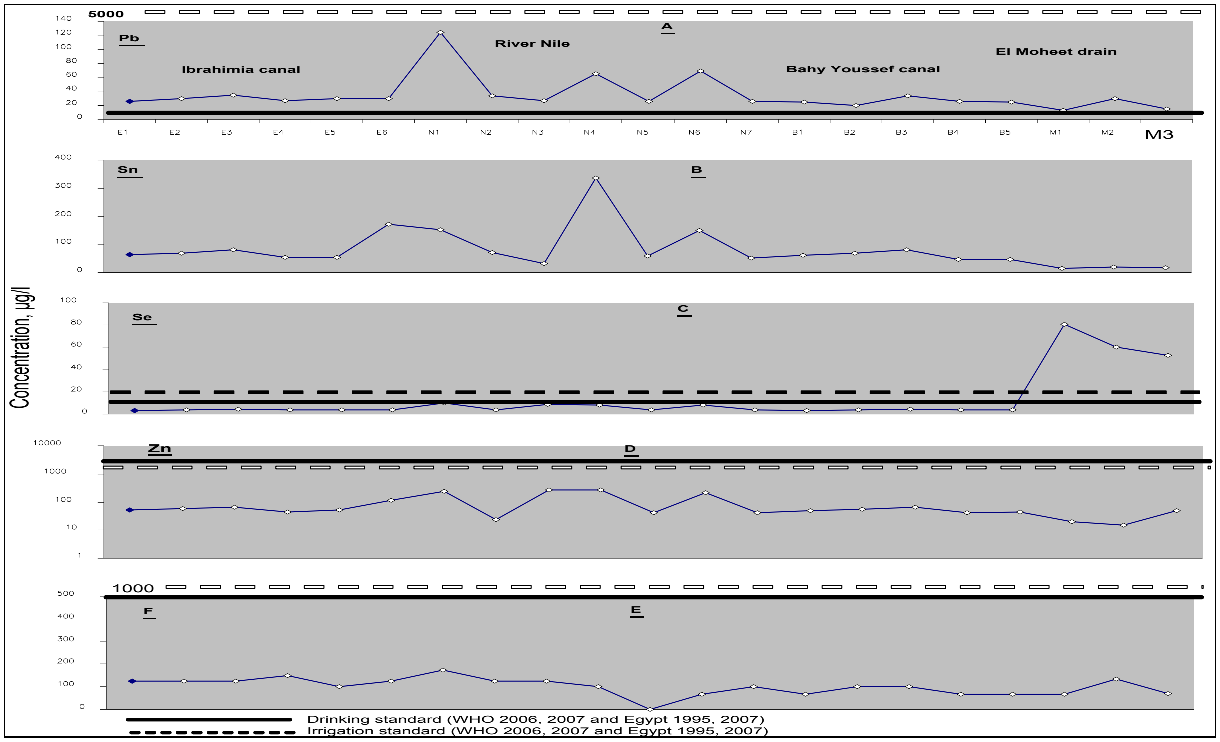


Fig. 6 Pb, Sn, Se, Zn, and F concentrations in surface water.

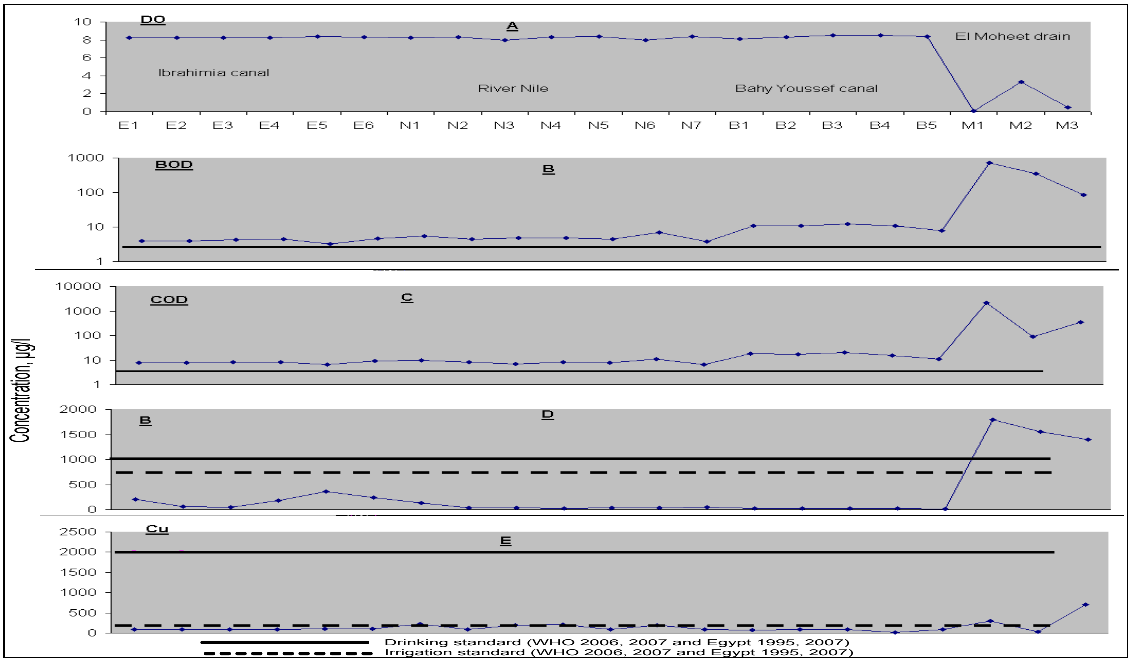


Fig. 7 DO, COD. BOD, B, and Cu concentrations in surface water.

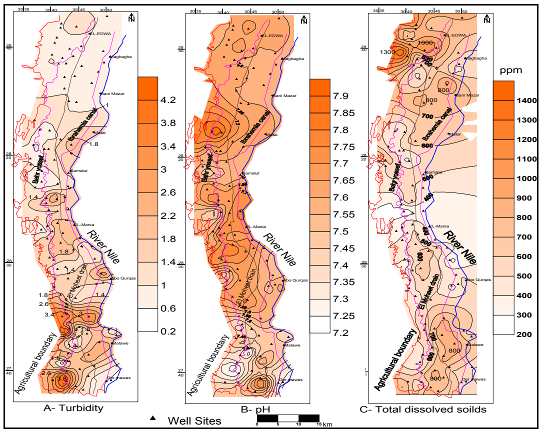


Fig 8

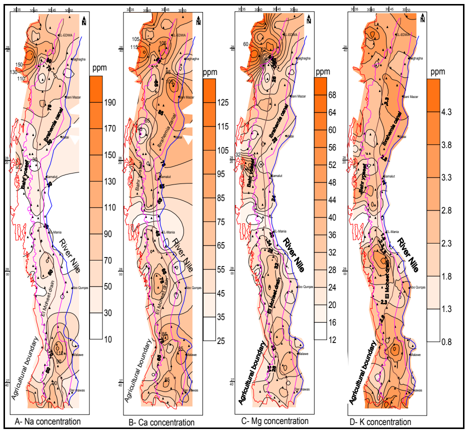


Fig. 9

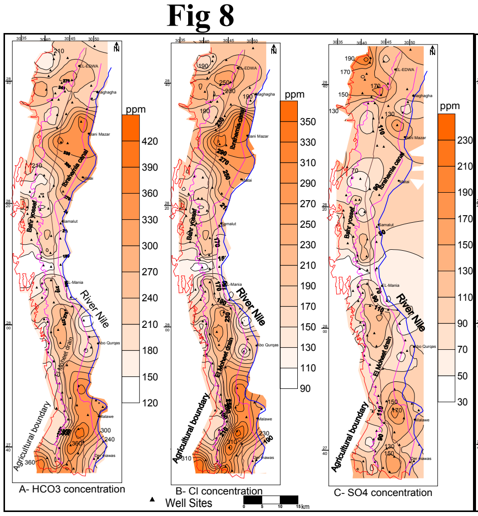


Fig. 10

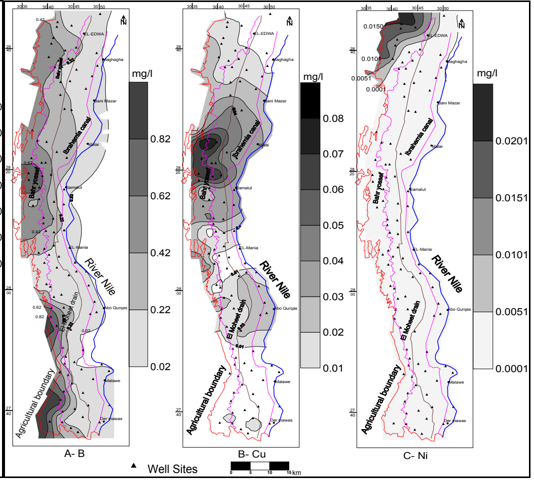


fig. 11

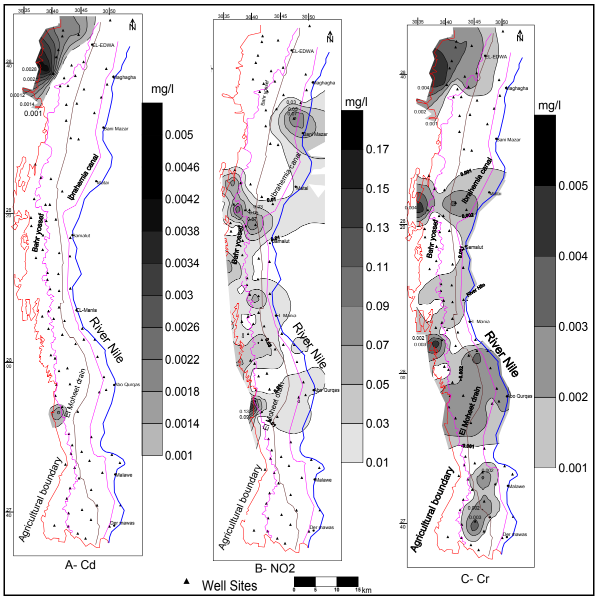


Fig. 12

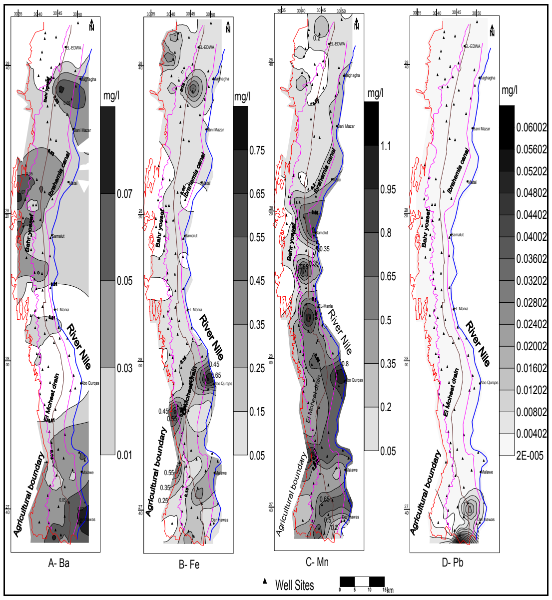


Fig 13

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  C A S E      0         5        10        15        20        25
Label     Num  +---------+---------+---------+---------+---------+
Case 77    75   -+
Case 84    81   -+
Case 96    93   -+-+
Case 95    92   -+ +---+
Case 46    45   -+ I   I
Case 55    54   -+-+   I
Case 63    61   -+     I
Case 78    76   -+     I
Case 85    82   -+     I Sub cluster A
Case 86    83   -+     +---------+
Case 73    71   -+     I         I
Case 74    72   -+     I         I
Case 87    84   -+-+   I         I
Case 80    77   -+ I   I         I
Case 81    78   -+ I   I         I
Case 89    86   -+ +---+         I Cluster I
Case 91    88   ---+             +-----------+
Case 88    85   ---+             I           I
Case 72    70   -+               I           I
Case 83    80   -+-+             I           I
Case 75    73   -+ I             I           I
Case 76    74   -+ +-----------+ I           I
Case 82    79   -+ I           I I           I
Case 92    89   -+-+           +-+ Sub       I
Case 90    87   -+ I           I   cluster B I
Case 94    91   ---+           I             I
Case 93    90   ---------------+             I
Case 11    11   -+                           I
Case 14    14   -+                           I
Case 10    10   -+-----+                     I
Case 3      3   -+     I                     I
Case 19    19   -+     I                     I
Case 16    16   -+     I Sub cluster C       I
Case 21    21   -+     +---------+           I
Case 22    22   -+     I         I           +-----------+
Case 23    23   -+---+ I         I           I           I
Case 32    32   -+   I I         I           I           I
Case 29    29   -+   +-+         I           I           I
Case 17    17   -+   I           I           I           I
Case 18    18   -+   I           I           I           I
Case 39    39   -+---+           I           I           I
Case 9      9   -+               I           I           I
Case 13    13   -+               I           I           I
Case 36    36   -+               +---+       I           I
Case 25    25   -+-+             I   I       I           I
Case 38    38   -+ I             I   I       I           I
Case 62    60   -+ I             I   I       I           I
Case 70    68   -+ +-------+     I   I       I           I
Case 69    67   -+-+       I     I   I       I           I
Case 57    56   -+ I       I     I   I       I           I
Case 60    58   -+ I       I     I   I       I           +-------+
Case 68    66   -+ I       I     I   I       I           I       I
Case 50    49   -+ I       I     I   I       I           I       I
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Case 54    53   -+-+       +-----+   +--------+          I       I
Case 24    24   -+         ISub      I Cluster II        I       I
Case 30    30   -+         Icluster DI                   I       I
Case 59    57   -+         I         I                   I       I
Case 65    63   -+---+     I         I                   I       I
Case 71    69   -+   I     I         I                   I       I
Case 8      8   -+   +-----+         I                   I       I
Case 15    15   -+   I               I                   I       I
Case 20    20   -+---+               I                   I       I
Case 7      7   -+                   I                   I       I
Case 66    64   ---------------------+                   I       I
Case 5      5   -+                                       I       I
Case 6      6   -+---+          Cluster III              I       I
Case 1      1   -+   +-----------------------------------+       I
Case 2      2   -+   I                                           I
Case 4      4   -+---+                                           I
Case 12    12   -+                                               I
Case 33    33   -+---------+                                     I
Case 49    48   -+         I                                     I
Case 34    34   -+         I                                     I
Case 47    46   -+         I                                     I
Case 51    50   -+         I                                     I
Case 53    52   -+         I         Cluster IV                  I
Case 48    47   -+         +-------------------------------------+
Case 52    51   -+---------+ Sub cluster E
Case 31    31   -+         I
Case 44    44   -+         I
Case 67    65   -+         I
Case 61    59   -+         I
Case 64    62   -+         I
Case 56    55   -+         I
Case 40    40   -+         I
Case 43    43   -+         I
Case 28    28   -+         I
Case 42    42   -+-+       I
Case 35    35   -+ +-------+ Sub cluster F
Case 37    37   -+ I
Case 41    41   -+-+
Case 26    26   -+
Case 27    27   -+
```

Fig. 14A Dendrogram investigation of major and trace elements of groundwater system.

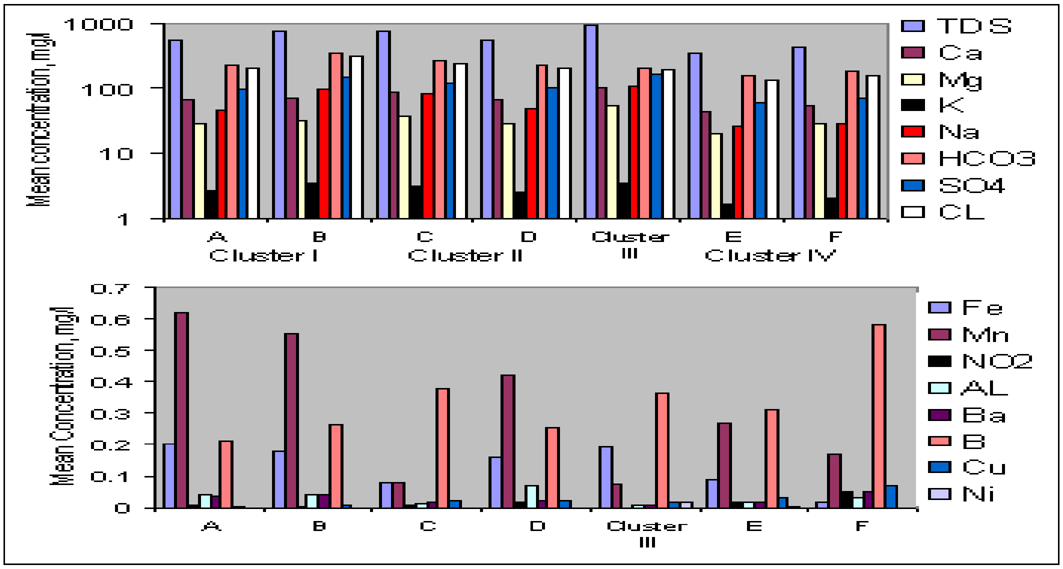

Fig. 14 B Mean concentrations of the sub clusters identified by HCA

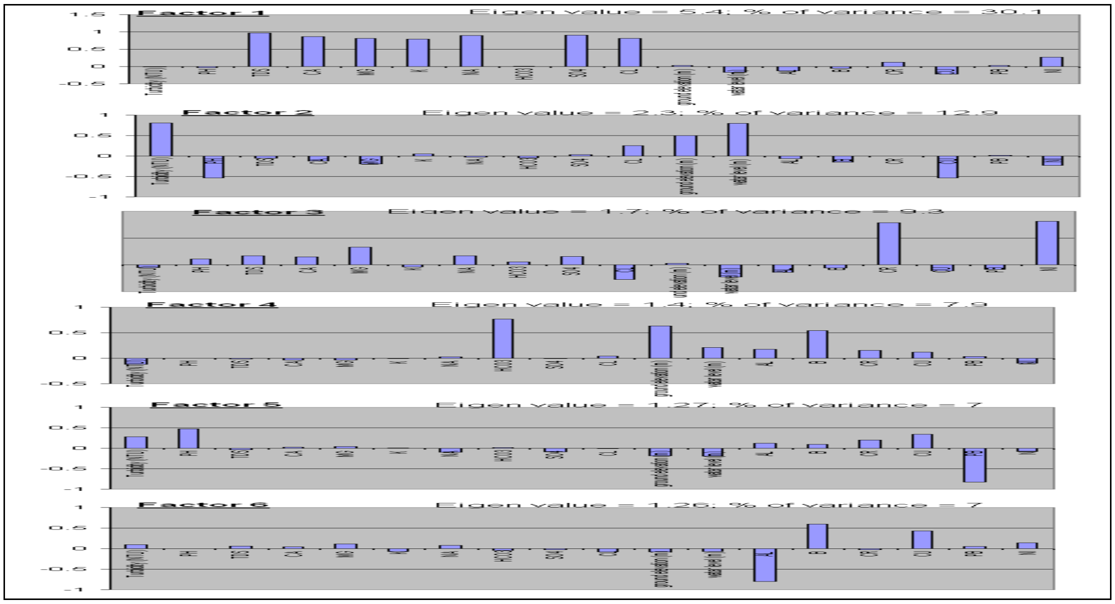

Fig. 15 Principle component analysis of the groundwater system between EL-Edwa -Der Mawas area.

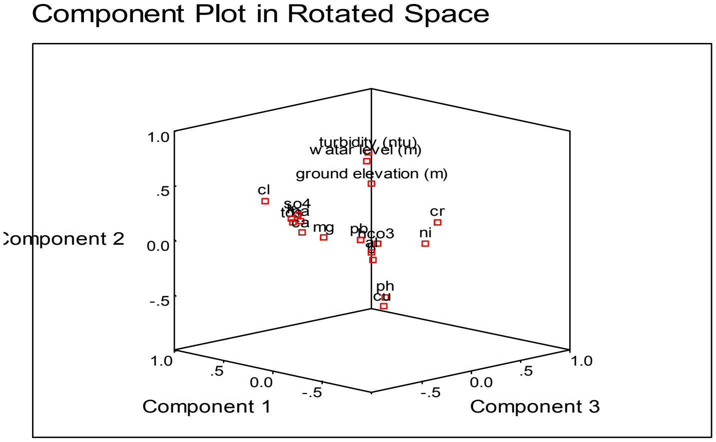

Fig. 16 The relationship among the first three factors.

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