The study deals with water chemistry and its impact on the quality of groundwater in 10th of Ramadan City which is among the new communities to the east of Nile Delta. This area is an intensive industrial settlement on the peripheria of Cairo. All types of wastewater from industrial and domestic practices are discharged into three unlined oxidation ponds to eliminate pollution. The study has been conducted to assess the extent of seepage to groundwater from the ponds and how efficient they are for pollution reduction. The chemistry of groundwater was outlined through the analysis of major cations and anions. Also, the pollution of groundwater was discussed on basis of detection of minor elements such as heavy inorganic, biological organic and bacteriological pollutants. The study indicated that most of the measured heavy metals such as Cd2+, Co2+, Zn2+, Mn2+, Pb2+ and Ni2+ are present in groundwater within the international standard limit. Many pollutants such as Al3+, Fe3+, Cr3+ ammonia, S2-, BOD, COD, TOC and PO43- exceed the standard limit where their concentrations reached 2.4, 4.16, 0.03, 33.1, 72.7, 109.3, 802, 297.7 and 21.0 mg/l, respectively, in oxidation ponds and some groundwater of eastern side which needs to be protected from this seepage processes.

**Key word:** water pollution, 10th of Ramadan, groundwater, Oxidation ponds

**Introduction**

Land reclamation projects in desert regions are of vital importance for agricultural development and the establishment of new communities on this land constitutes an important national target. In Egypt, great effort has been done to increase the land reclamation. During the last fifty years, heavy investments have been devoted to turn territories of the unproductive desert into green productive areas, to survive the highly increasing rate of population. Pronounced portions of the Egyptian deserts have been reclaimed. Priorities of land reclamation are given to the west and east Nile delta regions due to the presence of high potential groundwater aquifers of quality and wide plains with deep sandy soil. Urbanization of land and human activities have significant effects on groundwater quality and can lead to serious degradation. The percolation of waste water from domestic or agricultural activities to groundwater depends on the load and behavior of the contaminants as well as geological and hydro geological factors that control the flow and dispersion of the contaminants.

The 10th of Ramadan city is one of the new settlements that are constructed on the peripheries near or close to Cairo city to extend the occupational area and to release the socio economic stresses affecting Cairo due to overpopulation and development practices. The concerned city is located on the fringes of the eastern Nile delta region along Cairo – Ismailia desert road between longitudes 31°30’–32°00’ and latitude 30°00’–30°30’, Fig. (1).

The 10th of Ramadan city occupies a portion of the rolling plain of the old delta; it is bounded by Ismailia canal on the North and West and on the South by a tactical escarpment along 10th of Ramadan fault. The general slope of the land surface is from south-west towards north-east. The altitude varies from about 80m+asl in the south to about 12m+asl near Ismailia canal in the North. The geological aspects of eastern Nile delta region is classified from the structural point of view into two forms, Fig.(2): up thrown south delta block and down thrown north delta embayment separated by number of step faults. The study area is located within the up thrown south delta block and has its surface cover by less than five meters of recent deposits of transformed sands (Pleistocene deposits). These Pleistocene deltaic deposits are dominated by coarse quartz sand with occasional clay lenses, cherty flinty pebbles and igneous fragments together with few fossil wood remains. This is followed downward by the Pleistocene deltaic rock unit which is formed of sand and gravel with clay lenses, the Pliocene and, Miocene sediments of marl shale sand and limestone. The Pleistocene formation represents the groundwater aquifer in the 10th of Ramadan city, its thickness ranges from 75 to 200m, decreasing towards the...
major fault at the South and southeast. These deposits attain about 200m thickness and rest directly on the Miocene shallow marine sandstone and sandy limestone, El Shazly et al., 1975. On the other hand, in the eastern side of the 10th of Ramadan city, the Miocene represented the groundwater aquifer. This aquifer is dominated by clastic facies and overlain by about 200m of Quaternary deposits (Pleistocene aquifer). The Miocene sediments are composed of alternating sandy limestone and clay lenses of loose quartz sand and marl. In Isthmus stretch, Fig. (3), Abdel Baki et al., 1995, the Miocene aquifer includes more clay intercalations with high slope to South direction and the water mostly exists under partially confined conditions due to presence of clay beds, El Shazly et al., 1975.

Generally, groundwater occurs under free water table condition and flows regionally from South and south-west toward North and north-east with some local anomalies (local movements) due to urbanization and activities accompanying settlement. The groundwater head varies from 6 to 16m+masl, Abd el-Samie et al., 2001.

The main sources of groundwater recharge are inflow and seepage from the Ismailia canal, excess of irrigation water from agricultural lands and infiltration from the oxidation ponds. Groundwater loss occurs through withdrawal for drinking and irrigation purposes as well as outflow towards Suez Canal. The hydraulic conductivity in the area of study has an average of 40m/day and the average specific yield is about 0.2, Fig. (4), RIGW, 1990.

This new city incorporate large industrial companies (more than 1130) distributed in three localities and includes many activities such as, textile industry, synthesis of detergent, electroplating, petroleum industries, iron and steel factory, battery manufactures, etc. The supplying production wells (withdrawal is about 25000 m$^3$/day) are mixed with treated surface water in the pipeline and used for drinking, domestic and industrial purposes. The withdrawal for irrigation purposes from the individuals reaches about 40000 m$^3$/day, (Abd el-Samie et al., 2001), where all types of wastewater discharge 280,000 m$^3$/day, the industrial drainage represented 80% and human activity 20%. All wastewater is discharged into three oxidation ponds for pollutants reduction and settlement of fines. The three ponds are unlined, accordingly; expected seepage to
groundwater and overflow due to undersize of the ponds is sometimes experienced the outflow water which is utilized for irrigation without any treatment.

This paper deals with the hydrogeological, hydrochemical and pollutant influence of the study area to assess the extent of groundwater pollution due to seepage from the ponds and to emphasize the role of the oxidation ponds on pollution reduction.

Materials And Methods

- Sampling and measuring technique:

  A total number of 31 samples were collected during summer 2010, Fig. (5), and classified into three classes.
  Class I: 6 surface water samples from Ismailia canal branches and water purification station
  Class II: 12 waste water samples; 3 samples from the inflow and 9 samples from the outflow of the three unlined ponds.
  Class III: 13 groundwater samples, A- 6 samples from western side and B- 7 samples from eastern side.

  These water samples were subjected to both field and laboratory analyses. Four kinds of analyzed water samples were taken from each of the above water points for different measurements. The first kind is for the measurement of TDS, major cations, anions, minor elements and total organic carbon (TOC). The second kind includes acidified samples by (nitric acid) for the measurements of trace elements and soluble heavy metals. The third kind is collected in special container for the measurements of biological oxygen demands (BOD) and chemical oxygen demands (COD). Finally, the fourth kind 19 samples are collected in a special antiseptic container for water quality and microbial contamination with coliform.

![Fig. 2: Reginal geology of the eastern Nile Delta including the study area.](image-url)
Fig. 3: Hydrogeological cross section in 10th of Ramadan city and its vicinities area, (After, 2).

Fig. 4: Water level map of represented samples of 10th of Ramadan city and its vicinities.

- **Field measurements:**

  In situ measurements of water samples location were carried out in the field using GPS model (Magellan Nave 5000 pro.) for the determination of latitudes and longitudes. Some physical and chemical characteristics of the collected water were determined by electrical conductivity meter, Jenway model (470) (EC in µs/cm) for the collected water samples. Dissolved oxygen and pH are measured using pH meter Jenway, model (3150) and DO meter WTW, model oxi 315I, respectively.

- **Laboratory analyses:**

  The analyses include the determination of EC, TDS, pH, concentration of major ions Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$, CO$_3^{2-}$, HCO$_3^-$, SO$_4^{2-}$ and Cl$. The minor, trace and soluble heavy metals and non metals are S$^2-$, NH$_4^+$, NO$_2^-$, NO$_3^-$, PO$_4^{3-}$, I-, Br$, soluble SiO$_2$, B$^{3+}$, Al$^{3+}$, Fe$^{3+}$, Mn$^{2+}$, Co$^{2+}$, Cu$^{2+}$, Ni$^{2+}$, Cr$^{3+}$, Cd$^{2+}$, Pb$^{2+}$, Sr$^{2+}$, V$^{2+}$ and Zn$^{2+}$, beside total organic carbon (TOC), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and
bacteriological measurements. Measurements were carried out by EC meter model Orion 150 A+, pH meter Jenway 3510, Flame photometer Jenway PFP 7, UV/Visible spectrophotometer Thermo-Spectronic 300 (Thermo Jerral Ash), and Inductively Coupled Argon Plasma (ICAP) poma 6500 spectrophotometer (Unicom, UK). The obtained chemical data are expressed in milligram per liter (mg/l). Also, The bacteriological examination was performed within 24 h of collection using standard Multiple Tube Fermentation Technique (MTFT) for the determination of Most Probable Number (MPN) index, nine multiple tube dilution technique using double and single strength Bromo-Cresol Purple MacConkey medium for detection of *E. coli* (Thermotolerant coliform, TTC) with production of yellow colour colonies on membrane filter at 44.5°C. For differentiation between different species of enteric bacteria, sub culturing colonies on Triple Sugar Iron (TSI) were done for contaminated water samples.

**Results And Discussion**

The chemical analysis results of 31 water samples collected from class I (Ismailia canal branches and purification station), class II (waste water of different Oxidation Ponds (1, 2 and 3), class III-A (western side groundwater samples of the Quaternary aquifer) and class III-B (eastern side groundwater samples of Miocene aquifer), are discussed through two main topics, table (1). The first topic concerns the hydrochemical aspects that include water salinity, total hardness, ion dominant and hypothetical salts. The second concerns the water pollution which can be divided according to the pollutant type into four types such as chemical inorganic, biological, organic and bacteriological pollutants. These topics will be discussed as follow:

1. **Hydrochemical aspects:**

1.1. Water salinity:

The total dissolved solids (TDS) for class I ranged from 220 to 276 mg/l with a mean value of 247 mg/l. All water samples are fresh water type, Freeze and Cherry (1979). While TDS for class II ranges from 948 to 2872 mg/l...
mg/l with mean value of 1456mg/l. The fresh water type represents 8% of the total samples, while the rest 92% is brackish water type. Although the water source is fresh water from drinking water system (class I), this high salinity is due to the effect of evaporation, leaching of soil and industries waste water, table (1).

| WEL NO | pH | EC | TDS | TH (mg/l) CaCO<sub>3</sub> | CH (mg/l) CaCO<sub>3</sub> | NH<sub>4</sub> (mg/l) CaCO<sub>3</sub> | Na (mg/l) | K (mg/l) | CO<sub>3</sub> (mg/l) | HCO<sub>3</sub> (mg/l) | SO<sub>4</sub> (mg/l) | Cl (mg/l) | Ass
|--------|----|-----|-----|----------------|----------------|----------------|-------|-----|----------------|----------------|-------------|--------|-----|
| 1      | 7.8 | 503 | 250 | 166 | 900 | 90 | 33.4 | 20.4 | 40 | 0.0 | 379.8 | 14 | 38.7 | I
| 2      | 9.1 | 566 | 260 | 142 | 162 | 20 | 0.0 | 32.0 | 27 | 0.0 | 177.2 | 20 | 31.1 | I
| 3      | 8.8 | 561 | 250 | 124 | 124 | 20 | 0.0 | 30.8 | 25 | 0.0 | 151.7 | 28 | 30.7 | I

The water type of groundwater from the Pleistocene aquifer from Ismailia canal, irrigation processes and high salinity is due to the recharge from the Pleistocene aquifer, leaching and dissolution of aquifer materials. In the groundwater of class III-B, the salinity ranged 4521 to 6701 mg/l with a mean value of 5393mg/l. This means that all the groundwater of Miocene aquifer is highly brackish water type due to the marine sediments in aquifer matrix together with leaching and dissolution processes.

### 1.2. Total hardness:

The total hardness is represented by only temporary hardness in 85% of class I water samples while being 100% of class II and class III-A water samples, which means that the permanent hardness is absent, due to the cantorial facies or meteoric origin. Despite, the meteoric origin of water samples of class I, 15% of its water have permanent hardness due to the effect of leaching and dissolution with some cation exchange processes. The temporary hardness is still greater than permanent hardness, table (1).

For the groundwater samples of class III-B, the permanent hardness is greater than the temporary hardness, this is due to leaching and dissolution of marine salts in aquifer matrix. The increase in permanent hardness reveals a regional flow of groundwater from West to East direction and also with the increase the water salinity.

### 1.3 Ion dominance:

The ion dominance and relationships between the water chemical analyses are well illustrated by the trilinear of (Piper, 1944), Fig. (6), in water samples of class I, table (1), where Ca>Na>Mg or Na>Ca>Mg as cations with HCO<sub>3</sub>ervatives and give secondary salinity with alkaline earth and weak acid with two chemical water types which are Ca-HCO<sub>3</sub> (83%) and Na-HCO<sub>3</sub> (17%). Those water types suggest primary stage of mineralization according to (Burdon, 1958 a).

In water samples of class II, the sequence of cations and anions are Na>Cu>Mg with HCO<sub>3</sub>ervatives and give primary salinity with alkaline earth and strong acid addition to no one cation-anion pair
exceeds 50% with two chemical water types as Na-HCO₃ (57%) and Na-Cl (43%), this is due to the meteoric origin of water (Ismailia Canal) which is affected by leaching and dissolution processes. This means that, the sources of inflow water of oxidation ponds (class II) from Class I but affected by some leaching and dissolution with some cation exchange processes.

The ion dominance of class III-A follows the orders Na>Ca>Mg or Na>Mg>Ca as cations with Cl>SO₄>HCO₃ and HCO₃>Cl>SO₄ as anions and gives primary salinity with alkali earth and strong acid addition to no one cation-anion pair exceeds with two chemical water types as Na-Cl (66%) and Na-HCO₃ (34%). This is due to meteoric origin source of water (Ismailia Canal) which is affected by leaching and dissolution processes. The samples of class II and class III-A display intermediate stage of mineralization.

The ion dominance of class III-B is Na>Mg>Ca as cations with Cl>SO₄>HCO₃ as anions to give primary salinity with alkali earth and strong acid with chemical water type Na-Cl (100%). This means that, the water in this side is affected by leaching and dissolution of marine salts in aquifer matrix with the original flow. These factors directed the water of this class to the final stage of mineralization.

![Fig. 6: Trilinear diagram for the represented water samples in study area.](image)

**1.4. Hypothetical Salt Combinations:**

The three classes of water samples in the study area are distinguished into four main assemblages of hypothetical salt combinations, table (1), as follows:
Measurements of trace elements, heavy metals and minor ions, including $\text{B}^{3+}$, $\text{Al}^{3+}$, $\text{Cd}^{2+}$, $\text{Co}^{2+}$, $\text{Cr}^{3+}$, $\text{Cu}^{2+}$, $\text{Fe}^{3+}$, $\text{Mn}^{2+}$, $\text{Mo}^{5+}$, $\text{Ni}^{2+}$, $\text{Pb}^{2+}$, $\text{Sr}^{2+}$, $\text{V}^{5+}$, $\text{PO}_{4}^{3-}$ and $\text{Zn}^{2+}$, in all water resources. This means that the hydrochemical facies of inflow water samples and outflow water samples of oxidation ponds (class II) are not changed by evaporation and residual time. Also, the groundwater of class III-A has one assemblage (I). On the other hand, the groundwater samples of class III-B have two types of hypothetical salt combinations (III and IV) that include two and three chloride salts, respectively. These salts are due to leaching and dissolution of marine facies within the aquifer matrixs.

2. Water pollution:


2.1. Chemical inorganic Pollutants:

The chemical inorganic pollutants of water samples in the studied area are discussed through the measurements of trace elements, heavy metals and minor ions, including $\text{B}^{3+}$, $\text{Al}^{3+}$, $\text{Cd}^{2+}$, $\text{Co}^{2+}$, $\text{Cr}^{3+}$, $\text{Cu}^{2+}$, $\text{Fe}^{3+}$, $\text{Mn}^{2+}$, $\text{Mo}^{5+}$, $\text{Ni}^{2+}$, $\text{Pb}^{2+}$, $\text{Sr}^{2+}$, $\text{V}^{5+}$, $\text{PO}_{4}^{3-}$ and $\text{Zn}^{2+}$, table (2).

| Assemblage | NaCl, Na$_2$SO$_4$, Na HCO$_3$, Mg (HCO$_3$)$_2$, Ca (HCO$_3$)$_2$ | NaCl, Na$_2$SO$_4$, MgSO$_4$, Mg (HCO$_3$)$_2$,Ca (HCO$_3$)$_2$ | NaCl, MgCl$_2$, MgSO$_4$, Mg (HCO$_3$)$_2$, Ca (HCO$_3$)$_2$ | NaCl, MgCl$_2$, Ca Cl$_2$, Ca SO$_4$, Ca (HCO$_3$)$_2$ | In water samples of class I, two assemblages (I and II) are present. These assemblages indicate the continental facies of water. In water samples of class II, there is one hypothetical salt (I) indicating the source of the water from Ismailia Canal branches (class I) and the seepage from irrigation process without any change in water facies. This means that the hydrochemical facies of inflow water samples and outflow water samples of oxidation ponds (class II) are not changed by evaporation and residual time. Also, the groundwater of class III-A has one assemblage (I). On the other hand, the groundwater samples of class III-B have two types of hypothetical salt combinations (III and IV) that include two and three chloride salts, respectively. These salts are due to leaching and dissolution of marine facies within the aquifer matrixs. |
b-For water samples of class I, all samples are within the acceptable and permissible limits of contamination for most heavy metals, table (2). On the contrary, all samples of this class have a high value than the acceptable level of Al$^{3+}$ (0.2ppm). This increase may be rendered to drainage of some industrial factories.

c- In water samples of class II, 83% and 50% of the total samples are contaminated with Al$^{3+}$ and Fe$^{3+}$ ions, respectively. These pollutants are from the waste water of industrial activities such as steel and iron in 10th of Ramadan city. On the other hand, the rest of elements have low detection limits of their concentration. This may be due to the precipitation of these elements from aeration in the oxidation ponds. Also, the Cu$^{2+}$ concentration of some samples (42% of the total samples) is higher than the acceptable limit (<0.05 ppm). The high concentration of Cu$^{2+}$ reveals source of the galvanic factory. The relatively high concentrations of B$^{3+}$ in some water points than the permissible limit (0.5 mg/l) in samples 12, 13,14,15,18 26, 27, and 28, is due to pollution from domestic sewage water which is rich in boron beside pollution from the excessive irrigation water. Moreover the PO$_4^{3-}$ has higher concentration than the acceptable limit (1 mg/l), (Doolid, and Best, 1992). Also only one sample No.11 in class II is higher than the permissible limit of Ni$^{2+}$ and 42% of total samples of this class have high concentration of Cr$^{3+}$ ion than the acceptable limit. This is due to the seepage from agricultural activities and from some industrial factors, where industrial sanitary wastewater effluents represent the important sources of phosphorus in natural water, table (3).

d-For water samples of class III-A, all samples are within the acceptable and permissible limits of contamination for all heavy metals, except only two samples Nos. 3 and 7 which attain Fe$^{3+}$ concentration higher than the permissible limit. On other hand, the concentration of Mo$^{2+}$ is higher than the permissible limit this may be due to leaching and dissolution from the aquifer matrix. The Mo$^{2+}$ ion has a relatively high geochemical mobility with a tendency to enter into solution in water under normal earth – surface conditions, (Kaback, 1976) and (Pentcheva, 1967). This is mainly due to interaction between groundwater and minerals of the aquifer matrices, which leads, to a great extent, to release of most soluble heavy metals.

e- In water samples of class III-B, all water samples are within the acceptable and permissible limits of contamination for all heavy metals except one sample No. (19), which has high concentration of Al$^{3+}$ ion than the acceptable level. Also, two groundwater samples Nos. 17 and 20 II have higher concentration than the permissible level of boron (0.5 mg/l) which may be attributed to excess fertilizers in agricultural activities and one sample No. (30) have higher than the acceptable limit of Cr$^{3+}$ due to the seepage from class II with regional flow of groundwater.

2.2. Biological pollutants:

1. Nitrogen compounds:

The nitrogen compounds play an important role in many processes that takes place in natural waters. Nitrogen is also one of the basic components of proteins, so it can enter surface waters in sewage and industrial wastewater from the breakdown of proteins and other nitrogenous compounds. Nitrogen fertilizers are used

### Table 3: Biological analysis of represented samples in 10th of Ramadan and its vicinities.

<table>
<thead>
<tr>
<th>No</th>
<th>NH$_3$</th>
<th>NO$_2$</th>
<th>NO$_3$</th>
<th>S$^{2-}$</th>
<th>DO</th>
<th>TOC</th>
<th>BOD</th>
<th>COD</th>
<th>PO$_4^{3-}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater of Oxidation ponds (Class II)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>33.1</td>
<td>268</td>
<td>0.05</td>
<td>56.6</td>
<td>0.4</td>
<td>25.5</td>
<td>109.3</td>
<td>802</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>27.1</td>
<td>400</td>
<td>0.04</td>
<td>72.7</td>
<td>1.3</td>
<td>297.7</td>
<td>102.3</td>
<td>472.5</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>29.1</td>
<td>442</td>
<td>0.05</td>
<td>48.5</td>
<td>0.8</td>
<td>42.53</td>
<td>106.5</td>
<td>538</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>24.5</td>
<td>9.5</td>
<td>0.7</td>
<td>48.5</td>
<td>3.1</td>
<td>34.02</td>
<td>88.4</td>
<td>472.5</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>7.5</td>
<td>4.3</td>
<td>0.21</td>
<td>40.4</td>
<td>8.5</td>
<td>25.5</td>
<td>50.4</td>
<td>219.8</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>21</td>
<td>19</td>
<td>0.32</td>
<td>48.5</td>
<td>1.4</td>
<td>34.2</td>
<td>73.5</td>
<td>263</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>--</td>
<td>27</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>150</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>--</td>
<td>42</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>133</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>--</td>
<td>28</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>125</td>
<td>--</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>--</td>
<td>18.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>170</td>
<td>--</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Eastern side of groundwater of Miocene aquifer (Class III-B)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1.6</td>
<td>36.3</td>
<td>0.02</td>
<td>40.4</td>
<td>3.9</td>
<td>8.5</td>
<td>3.9</td>
<td>98.9</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>31.5</td>
<td>0.01</td>
<td>0</td>
<td>4.3</td>
<td>4.1</td>
<td>0</td>
<td>17.1</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1.1</td>
<td>11</td>
<td>0.01</td>
<td>0</td>
<td>4.4</td>
<td>4.0</td>
<td>0</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>0.8</td>
<td>2</td>
<td>0.01</td>
<td>0</td>
<td>4.2</td>
<td>8.1</td>
<td>15</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Permissible Limit</td>
<td>0.5</td>
<td>45</td>
<td>4.5</td>
<td>&lt;1</td>
<td>8</td>
<td>10</td>
<td>6</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

extensively in agriculture, and the excess over crop requirements is mostly leached into drainage water, table (3).

**A. Ammonia content:**

In each of class I and class III-A of 10th of Ramadan city, the concentration of NH$_3$ is less than the permissible limit (0.5mg/l). while the samples of class II, possess concentrations higher than the permissible limit which ranged from 7.5 to 33.1 mg/l. or mentioning that, the samples of inflow water to oxidation ponds (Nos. 9, 10, 11 and 13) have higher ammonia content than the samples of outflow water (Nos. 15 and 18). This means that, the oxidation ponds react as reduction agent of NH$^+$ concentration. The high NH$_3$ concentration is due to sludge of human activity. Also, the samples of class III-B have greater concentration than the permissible limit since it ranged from (0.8 to 1.6 mg/l). This high value of class III-B is due to the seepage from the oxidation ponds (class II) with original flow of groundwater from southwest to northeast and fertilizer use in agriculture process.

**B. Nitrite content:**

Concentration of NO$_2^-$ in all water samples of the studied area (all classes) ranged from a trace amount (0.01) up to 0.7 mg/l, but still below the acceptable level of pollution (4.5 mg/l). The low value of nitrite concentration reveals the instability of nitrite form.

**C. Nitrate content:**

Some representative samples of class I and class III (A and B) have low nitrate concentrations that ranged from 0.1 to 36.3 mg/l. On the other hand, some water samples of class II have higher concentration than the permissible limit (45mg/l). Meanwhile the samples of inflow water (9, 10, 11 and 13) have greater NO$_3^-$ content than the samples of outflow water (15 and 18). This means that, the oxidation ponds caused reduction processes for the concentration of NO$_3^-$ ion. This variation may be due to the human activity and excess fertilizer use in agriculture.

Noteworthy to mention that NO$_3^-$ is considered the final stage of NH$_4^+$ oxidation passing with NO$_2^-$ in the presence of bacteria and oxygen. Consequently, the authors believe that the presence of high ammonium concentration (more than nitrate) in class II and some samples of groundwater class III-B confirms that the concerned water was subjected to reducing conditions more than oxidizing ones. On the contrary, when NO$_3^-$ concentration exceeds NH$_4^+$ in such water, this confirms the prevalence of oxidizing conditions.

2. **Sulfide content:**

Sulfide is a pollutant (> 1 mg/l) in most samples representing class II where its content ranges from 8.08 mg/l in sample No. (16) for class I surface water up to 72.7 mg/l in sample No. (10) of class II inflow water of oxidation ponds, table (3). The S$^{2-}$ presence is attributed to the depletion of oxygen and reduction of sulfate ions, caused by biochemical degradation of high content of organic matter while the rest of samples of outflow water of oxidation ponds are less than the inflow water. This means that, the oxidation ponds decreased the sulfide concentration. On other hand, the sulfide pollutant is present in some groundwater of Miocene aquifer in eastern side (class III-B), indicating the seepage from these ponds to the aquifer with original flow of groundwater.

3. **Phosphate content:**

In the Class II, phosphate ions concentration ranges from not detected level to 21 mg/l, table (3). The high PO$_4^{3-}$ concentration (21 mg/l) refers to the disposal of industrial waste which is adjacent to such drain. The maximum permissible concentration of phosphate ions in surface water is 1 mg/l (Dojlido and Best, 1992).

On the other hand, in all samples of class I and class III-B phosphate is not found except in the sample No. 24 for the class I of surface water where the concentration of phosphate ions is 0.2mg/l. This is due to the sanitary wastewater mixed with such water.

2.3. **Organic pollutants:**

Various methods have been used to estimate the requirement of given water for oxygen or to evaluate the organic pollution load in a quantitative way. These include measurement of biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC), table (3).
1. Biochemical oxygen demand (BOD):

The representative samples of classes I, II and III-B have BOD values that ranged from 3.9 to 73.5 mg/l with a mean value of 20.4 mg/l, indicating less contamination level for outflow water of oxidation ponds, while BOD of the inflow water of oxidation ponds ranges from 88.8 to 109 mg/l with a mean value of 102 mg/l. This means that, the oxidation ponds acts as a reduction agent for the pollution of human activity. Since the BOD value of non-polluted fresh water is 6 mg/l. The increase in concentration in BOD reveals more human activity in the study area. The appearance of contamination of groundwater in eastern side of the 10th of Ramadan (class III-B) indicates the original flow. These results are confirmed by the occurrence of pathogenic microorganisms belonging to family interobactriaceae in such water.

2. Chemical oxygen demand (COD):

The results of COD determinations obviously do not correspond to the values obtained by BOD determination where COD values are higher than BOD values, but they may be helpful in comparing conditions in a stream at one time with those at another time.

Results revealed that the water samples of class I, class II and class III-B have high values of COD that ranged from 15 to 802 mg/l, i.e., more than the acceptable level (10 mg/l), except for samples of class I (branches of Ismailia canal) which have COD concentration lower than 10 mg/l, indicating non-polluted water, i.e., these waters have low material loads. On the other hand, the value (802mg/l) of COD for inflow water of class II is higher than that of the outflow water samples of oxidation ponds which have low value. This means that, the oxidation ponds reduced the concentration of COD.

3. Total organic carbon (TOC):

The TOC values ranged from non detectable in water samples of class I to 297.7mg/l out of the mechanical separate station of waste water (inflow water of oxidation ponds) which represents class II, indicating non-polluted water according to permissible limit (10 mg/l), this may be related to disposal of sanitary wastewater from human activity. With regard to, class III-B there is some contamination but still below the detection limit indicating seepage from oxidation ponds (class II) with flow of groundwater.

Statistical analysis (Cluster Analysis):

The different classes of water sampling points were divided into groups with similar physical and geochemical characteristics through cluster analysis in summer 2010 (Dugin et al., 2007). The classified groups can be effectively used to characterize groundwater contamination. The water sampling points in three classes (I, II and III-B) were divided into groups with regard to NH₄⁺, COD, BOD, NO₂⁻, PO₄³⁻, DO and S²⁻ through cluster analysis based on their nearness or similarity. The results showed that three groups were clustered. These groups were designated on the map with symbols in Fig. (7). The first cluster dominates twelve cases (67% of total samples) representing all groundwater samples of class III-B of eastern side of 10th Ramadan, all samples of class I representing the surface water and 40% of total samples of class II representing the outflow water of oxidation ponds. The second cluster includes two cases (11% of total samples) representing outflow samples of class II while the third cluster has three samples from class II (16% of total samples) representing the inflow water have a high concentration of COD and BOD and sample no. (9) representing the inflow water of class II (6% of total samples) that considered as independent on secondary cluster. This classification of clusters to different water resources in the study area confirmed that class III-B is an intermediate stage of concentration of contaminants between classes I and II where class I is the source of recharge with the lowest polluted waters and class II have the highest polluted waters. In the same time, the data show that class II is responsible for contamination of the groundwater samples.

In brief, the obtained results of 31 analysed samples collected from different water classes show that the hydrogeological structure, hydrogeochemical evolution, surface flow and groundwater movement effect on groundwater of class III-B tapping the Miocene aquifer due to seepage of water from oxidation ponds.

2.4. Bacteriological pollutants:

The microbiological analysis of 19 samples representative of all classes is shown in Table (4). Total colony count for samples 22, 23 and 24 of class I being 29, 80 and 45 × 10² cfu/ml. The most probable number (MPN) for total coliforms counts of the water sample being 35, 17 and 11 MPN/100ml. Owing to that the total coliform counts of these water samples were grossly contaminated. TSI test recorded the presence of E.coli or Klebsiella in the three tested samples. Although the branches of Ismailia canals and purification station class I
are a flowing one it is open to various objects uses and gross contamination as well as turbidity which may result from high level of organic matter.

![Dendrogram of the cluster analysis of the data sampled in the area of study.](image)

Table 4: Bacteriological analysis of representative samples in 10th of Ramadan and its vicinities.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Coliform Count (M.P.N/100ml)</th>
<th>Total colony count ×10^2 (S.P.C/ml at 37 °C)</th>
<th>Triple Sugar Iron (TSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Branches of Ismailia canals and purification station (Class I)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>35</td>
<td>29</td>
<td>E.coli or Klebsiella</td>
</tr>
<tr>
<td>23</td>
<td>17</td>
<td>80</td>
<td>E.coli or Klebsiella</td>
</tr>
<tr>
<td>24</td>
<td>11</td>
<td>45</td>
<td>E.coli or Klebsiella</td>
</tr>
<tr>
<td><strong>Wastewater of Oxidation ponds (Class II)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>45</td>
<td>169</td>
<td>Shigella</td>
</tr>
<tr>
<td>13</td>
<td>1800</td>
<td>420</td>
<td>E.coli</td>
</tr>
<tr>
<td>15</td>
<td>110</td>
<td>74</td>
<td>E.coli or Klebsiella</td>
</tr>
<tr>
<td>18</td>
<td>350</td>
<td>139</td>
<td>E.coli or Klebsiella</td>
</tr>
<tr>
<td>25</td>
<td>1800</td>
<td>360</td>
<td>E.coli or Klebsiella</td>
</tr>
<tr>
<td>26</td>
<td>900</td>
<td>213</td>
<td>Salmonella</td>
</tr>
<tr>
<td>27</td>
<td>275</td>
<td>85</td>
<td>Shigella</td>
</tr>
<tr>
<td>28</td>
<td>1600</td>
<td>146</td>
<td>Shigella, Salmonella</td>
</tr>
<tr>
<td><strong>Western side groundwater of Pleistocene aquifer (Class III-A)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>13</td>
<td>-</td>
</tr>
<tr>
<td><strong>Eastern side of groundwater of Miocene aquifer (Class III-B)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>-</td>
<td>82</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td>110</td>
<td>234</td>
<td>Salmonella</td>
</tr>
<tr>
<td>20</td>
<td>-</td>
<td>69</td>
<td>-</td>
</tr>
<tr>
<td>21</td>
<td>-</td>
<td>74</td>
<td>-</td>
</tr>
</tbody>
</table>

Total colony counts of waste water of oxidation ponds class II represented by samples 11, 13, 15, 18, 25, 26, 27 and 28 were generally high and ranged between 74 to 420 ×10^2 cfu/ml., this being generally higher than the recommended value (1×10^2 cfu/ml) for water. Recommended standard for water is nil, (FAO, 1997) and (Okonko, 2008). Also, the highest total coliforms counts for all tested water samples recorded in class II ranged between 45 and 1600 MPN/100 ml. Recommended standard for water is less than 2 MPN/100ml, TSI recorded the presence of E.coli or Klebsiella in samples 11, 13, 15, 18 and 25 but Salmonella in sample 26 Shigella in sample 27 and both Salmonella and Shigella in sample 28. The presence of coliforms group in most of these water samples generally suggests that a certain of water samples may have been contaminated with faeces either of human or animal origin. Other more dangerous microorganisms could be present, (Okonko IO, 2008 and Richman, 1997). The presence of enteric bacteria- as reported in this study is an indication of the faecal contamination as a result of possible burst along pipelines or unhygienic handling of the water right from the treatment plant for tap water and borehole water. In this regard, (Umeh, 2005) reported the presence of enteric
bacteria associated with faecal contamination including *Escherichia coli*, *Shigella* sp., *Enterobacter aerogenes*, *Serratia* sp. and *Klebsiella* sp.

On the other hand, the groundwater representing the class III-A, water samples 2, 3, 4 and 5 recorded presence of coliforms group and enteric bacteria and gave total colony counts of 18, 25, 20 and 13 respectively.

On the other hand, the groundwater of class III-B represented by samples 17, 19, 20 and 21. Water pollution significantly recorded in sample 19, being 234 for total colony counts and 110 for coliforms count. Also, TSI recorded the presence of *Salmonella* whereas water samples 17, 20 and 21 recorded the absence of coliforms group and enteric bacteria and gave total colony counts of 82, 66 and 74, respectively.

**Summary And Conclusion:**

This objective of this work is concerned with the hydrogeochemistry and the pollution impact on groundwater from oxidation ponds in 10\textsuperscript{th} of Ramadan city, East Nile Delta, Egypt, through the study of different types of pollutants in 31 collected water samples. These samples represent the available water points namely surface water (Ismailia canal branches; class I), oxidation ponds (class II) and groundwater of Quaternary aquifer in the western side (class III-A) and Miocene aquifer in the eastern side (class III-B).

The total dissolved solids (TDS), 100%, 83% and 75 of the total water samples of classes I, II and III-A are fresh water type, respectively. On the other hand, 17% and 25% of the total samples of classes II and III-A are of brackish water type. While, all groundwater of class III-B is related to saline water type.

The total hardness is represented by only temporary hardness in 85%, 100% and 100% of the whole water samples of class I, class II and class III-A respectively. On the other hand, in the groundwater samples of class III-B, the total hardness is either permanent or temporary with obviously greater permanent hardness than the temporary one.

The ion dominance in water samples changes from Ca-HCO\textsubscript{3} to Na-Cl chemical water type according to different classes, (class I to class III-B).

The hypothetical salt combinations of assemblage (I) represent 83%, 100% and 100% for classes I, II and III-A, respectively. But only 17% of the total samples of class I is related to assemblage (II). On the other hand, the groundwater samples of class III-B have two hypothetical salts (III and IV).

The water pollution is discussed through determining chemical inorganic, biological, organic and bacteriological pollutants and the obtained results reveal:

- For water samples of class I, all samples exceed detection limit of Al\textsuperscript{3+} ion concentration.
- In class II, 83% and 50% from total samples are contaminated by Al\textsuperscript{3+} and Fe\textsuperscript{3+}, respectively. Most samples have a high concentration than the permissible levels of B\textsuperscript{3+} and phosphate ions.
- For water samples of class III-A, some samples Nos. 3 and 7 have Fe\textsuperscript{3+} concentration higher than the permissible limit. In addition, all samples have high concentration than the permissible limit of Mo\textsuperscript{2+}, but samples Nos. 17 and 20 have high concentrations of B\textsuperscript{3+} ions.
- In water samples of class III-B, only sample No. 19 has a higher concentration than the acceptable levels of Al\textsuperscript{3+} ion.

The biological pollutants are present in most water samples of class II and some samples of class III-B.

- The representative samples of water classes I, II and III-B, have high contamination level of BOD. Likewise, these water classes have high values of COD than the acceptable level of pollution.
- The TOC values ranged from non-detectable up to 297.7 mg/l in the mechanical separate station of waste water.
- Some samples representing Ismailia canal branches, oxidation ponds, and groundwater in class III-A and class III-B are infected by bacteria which are considered as an indicators of potential bacterial contamination.

**Recommendations:**

According to the obtained results, the following recommendations should be followed:

1. Chemical fertilizers and pesticides treatments should be used at minimum limits as they pollute oxidation ponds of class II that feed groundwater.
2. The area should be sewerred and sanitary wastewater should be treated in a central plant. Treated water can be reused for irrigation depending on its quality. Industrial wastewater should be treated at the industry’s site where it may be recycled in the plant.
3. The use of hydrogel or resin with nonmaterial composites for treatment of soluble heavy metals, biological and organic pollutants in industrial drains and human activity before disposal of industrial wastes into oxidation bonds.
4. Carrying out periodical chemical, organic, biological and bacteriological analyses for all water of these classes to follow up the changes specially in the groundwater of eastern side.
References


