Quantitative Study of Surface and Groundwater Systems in the Western Part of the River Nile, Minia Governorate, Upper Egypt: Water Quality in Relation to Anthropogenic Activities

By

Ashraf M. T. Elewa
Esam El Sayed
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Mamdouh Morsi
**Research Article**

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Ashraf M. T. Elewa*¹, Esam El Sayed¹, Mohamed El Kashouty² and Mamdouh Morsi³

¹Minia University, Faculty of Science, Geology Department.
²Cairo University, Faculty of Science, Geology Department.
³Environmental Department, Minia Governorate.

*Corresponding Author's Email: ashraf.aleiwa@mu.edu.eg

**ABSTRACT**

Quantitative analyses of ninety-six groundwater samples and twenty-one surface samples from the western part of the River Nile of Minia Governorate, Upper Egypt, enabled to evaluate the water quality of the region in relation to anthropogenic activities such as industrial & agricultural activities, domestic & municipal wastewater and river navigation. The use of Cluster Analysis (CA), based on the correlation coefficient of similarity (the paired group average method), revealed the distinction of six groups of ground water samples, and three groups of surface water samples; each has its characteristic composition and geographic setting. Moreover, Principle Coordinate Analysis (PCOA), based on Gower's coefficient of similarity, made it possible to distinguish the most important elements affecting the quality of water in the studied area.

Keywords: Egypt, River Nile, quantitative study of surface and groundwater systems.

**INTRODUCTION**

Water is vital to the existence of all living organisms, but this valued resource is increasingly being threatened by human populations grow and more demand water of high quality. The River Nile forms the main water resource of Egypt. The release of water from the High Dam varies between 52.9 and 57.4 billion cubic meter/year. In the Nile Valley and Nile Delta, groundwater supply equals about 4.4 billion cubic meter/year. Saad & Goma, 1994 and Fisher & Khalifa, 2003 reported that the construction of the High Dam resulted in great modification in the hydrodynamic regime of the River Nile, with significant changes in physico-chemical and biological characteristics of the downstream water. According to the National Water Research Center (NWRC, 2000), the River Nile from Aswan to El-Kanater Barrage receives wastewater discharge from 124 point sources, of which 67 are agricultural drains and the remainders are industrial sources. Gustavson et al. (2000) mentioned that the chemical substances which affect the quality of water are numerous, act in a great range of concentration and vary continuously and erratically in concentration. 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, (Tanzi and Valoppi 1989; Santos et al 2002). 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. 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
 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 and Pogotto et al. 2001). Cd is often present in artificial fertilizers and may accumulate in soils in areas that have been used for agriculture for long period (Mahvi et al. 2005; Rattan et al. 2005 and Nouri et al. 2006). At this time, Minia governorate gives its attention to industrial development, land reclamation and population re-habitation. These activities affected the water resources which included the River Nile, irrigation canals as well as groundwater. 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. Major, minor and heavy metals concentrations were assessment in surface and groundwater, in addition to DO, COD, and BOD in case of surface water. The results were analyzed in comparing with the guidelines of WHO (2004) and Egyptian standards (2007).

Location

The study area is located between latitudes 27° 30' and 28° 40' N and longitudes 30° 30' and 31° 00' E, at the western bank of River Nile. It covers about 3375 km² in Minia Governorate, Egypt (Fig. 1). The area is limited by River Nile from east, reclamation and limestone plateau from west, Fashn Markaz (Beni Suef Governorate) from north, and Dairut Markaz (Assiut Governorate) from south. It includes 9 towns, 54 main villages and 340 subordinate villages. Number of population is about 4.3 million people in Minia governorate (about 4 million people in the study area). 18% of people live in urban area and 82% of them live in rural area. River Nile forms the main water resource of Minia (share about 4.32 BCm/ year); 84% for agriculture (about 437957 fadan), 1.3% for drinking purpose and the rest for industrial and other purposes.
Climate

The area is arid to semi arid, hot climate, dry, rainless in summer and mild with rare precipitation in winter. According to Egyptian Meteorological Authority, climatic records for the average long terms for the period (1960 - 2006) of Minia governorate (Fig. 2).

Temperature: The minimum and maximum temperature varies from 4.6 °C in January to 20.5 °C in July and 20.4 °C in January to 37.1 °C in June respectively (Fig. 2-A).

Rainfall: The rainfall ranges from 1.74 mm/month in March to zero in July, and rare in June, August, and September; with average value of 0.87 mm/month, where the amount of rainfall is annually about 4 mm/year (Fig. 2-B).

Evaporation: Evaporation in Minia governorate ranges from 14.85 mm/month in June to 3.54 mm/month in December, with average value of 8.92 mm/month, and total amount of about 107.04 mm/year. Evapotranspiration at Minia is 4897.91 mm/year (Korany 1980 and Korany et al. 2008) (Fig. 2-C).

Relative Humidity: The mean monthly relative humidity during daytime according to Egyptian Meteorological Authority data ranges from 39.2 % in May to 68.8 % in December; with average value of 54.76% (Fig. 2-D).

Wind: Wind come from north direction represent the main winds direction. It is represented by 43%, and followed by NW of about 24%, NE of about 12%, quit state of about 6%, south of about 4%, SE of about 4%, west of about 3%, and finally SW of about 3% . The maximum speed is 9.4 knot/hour in June, and the minimum speed is 4.9 knot/hour in December, with average of 7 knot/hour (Fig. 2-E).

Sunray spread: It ranges from 84.7 % about 301.3 hour / month in (January) to 124.01 % about 446.76 hour / month in (July) (Fig. 2-F).
Fig. (2): The average of climatic records for long-terms period (1960 - 2006) of Minia Governorate (Egyptian Meteorological Authority)

MATERIALS AND METHODS

Ninety-six groundwater and twenty-one surface water samples were collected from the Pleistocene aquifer and irrigated surface water of Ibrahimia canal, River Nile, and Bahr Youssef, as well as El-Moheet drain. These samples have been collected from locations between Maghagha and Der Mawas cities of Minia Governorate (Fig. 3). We used the GPS instrument (model: Garmin eTrex Summit® to locate the studied sites. The water analyses were accomplished during the summer season of the year (2011).
The water analyses were carried out in Minia Chemical Laboratory for Analysis of Drinking Water and Waste Water, and in Embaba Environmental Monitoring Center, according to the methods adopted by Rainwater and Thatcher (1960), and the methods described by Fishman and Friedman (1985).

The dissolved oxygen content (DO) was performed by Azide Modification, COD by Potassium Dichromate Oxidation and BOD by incubation 5 days methods. Calcium (Ca$^{2+}$), magnesium (Mg$^{2+}$), carbonate (CO$_3^{-}$), bicarbonate (HCO$_3^{-}$), and chloride (Cl$^{-}$) were measured by titration. Sulfate (SO$_4^{2-}$), ammonia (NH$_3$), nitrite (NO$_2^-$), and nitrate (NO$_3^-$) were estimated by using UV Spectrophotometer. Sodium (Na$^+$) and potassium (K$^+$) constituents were assessed by using Flame Photometer.

Water samples were acidified with ultra pure nitric acid after filtration to avoid complication and adsorption. The acidification was accomplished in site and in case of toxic metals determination. These samples transported to laboratory and stored in a refrigerator at approximately 20°C to prevent change in volume due to evaporation. The toxic metals include lead (Pb$^{2+}$), cadmium (Cd$^{2+}$), nickel (Ni$^{2+}$), arsenic (As), chromium (Cr), mercury (Hg), selenium (Se), aluminium (Al$^{3+}$), iron (Fe$^{3+}$), copper (Cu$^{2+}$), cyanide (Cn), zinc (Zn$^{2+}$), boron (B$^{3+}$), barium (Ba), phosphate (PO$_4^{3-}$), silicate (SiO$_2$), and manganese (Mn). These were determined by the ICP (Inductive Couples Plasma)-Mass (Optima 3000; Perkin Elmer). Figs (4,5)
Cluster analysis (CA) based on the correlation coefficient of similarity (the paired group average method) has been applied to the raw data matrix of groundwater samples and to that of the surface samples, to discriminate the existing groups of water samples. Then principle coordinate analysis (PCOA), based on the Gower’s coefficient of similarity, of the two raw data matrices was accomplished to distinguish the most important elements affecting the quality of water in the region. The computer program used in this study is included in a software package called PAST, version 2.09 (May, 2011); see Hammer et al. (2001). The results were analyzed in comparing with the guidelines of WHO (2004) and Egyptian standards (2007) table (1)

Table (1): WHO Guidelines and Egypt Standards for Drinking Water Quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>WHO Guidelines¹</th>
<th>Egypt Standards²</th>
</tr>
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<tbody>
<tr>
<td>Alkalinity</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Aluminium (Al)</td>
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<td>0.2</td>
</tr>
<tr>
<td>Ammonia (NH₃)</td>
<td>mg / L</td>
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<td>0.5</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>mg / L</td>
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<td>0.01</td>
</tr>
<tr>
<td>Barium (Ba)</td>
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<td>0.7</td>
</tr>
<tr>
<td>Bicarbonate (HCO₃)</td>
<td>mg / L</td>
<td>#</td>
<td>#</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>mg / L</td>
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<td>0.5</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>mg / L</td>
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</tr>
<tr>
<td>Calcium (Ca)</td>
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<tr>
<td>Chloride (Cl)</td>
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<tr>
<td>Chromium (Cr)</td>
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<td></td>
<td>6.5 - 8</td>
<td>6.5 - 8.5</td>
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<tr>
<td>Potassium (K)</td>
<td>mg / L</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>mg / L</td>
<td>0.01</td>
<td>0.01</td>
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</table>

* - Not applicable
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<tr>
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<td>Sodium (Na) mg/L</td>
<td>200</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Sulfate (SO₄) mg/L</td>
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<td>250</td>
<td></td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS) mg/L</td>
<td>600</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Turbidity NTU</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Zinc (Zn) mg/L</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

* No guideline

1 WHO Guidelines were mentioned in "Water Quality For Ecosystem and Human Health", 2006 & "Global Drinking Water Quality Index Development and Sensitivity Analysis Report", 2007 Prepared and Published by the United Nations Environment Programme Global Environmental Monitoring System/ Water Programme

2 Egypt Standards according to the Minister of Health decree Number (108) for 1995 and (458) for 2007

RESULTS AND DISCUSSION

Multivariate data analyses were successful in solving problems related to different aspects of paleoecology and morphometrics (e.g. Elewa, et al. 1999; Elewa 2002; Elewa 2004a,b; Elewa and Morsi 2004; Elewa 2008a,b,c; Elewa and Dakrory 2008a,b; Elewa 2010; Abdel Hady and Elewa 2010). In the mean time, the use of these techniques for evaluating the water quality is herein established to be effective in detecting the most severe localities prohibited for drinking and irrigation.

Alternatively, it can be achievable to differentiate the studied localities into groups; each has its characteristic composition and geographic setting; taking into consideration the depiction of the various elements in water and the relation of these constituents to water use in drinking and irrigation.

Firstly, we will discuss the groundwater system; and then we will proceed with the surface water system of the studied area.

1. Groundwater system:

a. Cluster analysis:

Cluster analysis could discriminate between six groups of groundwater samples (Fig. 5). Group “A” contains sample 26 in north of Samalut city, and sample 44 in north of Minia city (Fig. 3). Group “B” is represented by one sample (28) in south of Samalut city.

![Dendrogram](image_url)

Fig. (5): Dendrogram resulted from cluster analysis based on correlation coefficient of similarity (the paired group average method) of 96 groundwater samples of the study area.
Group “C” contains samples: 17 between Matay and Bani Mazar cities, 36 opposite to Samalut city, and 37 in north of Samalut city, 72 in north of Malawi city, 75 in north of Der Mawas city, 76 in north of Malawi city, 82, 83, 85, 86, 87 (all these samples are around the western side of Malawi city), and 90, 92, 93 (all these samples are around the western side of Der Mawas city).

Group “E” includes sample 35 opposite to Samalut city, and sample 38 in north of Samalut city.

Group “F” confines samples: 3 in north of El Edwa city, 1, 2, 4, 5 between El Edwa and Maghagha cities, 7, 9, 10, 11, 12, 13 between Maghagha and Bani Mazar cities, 14 opposite to Maghagha city, 25 between Matay and Samalut cities, 39 opposite to Malawi city, 79 in south of Malawi city.

Group “D” contains all remaining samples which scattered from north at El Edwa city to south at Der Mawas city.

Although there seems no definite geographical setting for these groups, however it can be indicated that group “F” is mostly represented by samples from the north of the study area (all samples of this group are from north of Minia city), whereas group “C” is almost characterized by samples from the south of the study area (most samples of this group are from south of Minia city; except samples 17, 36, and 37). Meanwhile, the other groups include scattered samples from north and south.

As to hydrogeochemical investigations, sample 28, which is the only representative of group “B”, exhibits low turbidity levels with relatively low Na and Cl content.

Group “A” shows relatively low EC, Ca, Mg, Na, HCO$_3^-$, SO$_4^{2-}$, and Cl contents.

Group “C” displays relatively high K, Na, HCO$_3^-$, SO$_4^{2-}$, and Cl contents.

As potassium releases from landfills for domestic waste is usually exceptionally high, this compound may be applied as an indicator for other toxic compounds in groundwater.

(Read more: http://www.lenntech.com/periodic/water/potassium/potassium-and-water.htm).

Sodium is attributed water hazard class 2, in other words it is a risk when present in water. Sodium chloride however is not a risk and is attributed water hazard class 1.

(See:http://www.lenntech.com/periodic/water/sodium/sodium-and-water.htm)


Group “E” demonstrates relatively high T, hardness, relatively low K content, as well as relatively low alkalinity.

Group “F” shows relatively high EC, Na, Mg, Ca contents. Calcium is largely responsible for water hardness, and may negatively influence toxicity of other compounds. Water hardness influences aquatic organisms concerning metal toxicity. However, various calcium compounds may be toxic. (For more details on the subject read at: http://www.lenntech.com/periodic/water/calcium/calcium-and-water.htm).

Group “D”, which includes all remaining samples, illustrates relatively moderate levels with normal values of the analyzed elements.

**b. Principle Coordinate Analysis:**

From cluster analysis, it could be distinguish six groups within the groundwater data. But principle coordinate analysis discovered new information. The analysis revealed that PCO1, PCO2 and PCO3 account for about 56% of total variation (Table 2), which seems reasonable to give good conclusions about the studied samples.

<table>
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<th>Axis</th>
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<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.2205</td>
<td>37.248</td>
</tr>
<tr>
<td>2</td>
<td>0.4161</td>
<td>12.699</td>
</tr>
<tr>
<td>3</td>
<td>0.19617</td>
<td>5.9869</td>
</tr>
</tbody>
</table>

From Figure (6), it can be noticed that PCO1 separates samples with relatively high Ca values (samples: 12, 19, 11, and 10 in the right part of the figure) from those with relatively low Ca values (samples: 56, 51, 64, 61 and others; in the left part of the figure) (see also Fig. 7). According to Piper’s classification, samples 10, 11, and 19 belong to subarea (1), in which alkaline earths exceed alkalies (Ca+Mg) > (Na+K). Sample 12 belongs to subarea (2), in which alkalies exceed alkaline earths (Na+K) > (Ca+Mg). Samples 51, 56, 61, and 64 are attributed to subarea (1), in which alkaline earths exceed alkalies (Ca+Mg) > (Na+K). This means that both samples distinguished by PCO1, with relatively low and high Ca values, are belonging to subarea (1), except sample 12, of Piper’s classification.
On the other hand, PCO2 discriminates samples with relatively high total dissolved solids (TDS) content (samples: 4, 12, and 2; in the upper part of the figure). Samples 4, 12, and 2 show TDS values higher than 1000 mg/l (the Egyptian Standards for Drinking Water Quality (Fig. 6); Egypt Standards according to the Minister of Health Decree Number (108) for 1995 and (458) for 2007), and thus these water samples are permissible but not good water for drinking. According to Hem’s classification (1970), samples 4, 12, and 2 can be attributed to slightly saline waters (TDS = 1000: 3000 ppm). The all remaining groundwater samples of the study area (except for samples 31, 45, 48, 49, 51, 53, 56, 64, and 67, which have TDS below 300 ppm, and thus belong to very fresh water mass) are below 1000 ppm, indicating fresh water mass (TDS = 300: 1000 ppm). Meanwhile, samples 31, 45, 48, 49, 51, 53, 56, 64, and 67 are defined by PCO1 to represent relatively low Ca values (Fig. 6), which means that these samples are the best within the studied groundwater samples for drinking. These samples are located around Minia city and between Minia and Abo Korkas cities.

As to irrigation, the degree of restriction on use, according to the FAO guidelines for irrigating water factors and the likelihood that water with each factor will cause soil problems, is slight to moderate. As samples 4, 12, and 2 range in TDS values between 1000 and 1500 ppm they indicate very satisfactory water for all classes of livestock and poultry (National Academy of Science and National Academy of Engineering, 1972). However, all remaining groundwater samples, with TDS values less than 1000 ppm, are excellent for all classes of livestock and poultry. PCO2 also isolates sample 63 with relatively high Mn value (in the lower part of Figure 10) (see also Fig. 9).

Figure 10 plots the relation between PCO2 and PCO3. From this graph it can be concluded that PCO3 distinguishes samples with relatively high K and Fe contents (samples: 92, 85, 90, and 93; in the upper part of the figure) (see also Figs. 10 and 11). Meanwhile, it segregates sample 66 with relatively high NO\textsubscript{2} content (0.183 mg/l) (in the lower part of the figure) (see also Fig. 13). This value is within the range of the Egyptian standards for drinking water quality and domestic uses (0.2 mg/l), but any slight increase in this value will lead to unsuitability of water in this well. Sample 66 is located opposite to Abo Korkas city in south of Minia city.

In conclusion, the best groundwater samples within the studied samples are located around Minia city and between Minia and Abo Korkas cities, in the middle part of the study area; while the worst water samples are between El-Edwa and Maghagha cities, in the northern part of the study area. Yet, principle coordinate analysis exposed that the area around Abo Korkas city needs decisive attention as it includes sample 63 (Fig. 3; with relatively high Mn content: 1.14 mg/l and the maximum permissible limit for drinking, domestic and laundry uses is: 0.05 mg/l according to the Egyptian Higher Committee for water (1995); and sample 66 (Fig. 5; with relatively high NO\textsubscript{2} content: 0.183 mg/l). The value for Mn is dangerous, but for NO\textsubscript{2}, as it was mentioned above, is within the range of the Egyptian standards for drinking water quality and domestic uses (0.2 mg/l), but any slight increase in this value will lead to unsuitability of water in this well.
Fig. (7): Ca concentration (mg/l) at 96 monitoring sites of groundwater.

Fig. (8): TDS concentration (mg/l) at 96 monitoring sites of groundwater.

Fig. (9): Mn concentration (mg/l) at 96 monitoring sites of groundwater.

Fig. (10): PCO2 vs. PCO3 for 96 groundwater samples of the study area.
2. Surface water system:

a. Cluster analysis:

Cluster analysis distinguished three groups of surface water samples (Fig. 14). Group “I” belongs to El-Moheet drain, and is represented by sample 21 (M1 in Fig. 3) in south of Minia city.

Group “II” is belonging to El-Moheet drain, and includes samples 19 (M3 in Fig. 3) and 20 (M2 in Fig. 3). These two samples are located between Samalut and Minia cities.

Group “III” contains all remaining surface water samples of the study area. These samples are scattered from El Edwa city in north to Der Mawas city in south.

Hydrogeochemically, group “I” together with group “II” reveal the lowest values of pH in the studied surface water samples of the study area. However, group “II” differs from group “I” in having the highest value of K, and group “I” shows higher values of K than group “III”.

Generally, groups “I” and “II” disclose higher values of HCO₃, SO₄, Cl, Fe, PO₄, SiO₂, B, NH₄, Ca, H, T, ALK, BOD, and COD than group “III”. Meanwhile, these two groups (“I” and “II”) exhibit low values of the dissolved oxygen (DO).

The only exception is that samples 14, 15, 16 (B1, B2, and B3 in Fig. 1, respectively) of group “III” exhibit relatively high Fe values close to those values of samples 19 (group “II”) and 21 (group “I”). It is also notable that
These three samples show relatively high values of Mn and PO$_4$. These three samples of group “III” belong to Baher Youssef.

Manganese is one out of three toxic essential trace elements, which means that it is not only necessary for humans to survive, but it is also toxic when too high concentrations are present in a human body. (Read more: http://www.lenntech.com/periodic/elements/mn.htm). Mansouir (2010) declared that the domestic waste waters and sewage may play important role for Mn concentration.

In general, Iron and manganese are unaesthetic parameters present mostly in groundwater, causing unwanted precipitation and color (see: http://www.lenntech.com/processes/iron-manganese/iron-removal.htm). As the recommended limits for Mn in reclaimed water for irrigation (Rowe and Abdel -Magid, 1995) ranges from 0.2 mg/l in long term use to 10 mg/l in short term use, and our values for samples 14, 15, and 16 not exceed 0.1 mg/l, therefore these values are in the normal limits, and these samples are suitable for irrigation.

Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate. The following criteria for total phosphorus were recommended by US EPA (1986):

1. No more than 0.1 mg/l for streams which do not empty into reservoirs?
2. No more than 0.05 mg/l for streams discharging into reservoirs, and
3. No more than 0.025 mg/l for reservoirs.

Groups “I” and “II” disclose very high values of PO$_4$, which indicate a serious pollution in the areas of the samples belonging to these two groups.

Fig. (14): Dendrogram resulted from cluster analysis based on correlation coefficient of similarity (the paired group average method) of 21 surface water samples of the study area.
In conclusion, groups “I” and “II” are specifically representing the most polluted samples of the surface water samples of the study area.

The above mentioned remarks indicate that pollution has reached its higher effect on the surface water samples of the study area around Minia city and between Minia and Samalut cities. This bad situation could be related to more anthropogenic activities in these areas when compared to the other studied areas of Minia Governorate.

b. Principle Coordinate Analysis:

Principle coordinate analysis has been applied to detect new information that could not be discovered by cluster analysis. The results (Table 3) indicate that the first two principles coordinates account for more than 87 % of variation, which is sufficient to describe the total variance of the studied samples.

Table 3 - Results of principle coordinate analysis (Gower’s coefficient of similarity) for 21 surface water samples of the study area.

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</table>

From Figure 14, showing the 1st vs. the 2nd principle coordinates, we can clearly notice five distinct groups (A, B, C, D, and E).

Group “E” stands for sample 19, which is characterized severely by the highest values of most recognized pollutants. Therefore, this sample is the most polluted one within the studied surface water samples. Unfortunately, it is located between the River Nile and El-Moheet drain at the boundary of the cultivated lands between Samalut and Minia cities.

Group “D” contains samples 20 and 21 of El-Moheet drain. These two samples represent the second level of pollution after sample 19, and thus they also should be taken into consideration together with sample 19 when we search for water suitable for drinking and irrigation.

Group “C” is represented by samples 14, 15, and 16 of Baher Youssef, which we mentioned above that they exhibit relatively high Fe values close to those values of samples 19 (group “II”) and 21 (group “I”). As it is mentioned above, these three samples show relatively high values of Mn (see Fig. 16), and they are located between Minia and Samalut cities (sample 16), opposite to Bani Mazar city (sample 15), and north of El Edwa city (sample 14).

Fig. (15): PCO1 vs. PCO2 for 21 surface water samples of the study area.
Fig. (16): Mn concentration (mg/l) at 21 monitoring sites of surface water.

Group “A” includes samples 7, 9, 10, and 12 (samples N1, N3, N4, and N6 in Fig. 1, respectively). These samples were collected from the River Nile, and show the highest values of Zn in the studied surface water samples (Fig. 15). Sample 7 (N1) is located opposite to Maghagha city. Samples 9 and 10 (N3 and N4) are situated between Samalut and Bani Mazar cities, and contain the highest values of Zn in the studied surface water samples. Sample 12 (N6) is collected from south of Minia city. Zinc was not attributed a water hazard class, because it is not considered a hazard. This however only concerns elementary zinc. Some zinc compounds, such as zinc arsenate and zinc cyanide, may be extremely hazardous (read more at: http://www.lenntech.com/periodic/water/zinc/zinc-and-water.htm). Even though, in these samples Zn does not exceed 0.237 mg/l (i.e. within the recommended limits for minor and trace constituents in reclaimed water for irrigation; Rowe and Abdel -Magid, 1995), which means no risk in irrigation from these samples.

Fig. (17): Zn concentration (mg/l) at 21 monitoring sites of surface water.

Group “B” contains the remaining samples with moderate values of all studied elements.

It seems conclusively that cluster and principle coordinate analysis applied to surface water samples from the Minia Governorate could detect the distribution of the elements responsible for pollution of water. From the results, it is clear that the area between Samalut and Minia cities is the most affected area by water pollution, and needs more consideration from the governors to prevent the causes of this serious pollution of water.

**SUITABILITY OF WATER FOR DRINKING, LAUNDRY AND DOMESTIC PURPOSES**

Generally, water used in drinking purpose should be colorless of turbidity, excessive amounts of dissolved salts and unpleasant odder or test. For using water in laundry purpose, it should be soft or moderately hard water . Moreover,
water used for livestock and poultry is subject to quality limitation of the same type as those relating to the qualities of drinking for human consumption (Tawfik, 1999).

**Evaluation of groundwater**

**For human drinking:**

According to salinity (TDS) and major ions groundwater, 95% of samples are ranging between acceptable, to permissible for human drinking. However, PCO2 indicated that samples 4, 12, and 2 show TDS values higher than 1000 mg/l (the Egyptian Standards for Drinking Water Quality; Egypt Standards according to the Minister of Health Decree Number (108) for 1995 and (458) for 2007), and thus these water samples are permissible but not good water for drinking.

According to minor and trace constituent, 63% of groundwater samples are unsuitable for human drinking due to high concentration of Fe, Mn, NO\textsubscript{2}, NH\textsubscript{4}, AL, B, Cd, Ni, and Pb. PCO2 isolated sample 63 (located north of Abo Korkas city) with relatively high Mn value, and the investigation pointed out that this sample exhibits relatively high contents of NH\textsubscript{4} and NO\textsubscript{2}. Conversely, the rest of samples (37%) are suitable for human drinking.

**For domestic and laundry:**

According to the classification of Durfor and Becker (1964) and (Hem, 1970), which depend on its hardness, All groundwater samples (100%) are very hard for domestic and laundry.

**For livestock and poultry:**

By comparing chemical analyses data of groundwater samples with the guideline of Mckee and wolf (1963) and NAS, NAE (1973) the most groundwater samples (94%) are excellent for livestock and poultry. the rest of samples (6%) are very satisfactory for livestock and poultry.

**Evaluation of surface water**

**For human drinking:**

According to salinity (TDS) and major ions, River Nile and main irrigation canals (Ibrahimia and Baher Youssef) and drain canal (EL-Moheet drain) are acceptable for human drinking, but drain canal (EL-Moheet drain) shows higher TDS concentration than River Nile and main irrigation canals. Principle coordinate analysis revealed that sample 19 (M3 in Fig. 1), which is characterized severely by the highest values of most studied elements, is the most polluted one within the studied surface water samples. It belongs to El-Moheet drain, between Minia and Samalut cities.

In relation to minor and trace constituent, 100% of River Nile and main irrigation canals (Ibrahimia and Baher Youssef) water samples are unsuitable for human drinking because of their higher content of Pb, Ni, AL, As, in most samples, in addition local increased in Cd, Cr, Se, Hg, B, especially in River Nile and EL-Moheet drain samples.

**For domestic and laundry:**

For water use in domestic laundry purpose, the hardness should be in the range from hard to very hard water. About 100% of surface water from River Nile and main irrigation canals and drain canal are unsuitable for laundry purposes because they range from hard to very hard.

**For livestock and poultry:**

Water is involved in every aspect of poultry metabolism. It plays important roles in regulating body temperature, digesting food, and eliminating body wastes. At normal temperatures, poultry consumes, at least, much water twice as feed. When heat stress occurs, water consumption will be double or quadruple. A safe and adequate supply of water is therefore essential for efficient poultry production. Excessive salinity in livestock drinking water can upset the animal's water balance and cause death. High levels of specific ions in water can cause animal health problems and death. In other words, to be used by livestock water is preferably of the same quality limitation of suitability for human drinking purposes. Most animals, however, are able to use water that has considerably higher dissolved solids concentration than the considered satisfactory for human purposes.
By comparing chemical analyses data of surface water samples with the guideline of McKee and Wolf (1963) and NAS, NAE (1973) the studied surface samples (100%) are suitable (Excellent) for livestock, but may be unsuitable for livestock and poultry according to the other parameters.

SUITABILITY OF WATER FOR INDUSTRIAL USE

Industrial water is quite diverse, and water quality requirements vary greatly for different industries and even for different plants within the same industry. So, water must be free from constituents, which cause precipitation scales on the equipment. Upon heating, bicarbonates is charged into steam, and carbonate combines with alkaline earth's principally calcium and magnesium to form crust like scale calcium carbonate that retards flow of heat through pipe walls and restricts flow of fluids in pipes. Water containing large amount of bicarbonate and alkalinity is undesirable in many industries. The presence of excess silica in water makes trouble, especially in industrial applications, where it causes severe scaling problem in boilers, heat exchangers, as well as formation of deposits on turbine blades. Therefore, silica content should be low in water to prevent such problems in industries. Comparing standards limits (recommended limits) with the concentration of some minor elements in the investigated water of the study area, the following conclusions could be achieved.

Groundwater samples are unsuitable for boilers until treated and unsuitable for all industries due to their high salinity, alkalinity and hardness except for some industries; where they can be used under certain conditions. For surface water samples, River Nile and main irrigation canals (Ibrahimia, Baher Youssef), water are suitable for boilers and all industries, while El-Moheet drain is unsuitable for boilers.

CONCLUSIONS

The study of twenty-one surface samples and ninety-six groundwater samples from the western part of the River Nile between El Edwa and Der Mawas cities of Minia Governorate, by means of multivariate data analyses, could give clear idea about the quality of water as well as the main pollutants in this area of Upper Egypt.

The north of the study area between El Edwa and Maghagha cities revealed the worst groundwater samples of the study area, where, the middle area between Minia and Abo Korkas cities disclosed the best quality for groundwater samples.

In the meantime, the worst surface water samples are located between Samalut and Minia cities. This situation could be related to the anthropogenic activities.

In general the water systems of Minia Governorate should have more careful and efficient efforts from governors and people to keep the water quality at its standards. Moreover, some areas need more focus to solve the problem resulted from the increase of pollutants close to the dangerous levels.

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