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Potential Ecological Risk Index of the Northern Egyptian Lagoons, South of Mediterranean Sea, Egypt

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Abstract: The Northern Egyptian Lagoons are (from east to west) Bardawil Lagoon, Manzala Lagoon, Burullus Lagoon, Edku Lagoons and Mariute Lagoon.These lagoons have been received the bulk of drainage water from the lands of Delta and from the other coastal areas. where, the heavy metals can be occur in Lagoons environments through a variety of sources, including industries, wastewaters and domestic effluents. The potential ecological risk index (RI) calculation of the bottom sediments of the northern lagoons depends contamination factor (CF), potential ecological risk factor and proposed toxic response factor (Tr). The average degree of contamination and modified degree of contamination of the northern lagoons were in the following descending order Bardawil>Mariute>Manzal>Edku>Burullus, while, the potential ecological risk index in the following descending order Bardawil>Manzal>Mariute>Edku>Burullus.
Keywords: Northern Lagoons – Nile Delta – Ecological Risk Index – Contamination Factors.

Introduction:

Coastal areas and lagoons are important subjects in the international debate for the environmental, sustainable development and future planning. They have become the very important site for extensive and diverse economic activities[1]. Coastal lagoons and lakes occupy 13% of worldwide coastal areas and are often subjected to both natural and man-made changes[2]. The coastal lagoons represent 25% of the total Mediterranean coastal wetlands[3]. Fishing and salt extraction along the borders of lagoons give the importance for these lagoons[4,5].

The northern lagoons of Egypt are called lagoons not lakes, there are many differences between three terms, Lagoon, Lake and Pond as following: There are about two million lakes around the world, whereas there are far less lagoons. A lagoon, though it looks like a lake, is a shallow water body near coastal areas and receives water from the ocean, and it is separated from the ocean by barrier islands made of sand. Lagoon is close to the ocean or Sea, whereas lakes are far away from oceans. Lagoon is saltwater body, whereas lakes are mostly freshwater bodies. A lake is a water body that is still or slow moving and is away from the oceans. Lakes are mostly freshwater lakes that are formed at the foothills of mountains. Lakes are surrounded by land on all sides though they are fed and drained into a river or any other stream. A pond is a body of standing water, may be natural or artificial, it is usually smaller than a lake size. It may be arise naturally in floodplains as part of a river system, or it may be somewhat isolated depressions with shallow water and aquatic plants and animals.

The northern coastal area of Egypt is characterized by the presence of several lagoons occupying a significant percentage of coastal area. Along the Egyptian northern coast there is a chain of lagoons (Fig.1A); most of them have an elongated shape aligned with the direction of the coast. These lagoons are Bardawil, Manzala, Burullus, Idku and Mariut receive the bulk of drainage water of the lands of Delta and from the other coastal areas. They are separated from the sea by sand barriers that are very narrow in several places and may be connected with the sea through outlets. Four of them considered a Deltaic lagoons such as Manzala, Burullus, Idku and Mariut, where they located in the coastal area of the Nile Delta. While, Bardawil Lagoon located in the coastal area of Sinai, thus it not considered a deltaic lagoon but northern lagoon.

The northern lagoons of Egypt have been undergoing continuous and pronounced changes through the Late Holocene to the present time, especially after construction of the Aswan High Dam in 1965. Before this date, the annual recharge of freshwater was continuous due to Nile floodwater entering through many canals and drains[6]. Bardawil Lagoon (Fig.1B) is a shallow, hypersaline lagoon (salinity 50.9 ‰), situated at the north of Sinai Peninsula. Its coordinates are 31^0 09^- to 31^0 03^- N latitude and 33^0 19.25^- to 32^0 46.75^- E longitudes. It about 90 Km long with a maximum width of 22 Km, it covers an estimated area of 650 Km2.The water depth ranges from 0.5 m to a rather rare 3 m., separated from the Mediterranean sea by a sedimentary sand bar with width range from 200 to 1000 m. The lagoon is a natural depression separated from Mediterranean Sea by two artificial opening in the west named Boghazes I & II and an eastern natural opening called Zaranik[7,8,9]. Bardaweel Lagoon has a great economic importance and global reputation of what is produced of high-quality fish, most of its production is exported to Europe.

Manzala lagoon is the largest of the Egyptian lagoons on the Mediterranean coast. It is located in the northeastern extremity of the Nile Delta (Fig.1C), between latitudes 31° 30`– 31° 00`N and longitudes 31° 45`-32° 15` E. It covers an area of about 1275 km^2, and has a maximum length of nearly 64.5 km, with a maximum width of about 49 km. The lagoon water is generally brackish, ranging in salinity from a low of 2 $g.l^{-1}$ in the western and southern regions to 16-23 $g.l^{-1}$ in the southeast and near the outlets at the north. The lagoon is very shallow with maximum depth of about 250 cm, and has recently decreased in size due to land reclamation. The rainfall occurs only in winter from November to April and the dry season lasts from May to October[6]. [10]stated that Manzala lagoon lost 12,000 acres (4.4%) between 1973 and 1984 with an annual loss rate of 1,090 acre/year. Drying of the lagoon was accelerated during the period 1984 and 2003. During this period El-Salam Canal south of the lagoon and the International Highway north of the lagoon were constructed. Most cut off from the lagoon occurred by the conversion of the water body to agricultural land. Between 1984 and 2003 the lagoon lost 82,000 acres (30.1%) with an annual loss rate of 4,316 acres/year. The total loss of the lagoon between 1973 and 2003 is 94,000 acres (34.5%). The lagoon water area is vulnerable to decrease between 2003and 2009.

Burullus Lagoon (Fig.1D) is the second largest of the Egyptian lagoons along the Mediterranean coast. It is located in the central part of the northern shoreline of the Nile Delta, between latitudes 31° 35`–31° 21`N and longitudes 30° 30` - 31° 10` E. It covers an area of about 568 km2, with length of nearly 64.5 km, and a width of about 16 km. The surface of the lake has decreased approximately 20% over the last century. The lagoon is very shallow, with a maximum depth of about 175 cm in the middle and western parts. Its water is generally brackish, with salinity ranging from 2.1 $g.l^{-1}$ in the west to 17.2 $g.l^{-1}$in the north. The lagoon is connected to the Mediterranean Sea at its northern edge through El-Borg inlet. The northern border is currently under development with construction of an international road. The lagoon plays host to large populations of migratory and resident water birds. It is subject to land reclamation, particularly along its southern and western edges. The northern border is currently under development with construction of an international road[6].

Edku Lagoon (Fig. 1E) is smaller than Burullus, and covers an area of about 124 km^2. It is situated between latitude 31° 12` - 31° 17` N and longitude 30° 07` - 30° 23` E, and is connected with the Mediterranean Sea at its northeastern edge through Boughaz El-Madaya inlet, it locate between Rosetta Nile branch and Alexandria about 20 km to the east of Alexandria and 15 km to the west of the Rossetta Nile branch. Where, The lagoon is connected to the adjacent Abu Qir Bay through Boughaz El Maadiya, a 20 m wide, 100 m long and 2 m deep channel. The lagoon is very shallow, with a maximum depth of about 200 cm. Its water is brackish with salinity ranging from 2.5 to 15 g l^{-1} near the northern inlet[6]. The actual surface area of the lake has been decreased since 1964 due to reclamation of a large area from the eastern side for cultivation purposes. It is surrounded by a productive agriculture to the south, by ongoing land reclamation activities to the east, and by housing and industry to the west side where much reclamation has occurred since the 19th century[11]. Its area diminished from 336.4 km^2 in 1800 to 17.1 km^2 in 2010, so it lost 319.3 km^2 in 210 years; with an annual average of 1.735 km^2[12].

Lagoon Mariut (Mariout, Maryut, Mareotis) (Fig.1F) is a 90–150 cm deep brackish water lagoon located in the north of Egypt southeast to the Alexandria city, belonging to the Nile river Delta system, and one of the most heavily populated urban areas in Egypt and in the world. It is located at 31° 07' north latitude and 29° along the 52' East coast of Egypt. Extreme northern point of 31°10' in the east – 29°56', in the south 31º04' to the west 29°51'. It forms the border of the Mediterranean in the south, Mariut Lagoon is 63.47 km^2 [13]. It lost about 25% from its original size for creation of agriculture lands. It is now divided artificially into four basins, the lagoon proper, the fish farm, the southeast and the southwest basins, the area of the lagoon proper reaches 27.3 km2 and its depth ranges from 90-150 cm. Also Lagoon Mariout is highly polluted with different heavy metals such as iron, copper and zinc[14,15]. [16]stated that in the last three decades, Lagoon Mariut has suffered from intensive pollution, although at one time it was a highly productive lagoon. This pollution increases with time; due to the successive increase in population and industry around the lagoon different types of untreated pollutants (sewage and industrial wastes and agricultural run-off) entering into the lagoon changed it into a highly eutrophic state. This beside reclamation of great areas from the lagoon has affected dramatically its fish production. In the past, it received unmodified Nile water. In the last two decades, however, its feeding water became contaminated with untreated sewage and industrial wastes, but at lower levels when compared with Lagoon Mariut. Lagoon Mariut suffers from almost all possible environmental problems and to quite an extreme degree. Land filling for building houses, infrastructures, and for agriculture has been reducing the area of the Lagoon from 700 km^2 to the present 250 km^2. All these three human activities have critical impacts on the remaining area of the Lagoon[17]. In Egypt, the industry uses 0.638 km3 a^{-1} of water, of which 0.549 km3 a^{-1} is discharged back into the drainage networks, mostly connected to the delta[18]. The lagoons are also regarded as optimal fishery grounds, supplying to 50% of the annual Egyptian fish yield[19]. The northern lagoons serve as collection basins for agricultural drainage, municipal sewage, and industrial wastewater. Consequently, Egyptian lagoons are suffering severe ecological risks.

The heavy metals can be introduced to coastal and marine environments through a variety of sources, including industries, wastewaters and domestic effluents[20]. [21]stated that a large portion of suspended matter, carried into a lake by inflowing water, precipitates on the bottom of the littoral zone and various kinds of soluble substances are released from bottom sediments into the water. In addition, wind and wave action cause the agitation and re- suspension of fine particulate matters, either organic or inorganic, in the surface layer of bottom sediments. Heavy metals are considered a major anthropogenic contaminant in coastal and marine environments worldwide[22]. They pose a serious threat to human health, living organisms and natural ecosystems because of their toxicity, persistence and bioaccumulation characteristics[23]. The analysis of heavy metals in sediments permit us to detect pollution that could liberated to water. Also, provides information about the critical sites of the water system under consideration[24,25].

Materials and Methods

2.1. Study Area and Sampling

The study area are the northern lagoons of Egypt which occupying a significant percentage of coastal area. These lagoon from east to west are Bardawil, Manzala, Burullus, Edku and Mariut (Fig.1A).

During 2013 to 2015, 50 surface bottom sediment samples were collected from the northern lagoons (Table 1). Where, Bardawil lagoon (10 samples taken from EL-Bady and Samy, 2015), Manzala lagoon (9 samples in 2015 by helping Egyptian Environmental Affairs Agency (EEAA)), Burullus lagoon (12 samples by helping EEAA), Edku lagoon (9 samples by EEAA) and Mariute lagoon (10 samples by EEAA).

2.2. Laboratory Analysis

The use of flame atomic absorption spectrometer is still regarded as the most convenient and appropriate technique for the purpose of heavy metal analysis in most cases. Bottom sediment samples of lagoons were air dried, and then, the <63μm size fraction was recovered by sieving. This size fraction is widely used to eliminate the effect of particle size and to obtain a more homogeneous grain distribution[28].

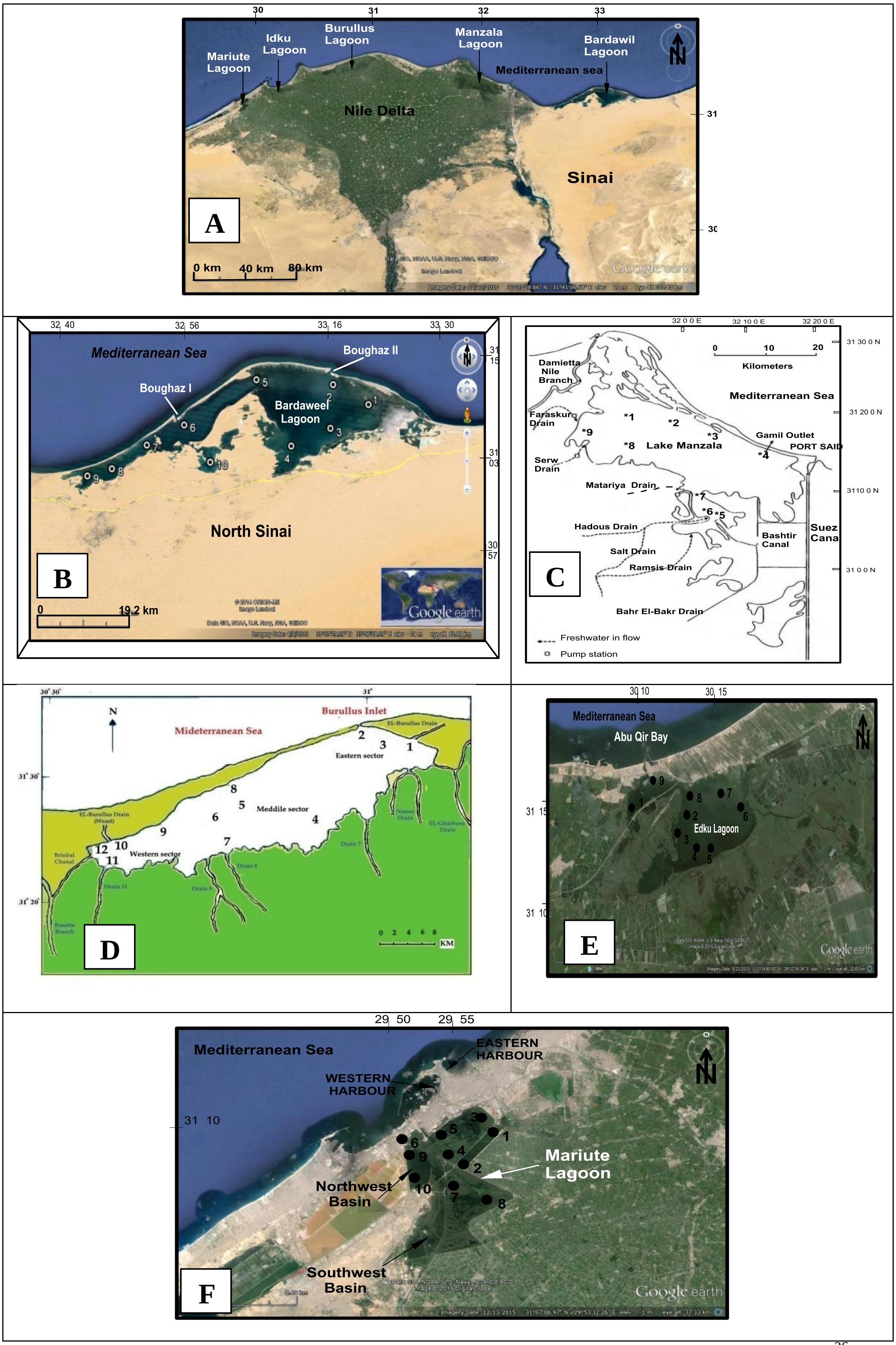

Fig. (1A): Location map of the northern Egyptian Lagoons, (1B): Bardawil Lagoon (after[26], (1C): Manzala lagoon (after[27], (1D): Burullus lagoon (from annual reports of EEAA), (1E): Edku lagoon, (1E) Mariute lagoon.

This fraction is also the most chemically active sediment phase consisting primarily of clay and silt particulates[29]. About (1.0 gm) of the most fine dried grains were digested with a mixture of conc. H_2O_2, HCl and HNO_3 as the method described in[30] and preserved in a refrigerator till analysis. The digestion solutions were analyzed using an air-acetylene flame atomic absorption spectrophotometer (AAS) (Perkin Elmer, Model 2380) at optimum instrument operating conditions recommended by the manufacturer. Fe, Mn, Pb, Cu, Cd, Cr, Ni and Zn were determined in the sample solution using atomic absorption spectrophotometry (Perkin Elmer, Model 2380).

2.3. Indices Calculations

In this article, we classified the commonly used pollution indices into two types: (i) single indices and (ii) integrated indices in an algorithm point of view. Single indices are indicators used to calculate only one metal contamination, which include contamination factor and ecological risk factor. Integrated indices are indicators used to calculate more than one metal contamination, which were based on the single indices. Each kind of integrated index might be composed by the single indices separately.

Contamination indices and ecological risk indices were analyzed to assess heavy metal contamination of bottom sediments of northern lagoons using single and integrated indices. In this study, contamination factor (CF) and ecological risk factor (Er) as single indices, the degree of contamination (DC), modified degree of contamination and the potential ecological risk index (RI), as integrated indices, were calculated.

Contamination factor (CF) and Degree of contamination (Dc)

The level of contamination can be expressed by the contamination factor (CF)[31]. The CF is the ratio obtained by dividing the concentration of each metal in the sediment by the baseline or Background value. The background value corresponds to the baseline concentrations reported by[32] and is based on element abundances in sedimentary rocks (shale). The following terminologies are used to describe the contamination factor: CF<1, low contamination factor; 1≤ CF <3, moderate contamination factors; 3≤ CF <6, considerable contamination factors; and CF ≥6, very high contamination factor.

Degree of contamination (Dc)

Another index that can be derived from the CF values is the Degree of contamination (Dc) defined as the sum of all contamination factors for a given site[31]:

$$\mathbf{Dc} = \sum_{i=1}^{i=n} CF$$

where, CF is the single contamination factor, and n is the count of the elements present. Dc values less than n would indicate low degree of contamination; n≤Dc<2n, moderate degree of contamination; 2n≤Dc<4n, considerable degree of contamination; and Dc>4n, very high degree of contamination[33,34]

For the description of the degree of contamination in the study area the following terminologies have been used: Dc < 8 low degree of contamination; 8<Dc<16 moderate degree of contamination; 16≤Dc<32 considerable degree of contamination; Dc > 32 very high degree of contamination. Where, n=8= the count of the studied heavy metals.

Modified degree of contamination (mDc)

Also another index can be derived from contamination factor is modified degree of contamination (mDc). [35]presented a modified and generalized form of the[31] equation for the calculation of the overall degree of contamination at a given sampling site. The modified equation for a generalized approach to calculating the degree of contamination is given below:

Table (1) The Locations of the samples in the northern lagoons

<table>
<tr><td colspan="7">Bardawil Lagoon</td></tr>
<tr><td>Samples</td><td>Stations</td><td>Long.</td><td colspan="2">Lat.</td><td colspan="2" rowspan="11"></td></tr>
<tr><td>1</td><td>West of Zaranik</td><td>31° 9'21.18"N</td><td colspan="2">33°21'11.16"E</td></tr>
<tr><td>2</td><td>Boughaz I</td><td>31°11'27.05"N</td><td colspan="2">33°16'34.03"E</td></tr>
<tr><td>3</td><td>Raba</td><td>31° 7'6.52"N</td><td colspan="2">33°16'3.92"E</td></tr>
<tr><td>4</td><td>EL-Kalss</td><td>31° 5'27.88"N</td><td colspan="2">33°10'49.68"E</td></tr>
<tr><td>5</td><td>EL-Nasser</td><td>31°12'10.42"N</td><td colspan="2">33° 6'25.47"E</td></tr>
<tr><td>6</td><td>Boughaz II</td><td>31° 7'52.54"N</td><td colspan="2">32°56'43.55"E</td></tr>
<tr><td>7</td><td>Messefek</td><td>31° 5'59.12"N</td><td colspan="2">32°51'42.91"E</td></tr>
<tr><td>8</td><td>EL-Telol</td><td>31° 3'43.38"N</td><td colspan="2">32°47'1.47"E</td></tr>
<tr><td>9</td><td>QarnSamda</td><td>31° 3'4.10"N</td><td colspan="2">32°43'45.57"E</td></tr>
<tr><td>10</td><td>EL-Roak</td><td>31° 4'5.93"N</td><td colspan="2">33° 0'3.91"E</td></tr>
<tr><td colspan="7">Manzala Lagoon</td></tr>
<tr><td>Samples</td><td>Stations</td><td>Samples</td><td colspan="2">Stations</td><td>Samples</td><td>Stations</td></tr>
<tr><td>1</td><td>El-Zarkaa</td><td>6</td><td colspan="2">Front of Hadous drain</td><td>7</td><td>West of El-Bashter</td></tr>
<tr><td>2</td><td>EL -Hamra(north of lagoon)</td><td>4</td><td colspan="2">Front of EL-Gamel Inlet</td><td>8</td><td>North of EL-Serw drain</td></tr>
<tr><td>3</td><td>EL-Temsah</td><td>5</td><td colspan="2">Front of Bahr EL-Bakar drain</td><td>9</td><td>South of EL-Serw drain</td></tr>
<tr><td colspan="7">Burullus Lagoon</td></tr>
<tr><td>Samples</td><td>Stations</td><td>Samples</td><td colspan="2">Stations</td><td>Samples</td><td>Stations</td></tr>
<tr><td>1</td><td>In the front of eastern EL-Burullus Drain</td><td>4</td><td colspan="2">In the front of Drain 7 outlet</td><td>7</td><td>Middle of outlets of Drain 8&9 (EL-Shakhlawea</td></tr>
<tr><td>2</td><td>Buoghaz EL-Burullus</td><td>5</td><td colspan="2">Middle of EL-Burullus Lagoon (EL-Zanka)</td><td>8</td><td>North of Lagoon near the coastal road (Mastrow)</td></tr>
<tr><td>3</td><td>Between samples 1&2 (AL-Boulak)</td><td>6</td><td colspan="2">Middle of lagoon north of Drain 8 & 9 outlet (El-Tawela)</td><td>9</td><td>North west the lagoon (Abu Amer)</td></tr>
<tr><td>10</td><td>Middle of the western sector (AL-Baraka)</td><td>11</td><td colspan="2">In the front of outlet of Drain 11 (Al-Hoksa)</td><td>12</td><td>In the front of Brinbal canal outlet (Nile outlet)</td></tr>
<tr><td colspan="7">Edku Lagoon</td></tr>
<tr><td>Samples</td><td>Stations</td><td>Samples</td><td colspan="2">Stations</td><td>Samples</td><td>Stations</td></tr>
<tr><td>1</td><td>Bab Zytone</td><td>4</td><td colspan="2">QarnDiab</td><td>7</td><td>Bab Harb (South of international road)</td></tr>
<tr><td>2</td><td>Inlet and drain of fish farms</td><td>5</td><td colspan="2">Al Baraka zone</td><td>8</td><td>North of international road</td></tr>
<tr><td>3</td><td>Al Nagaa canal</td><td>6</td><td colspan="2">El-Khairy Drain outlet</td><td>9</td><td>Boughaz El-Meadia</td></tr>
<tr><td colspan="7">Mariute Lagoon</td></tr>
<tr><td>Samples</td><td>Stations</td><td></td><td>Samples</td><td colspan="2">Stations</td><td></td></tr>
<tr><td>1</td><td>First fish farm (1000 acre)</td><td rowspan="2">Fish basins</td><td>7</td><td colspan="2">First fish pond 5000 acre</td><td rowspan="3">Northwest basin</td></tr>
<tr><td>2</td><td>Last fish farm (1000 acre)</td><td rowspan="2">8</td><td colspan="2" rowspan="2">Last fish pond 5000 acre</td></tr>
<tr><td>3</td><td>Front of ElKala drain</td><td rowspan="4">Main basin</td></tr>
<tr><td>4</td><td>North east abuElkher bridge</td><td>9</td><td colspan="2">Front of Al</td><td rowspan="2">Southwest basin</td></tr>
<tr><td>5</td><td>Middle of pond 5000 acre</td><td>10</td><td colspan="2">Middle of fish pond 2000 acre</td></tr>
<tr><td>6</td><td>Front of TolmbatAlMax</td><td colspan="4"></td></tr>
</table>

$$\mathbf{mDc} = \left(\sum_{i=1}^{i=n} \boldsymbol{Dc}\right)/\boldsymbol{n}$$

Where n = number of analyzed elements and i = ith element (or pollutant) and CF = Contamination factor. Using this generalized formula to calculate the mDc allows the incorporation of as many metals as the study may analyze with no upper limit. For the classification and description of the modified degree of contamination (mDc), the following gradations have been given below (Table. 2).

Table. (2): grading of modified degree of contaminations

Modified degree of contamination (mDc)	According to[36]
mDC< 1.5	Nil to very low degree of contamination
1.5 <mDC< 2	Low degree of contamination
2<mDC< 4	Moderate degree of contamination
4 <mDC< 8	High degree of contamination
8<mdC< 16	Very high degree of contamination
16 <mDC< 32	Extremely high degree of contamination
mdC>32	Ultra high degree of contamination

Ecological risk factor (Er) and potential ecological risk index(RI)

An ecological risk factor (Eri) to quantitatively express the potential ecological risk of a given contaminant also suggested by[31]

$$\mathbf{Er = Tr \times CF}$$

Where Tr is the toxic-response factor for a given substance, and CF is the contamination factor. The Tr values of heavy metals suggested by[31]. The Tr values of Pb, Cu, Co, Cd, Cr, Ni and Zn are 5, 5, 5, 30, 2, 3, and 1, respectively. The following terminologies are used to describe the risk factor: Er<40, low potential ecological risk; 40≤Er<80, moderate potential ecological risk; 80≤Er<160, considerable potential ecological risk; 160≤Er<320, high potential ecological risk; and Er≥320, very high ecological risk.

The potential ecological risk (RI) of the heavy metals is quantitatively evaluated by the potential ecological risk index (Er) [31,37] which takes into account both contamination factor (CF), and the "toxic-response" factor. The potential ecological risk values obtained were compared with categories grade of Er and RI of metal pollution risk on the environment suggested by[31,38]. The potential ecological risk index (RI) was in the same manner as degree of contamination defined as the sum of the risk factors.

$$\mathbf{RI} = \sum_{i=1}^{i=n} \boldsymbol{Er}$$

whereEr is the single index of ecological risk factor, and n is the count of the heavy metal species. The following terminology was used for the potential ecological risk index: RI<150, low ecological risk; 150≤RI<300, moderate ecological risk; 300≤RI<600, considerable ecological risk; and RI>600, very high ecological risk[31,38]. Where, Er and RI denote the potential ecological risk factor of individual and multiple metals, respectively.

Results and Discussion

Heavy Metals Distribution:

Distribution of heavy metals in the northern lagoons (Bardawil, Manzala, Burullus, Edku and Mariute) is given in tables 3, 4, 5, 6 and 7. The means of heavy metal contents (Table. 8) in Bardawil bottom sediments are 2092.7, 352.57, 52.93, 46.01, 30.29, 42.09, 29.8, 15.79, Fe, Mn, Zn, Cu, Ni, Cr, Pb and Cd respectively. The mean concentrations of heavy metals in Bardawil bottom sediments were arranged in descending order as follows: Fe>Mn> Zn > Cu>Cr >Ni >Pb> Cd.

The means of heavy metal contents in Manzala bottom sediments (Table. 8) are 1074.55, 725.55, 39.53, 31.21, 30.83, 40.95, 0.077, 1.67, Fe, Mn, Zn, Cu, Ni, Cr, Pb and Cd respectively. The mean concentrations of heavy metals in Manzala bottom sediments were arranged in descending order as follows: Fe>Mn> Cr > Zn > Cu> Ni > Cd >Pb.

The means of heavy metal contents in Burullus bottom sediments (Table. 8) are 17546.67, 948.08, 51.58, 30.08, 35.66, 47.75, 31.41 and 0.18, Fe, Mn, Zn, Cu, Ni, Cr, Pb and Cd respectively. The mean concentrations of heavy metals in Burullus bottom sediments were arranged in descending order as follows: Fe>Mn> Zn> Cr >Ni >Pb> Cu > Cd.

The means of heavy metal contents in Edku bottom sediments (Table. 7) are 20948.22, 1561.55, 69.44, 29.55, 42.77, 45, 29.11, and 0.49, Fe, Mn, Zn, Cu, Ni, Cr, Pb and Cd respectively. The mean concentrations of heavy metals in Edku bottom sediments were arranged in descending order as follows: Fe>Mn> Zn > Cr >Ni >Cu>Pb> Cd.

The means of heavy metal contents in Mariute bottom sediments (Table. 8) are 18384.6, 467.2, 95.6, 79.686, 37.2, 26.82, 55.4 and 0.58, Fe, Mn, Zn, Cu, Ni, Cr, Pb and Cd respectively. The mean concentrations of heavy metals in Mariute bottom sediments were arranged in descending order as follows: Fe>Mn> Zn> Cu >.Pb> Ni > Cr > Cd.

Comparison between the mean concentrations of heavy metals in bottom sediments of northern lagoons (Table. 8 and Fig. 2) as following: Mean concentrations of Fe in the northern lagoons were showed the descending order as follows: Edku>Mariute>Burullus>Bardawil>Manzala. Mn of the northern lagoon showed the following descending order: Edku>Burullus>Manzala>Mariute>Bardawil. Zn mean concentrations of the northern lagoons showed the following descending order: Mariute>Edku>Bardawil>Burullus>Manzala. Mean concentrations of Cu in the northern lagoons were showed the descending order as follows: Mariute>Bardawil>Manzala>Burullus>Edku. Mean concentrations of Ni in the northern lagoons were showed the descending order as follows: Edku>Mariute>Burullus>Manzala>Bardawil. Mean concentrations of Cr in the northern lagoons were showed the descending order as follows: Burullus>Edku>Bardawil>Manzala>Mariute. Mean concentrations of Pb in the northern lagoons were showed the descending order as follows: Mariute>Burullus>Bardawil>Edku>Manzala. Mean concentrations of Cd in the northern lagoons were showed the descending order as follows: Bardawil>Manzala>Mariute>Edku>Burullus.

Table. (3): concentration of heavy metals in Bardawil Lagoon bottom sediments

Samples	Fe	Mn	Zn	Cu	Ni	Cr	Pb	Cd
1	1006	230.2	40.6	28.2	12.2	7.9	15.2	5.6
2 (BII)	2405	360.3	71.6	56.2	35.6	35.3	64.3	23.3
3	2205	290.7	46.2	32.8	22.3	25.3	18.5	6.5
4	2015	230.3	42.4	45.4	33.8	46.6	34.3	21.2
5	2320	360.3	54.3	56.2	35.4	44.5	13.3	7.5
6 (BI)	2020	222.2	46.6	33.2	22.1	35.3	47.3	26.6
7	2500	390.8	64.2	64.2	41.3	69.9	28.3	12.3
8	1523	330.2	57.5	33.3	24.3	33.8	20.2	19.2
9	2830	860.4	60.5	61.2	39.3	65.6	18.3	10.5
10	2103	250.3	45.4	49.4	36.6	56.7	38.3	25.2
Means	2092.7	352.57	52.93	46.01	30.29	42.09	29.8	15.79
Average	47200	850	95	45	68	90	20	0.3
Tr	-	-	1	5	3	2	5	30

Average shale, after [32],Tr, Tr:toxic-response factor of [31],1 mg/kg =1ug/g

Table. (4): concentration of heavy metals in Manzala Lagoon bottom sediments

Samples	Fe µg/g	Mn µg/g	Zn µg/g	Cu µg/g	Ni µg/g	Cr µg/g	Pb µg/g	Cd µg/g
1	989	547	22.54	23.43	14.56	13.4	0.02	1.22
2	1534	1201	18.13	11.23	10.68	7.89	0.11	2.14
3	1445	1121	20.56	17.43	11.67	8.45	0.11	1.54
4	1543	1203	19.32	10.76	10.65	9.89	0.12	2.11
5	865	453	45.47	53.54	53.87	88.76	0.07	1.99
6	798	543	76.54	51.42	49.89	78.9	0.09	1.92
7	876	453	43.68	32.67	34.78	58.9	0.01	1.77
8	822	548	64.77	42.68	46.9	69.88	0.09	1.23
9	799	461	44.76	37.78	44.54	32.54	0.08	1.11
Means	1074.55	725.55	39.53	31.21	30.83	40.95	0.077	1.67
Average shale	47200	850	95	45	68	90	20	0.3
Tr			1	5	3	2	5	30

Average shale, after [32],Tr, Tr:toxic-response factor of [31],1 mg/kg =1ug/g

Table. (5): concentration of heavy metals in Burullus Lagoon bottom sediments

Samples	Fe µg/g	Mn µg/g	Zn µg/g	Cu µg/g	Ni µg/g	Cr µg/g	Pb µg/g	Cd µg/g
1	25264	1580	58	52	44	75	22	0.12
2	8695	365	36	19	29	35	42	0.1
3	10232	564	42	18	33	36	26	0.11
4	29023	1645	78	59	52	77	42	0.5
5	7500	355	35	15	22	25	19	0.1
6	18921	752	55	25	35	55	25	0.2
7	20256	1002	56	32	45	56	33	0.3
8	16245	960	45	25	29	35	35	0.1
9	15265	856	49	24	30	38	26	0.2
10	16656	986	52	26	25	40	34	0.11
11	26245	1352	74	45	49	66	41	0.3
12	16258	960	39	21	35	35	32	0.11
Means	17546.67	948.08	51.58	30.08	35.66	47.75	31.41	0.18
Average shale	47200	850	95	45	68	90	20	0.3
Tr			1	5	3	2	5	30

Average shale, after [32],Tr, Tr:toxic-response factor of [31],1 mg/kg =1ug/g

Table. (6): concentration of heavy metals in Edku Lagoon bottom sediments

Samples	Fe µg/g	Mn µg/g	Zn µg/g	Cu µg/g	Ni µg/g	Cr µg/g	Pb µg/g	Cd µg/g
1	12232	1457	45	17	28	15	44	1.08
2	4567	240	45	20	30	14	42	1.01
3	15233	985	68	19	55	25	16	0.05
4	27856	1956	91	44	52	81	22	0.23
5	28112	2456	88	39	58	77	32	0.06
6	29611	2711	91	41	54	68	21	0.9
7	21342	895	55	22	32	25	25	0.05
8	27436	2112	90	46	49	81	36	0.9
9	22145	1242	52	18	27	19	24	0.2
Means	20948.22	1561.55	69.44	29.55	42.77	45	29.11	0.49
Average	47200	850	95	45	68	90	20	0.3
Tr			1	5	3	2	5	30

Average shale, after [32],Tr, Tr:toxic-response factor of [31],1 mg/kg =1ug/g

Table. (7): concentration of heavy metals in Mariute Lagoon bottom sediments

Samples	Fe µg/g	Mn µg/g	Zn µg/g	Cu µg/g	Ni µg/g	Cr µg/g	Pb µg/g	Cd µg/g
1	2541	250	36	2.45	7	3.2	66	1.02
2	6591	290	42	12.5	9	5.6	82	0.2
3	25235	565	45	22.3	55	41	25	0.06
4	25365	541	125	121	54	35	29	0.3
5	24123	457	142	141	41	33	34	0.5
6	15324	542	155	99	39	16	55	1.11
7	27326	621	162	162	75	56	28	1.01
8	27892	639	170	178	71	62	35	0.6
9	15214	356	39	55	9	6.6	101	0.6
10	14235	411	40	3.61	12	9.8	99	0.4
Means	18384.6	467.2	95.6	79.686	37.2	26.82	55.4	0.58
Average shale	47200	850	95	45	68	90	20	0.3
Tr			1	5	3	2	5	30

Average shale, after [32],Tr, Tr:toxic-response factor of [31],1 mg/kg =1ug/g

Table. (8):The means concentrations of heavy metals of the bottom sediments of northern lagoons and the descending order of the heavy metals

Lagoons	**Mean concentrations of heavy metals**							
	Fe μg/g	**Mn μg/g**	**Zn μg/g**	**Cu μg/g**	**Ni μg/g**	**Cr μg/g**	**Pb μg/g**	**Cd μg/g**
Bardawil lagoon	2092.7	352.57	52.93	46.01	30.29	42.09	29.8	15.79
Manzala lagoon	1074.55	725.55	39.53	31.21	30.83	40.95	0.077	1.67
Burullus lagoon	17546.67	948.08	51.58	30.08	35.66	47.75	31.41	0.18
Edku lagoon	20948.22	1561.55	69.44	29.55	42.77	45	29.11	0.49
Mariute lagoon	18384.6	467.2	95.6	79.686	37.2	26.82	55.4	0.58
Descending order of heavy metals								
	Fe μg/g	Mn μg/g	Zn μg/g	Cu μg/g	Ni μg/g	Cr μg/g	Pb μg/g	Cd μg/g
	Edku lagoon	Edku lagoon	Mariute lagoon	Mariute lagoon	Edku lagoon	Burullus lagoon	Mariute lagoon	Bardawil lagoon
	Mariute lagoon	Burullus lagoon	Edku lagoon	Bardawil lagoon	Mariute lagoon	Edku lagoon	Burullus lagoon	Manzala lagoon
	Burullus lagoon	Manzala lagoon	Bardawil lagoon	Manzala lagoon	Burullus lagoon	Bardawil lagoon	Bardawil lagoon	Mariute lagoon
	Bardawil lagoon	Mariute lagoon	Burullus lagoon	Burullus lagoon	Manzala lagoon	Manzala lagoon	Edku lagoon	Edku lagoon
	Manzala lagoon	Bardawil lagoon	Manzala lagoon	Edku lagoon	Bardawil lagoon	Mariute lagoon	Manzala lagoon	Burullus lagoon

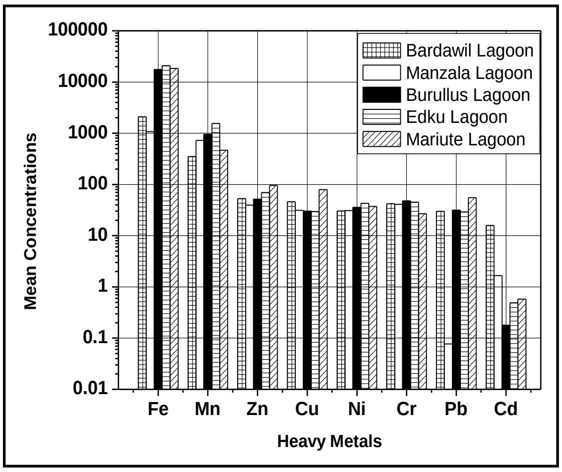

Fig. (2): The means concentrations of heavy metals of the bottom sediments of the Egyptian northern lagoons

Possible Biological Effects

Heavy metals are regard as serious pollution of aquatic ecosystem because of their environmental persistence, toxicity effects on living organisms. To estimate the biological effects of metals, ERL (Effects-Range Low) and ERM (Effects-Range Median) reported by [39] and [40] were used. Also, TEL (threshold effect level); LEL (lowest effect level); MET (minimal effect threshold); PEL (probable effects level); TET (toxic effect threshold); SEL (severe effect level); TRV, (Toxicity reference value); AV, (average shale); EC, (earth crust) were used[41,42,43,44,45,32,46](Table 9).

Table. (9): Sediment quality guidelines according to[39]; [40]; [41]; [42]; [43]; [44]; [45]

SQG	Fe	Mn	Cd (ppm)	Cr (ppm)	Cu (ppm)	Pb (ppm)	Ni (ppm)	Zn (ppm)	References
TEL[1]			0.6	37.3	35.7	35	18	123	a
ERL			5	80	70	35	30	120	a,e
			1.2	81	34	46.7	20.9	150	f
LEL[2]			0.6	26	16	31	16	120	a
MET[3]			0.9	55	28	42	35	150	a
PEL[1]			3.53	90	197	91.3	36	315	a,b,c,d,e
ERM			9	145	390	110	50	270	a.b.c.d.e
			9.6	370	270	218	51.6	410	f
TET			3	100	86	170	61	540	a,b,c,d
SEL[1]			10	110	110	250	75	820	a,b,c,d
TRV			0.6	26	16	31	16	110	g
AS	47200	850	0.3	90	45	20	68	95	h
EC	56300	850	0.15	100	55	12.5	75	70	i

SQG, Sediment quality guideline; TEL, threshold effect level; ERL, effects range low; LEL, lowest effect level; MET, minimal effect threshold; PEL, probable effects level; ERM, effect range median; TET, toxic effect threshold; SEL, severe effect level; TRV,Toxicity reference value proposed by [45]; AV, average shale proposed by [32]; EC, earth crust proposed by [46].

1Same as Canadian Freshwater Sediment Guidelinesb; 2Same as Ontario Ministry of Environment Screening Level Guidelinesb; 3Same as MEL in SQAVsc(SQAV, Sediment Quality Advisory Value), a[41); b[42]; c[43]; d[44]; e[39]; f[40]; g [45]; h[32] i [46], 1 mg/kg =1ug/g

Several sediment quality guidelines have been proposed by different countries and organizations. However, it has been rather difficult to establish internationally accepted guidelines. Table 3 list some of the common guidelines for Cd, Cu, Cr, Pb, Ni and Zn. Comparing the concentration of these metals in the bottom sediments of northern lagoons (Tables 3,4,5,6 and7) with the guidelines given in Table 9. Some guidelines (ERL and ERM of [40], TET and SEL of [41,42,43,44] were compared with the concentrations of heavy metals in each station or site in each lagoon and the others guidelines (LEL of [41], SEL, TRV, AS and EC) (Table 10) compared with the means concentrations of each metals in the northern lagoons. It appears that in Bardawil Lagoon Cd > ERL in all samples and it > ERM in all samples except in samples 1 and 5. Cr < ERL, ERM, TET and SEL. Pb< ERL except in samples 2 and 6, while it < ERM, TET and SEL in all samples. Cu > ERL except in samples 1,3,6 and 8, while it < ERM, TET and SEL in all samples. Ni > ERL except in sample 1, while it < ERM, TET and SEL. Zn < ERL, ERM, TET and SEL.

In Manzala Lagoon, Cd > ERL except in samples 9, while it < ERM, TET and SEL in all samples. Cr < ERL, ERM, TET and SEL in all samples. Cu <ERL in samples 1,2,3,4 and 7, while, it > ERL in the other samples, and Cu < ERM, TET and SEL. Pb< ERL,ERM, TET and SEL. Ni < ERL in samples 1,2,3 and 4, while it > in samples 5,6,7,8 and 9, Ni < ERM in all samples except in sample 5 and Ni < TET and SEL. Zn < ERL, ERM, TET and SEL in all samples.

In Burullus Lagoon, Cd < ERL,ERM, TET and SEL in all samples, also Cr, pb and Zn < ERL,ERM, TET and SEL in all samples. Cu < ERL except in samples 1,4 and 11, while it < ERM in all samples. Ni > ERL, ERM, TET and SEL.

In Edku Lagoon, Cd, Pb and Zn < ERL,ERM, TET and SEL in all samples. Cr ≤ ERL while, it < ERM, TET and SEL in all samples. Cu < ERM in all samples, while Cu < ERL in samples 1,2,3,7 and 9 and it > ERL in other samples. Ni > ERL in all samples, Ni > ERM in samples 3,4,5 and 6, while it < ERM in 1,2,7,8 and 9.

In Mariute Lagoon, Cd and Cr < ERL,ERM, TET and SEL in all samples. Cu < ERL in samples 1,2,3 and 10 and it > in the others. Cu < ERM in all samples, and it < TET in samples 1,2,3, 9 and 10, while it > in the other samples. Cu < SEL in samples 1,2,3,6,9 and 10, and it > in the others. Ni > ERL in all samples except in samples 1,2,9 and 10. Ni < ERM in all sample except in samples 3,4,7 and 8. Pb< ERL in all samples except in samples 1,2,6,9 and 10, while Pb< ERM, TET and SEL in all samples. Zn < ERL in all samples except in samples 6,7 and 8, while Zn < ERM, TET and SEL in all samples.

Here, another comparison between the mean concentrations of the heavy metals in the northern lagoons compared with LEL, SEL, TRV, AV and EC as in Table 10. Mean concentrations of Fe are < AV and EC in all northern lagoons. Means of Mn were < AV and EC in Bardawil, Manzala and Mariute lagoons, while Means of Mn> AV and EC in Burullus and Edku lagoons. Mean concentrations of Zn were < LEL, SEL, TRV, AV and EC in all northern lagoons except Mariute lagoon showed some changes, where Zn > AV and EC. Cu means >LEL, TRV, AV and EC, and < SEL in Bardawil lagoon. Cu means < LEL, SEL, TRV, AV and EC in Burullus and Edku lagoons. Cu means < LEL, AV and EC, and > TRV in Manzala lagoon. Cu means > LEL, TRV, AV and EC, and< SEL in Mariute lagoon. Ni means in Bardawil lagoon were > LEL, < SEL, > TRV, > AV, >EC. In Manzal lagoon, Ni means were > LEL, < SEL, > TRV, < AV, <EC. In Burullus lagoon, Ni mean concentrations were > LEL, < SEL, > TRV,< AV, <EC. In Edku lagoon, Ni mean concentrations were > LEL, < SEL, > TRV, < AV, <EC. In Mariute lagoon, Ni mean concentrations were > LEL, < SEL, > TRV, < AV, <EC. Cr means were < LEL, < SEL, > TRV, < AV, <EC in all the northern lagoons. Pb mean concentrations were< LEL, < SEL, < TRV, > AV, >EC in Bardawil and Fdku lagoons. Pb mean concentrations were < LEL, TRV, AV and EC in Manzala lagoon. Pb mean concentrations were< LEL, < SEL, > TRV, > AV, >EC in Burullus lagoon. In Mariute lagoon, Pb mean concentrations were > LEL, < SEL, > TRV, > AV, >EC. Cd means > LEL, SEL, TRV, AV and EC in Bardawil lagoon. In Manzal lagoon, Cd means > LEL, < SEL, > TRV, > AV, >EC. In Burullus lagoon, Cd mean concentrations were < LEL, < SEL, < TRV, < AV, >EC. In Edku lagoon, Cd means > LEL, < SEL, < TRV, >AV, >EC. In Mariute lagoon, Cd mean concentrations were < LEL, < SEL, < TRV, >AV, >EC.

Heavy metal pollution indices:

The pollution in bottom sediments of the northern lagoons can be assessed by determining some of indices such as the contamination factors (CF), degree of contaminations (Dc), modified degree of contaminations (mDc) and ecological risk index (RI) (Table. 11). Potential ecological risk index (RI) depends on the potential ecological risk factor (Er), the toxic-response factor (Tr) and the contamination factors (CF). The evaluation of the pollution degree of bottom sediments of the northern lagoon depend on many indices (Table 11 and Figs.3, 4, and 5).

In Bardawil Lagoon, degree of contamination (Dc) was very high degree of contamination in all samples except in samples 1 and 3 was considerable degree of contamination. Modified degree of contamination (mDc) was moderate degree of contamination in samples 1,3 and 5, it was high degree of contamination in samples 7 and 9, and it was very high degree of contamination in samples 2, 4, 6, 8 and 10. The potential ecological risk index (RI) was very high ecological risk in all samples except in sample 1 was considerable ecological risk index (Table 11 and Figs.3, 4, and 5)

Table. (10) Comparison between mean concentrations of heavy metals of the northern lagoons with the LEL, SEL, TRV, AV and EC values of many guidelines.

Lagoons	Means of heavy metals							
	Fe µg/g	**Mn µg/g**	**Zn µg/g**	**Cu µg/g**	**Ni µg/g**	**Cr µg/g**	**Pb µg/g**	**Cd µg/g**
Bardawil lagoon	2092.7	352.57	52.93	46.01	30.29	42.09	29.8	15.79
			< LEL	> LEL	> LEL	< LEL	< LEL	> LEL
			< SEL	< SEL	< SEL	< SEL	< SEL	> SEL
			< TRV	> TRV	> TRV	> TRV	< TRV	> TRV
	< AV	< AV	< AV	> AV	< AV	< AV	> AV	> AV
	< EC	< EC	< EC	> EC	< EC	< EC	>EC	>EC
Manzala lagoon	1074.6	725.55	39.53	31.21	30.83	40.95	0.077	1.67
			< LEL	< LEL	> LEL	>LEL	< LEL	> LEL
			< SEL	< SEL	< SEL	< SEL	< SEL	< SEL
			< TRV	> TRV	> TRV	> TRV	< TRV	> TRV
	< AV	< AV	< AV	< AV	< AV	< AV	< AV	> AV
	< EC	< EC	< EC	< EC	< EC	< EC	< EC	>EC
Burullus lagoon	17546.7	948.08	51.58	30.08	35.66	47.75	31.41	0.18
			< LEL	< LEL	> LEL	>LEL	< LEL	< LEL
			< SEL	< SEL	< SEL	< SEL	< SEL	< SEL
			< TRV	< TRV	> TRV	> TRV	> TRV	< TRV
	< AV	> AV	< AV	< AV	< AV	< AV	> AV	< AV
	< EC	> EC	< EC	< EC	< EC	< EC	> EC	>EC
Edku lagoon	20948.2	1561.55	69.44	29.55	42.77	45	29.11	0.49
			< LEL	< LEL	> LEL	>LEL	< LEL	> LEL
			< SEL	< SEL	< SEL	< SEL	< SEL	< SEL
			< TRV	< TRV	> TRV	> TRV	< TRV	< TRV
	< AV	> AV	< AV	< AV	< AV	< AV	> AV	>AV
	< EC	> EC	< EC	< EC	< EC	< EC	> EC	>EC
Mariute lagoon	18384.6	467.2	95.6	79.686	37.2	26.82	55.4	0.58
			< LEL	> LEL	> LEL	< LEL	> LEL	< LEL
			< SEL	< SEL	< SEL	< SEL	< SEL	< SEL
			< TRV	> TRV	> TRV	> TRV	> TRV	< TRV
	< AV	< AV	> AV	>AV	< AV	< AV	> AV	>AV
	< EC	< EC	> EC	> EC	< EC	< EC	> EC	>EC

LEL- Lowest effect level; SEL- Severe effect level Ontario Ministry of Environment and Energy through aquatic sediment quality guidelines [43]; TRV- Toxicity reference value proposed by [45]); AV, average shale proposed by [32]; EC, earth crust proposed by [46]. 1 mg/kg =1ug/g

In Manzala Lagoon, degree of contamination (Dc) was degree of contamination in samples 1,38 and 9. It was moderate degree of contamination in sample 2,4,5,6 and 7. Modified degree of contamination (mDc) was very low degree of contamination in all samples. The potential ecological risk index (RI) was low ecological risk in samples 1,8 and 9, and it was moderate ecological risk in other samples (2, 3, 4, 5, 6, and 7) (Table 11 and Figs.3, 4, and 5).

In Burullus Lagoon, degree of contamination (Dc) was low degree of contamination in all samples except in samples 4 and 11 was moderate degree of contamination. Modified degree of contamination (mDc) was very low degree of contamination in all samples. The potential ecological risk index (RI) was low ecological risk in all samples (Table 11 and Figs.3, 4, and 5).

In Edku Lagoon, degree of contamination (Dc) was low degree of contamination in samples 2,3,7 and 9, it was moderate degree of contamination in samples 1,4,5,6 and 8. Modified degree of contamination (mDc) was very low degree of contamination in all samples. The potential ecological risk index (RI) was low ecological risk in all samples (Table 11 and Figs.3, 4, and 5).

In Mariute Lagoon, degree of contamination (Dc) was low degree of contamination in samples 1,2,3 and 10, and it was moderate degree of contamination in other samples. Modified degree of contamination (mDc) was very low degree of contamination in all samples except in samples 7 and 8 was Low degree of contamination. The potential ecological risk index (RI) was low ecological risk in all samples (Table 11 and Figs.3, 4, and 5).

The average degree of contamination and modified degree of contamination of the northern lagoons were in the following descending order Bardawil>Mariute>Manzal>Edku>Burullus, while, the potential ecological risk index in the following descending order Bardawil>Manzal>Mariute>Edku>Burullus.

Conclusions

Average concentrations of Fe in the northern lagoons were showed the descending order as follows: Edku>Mariute>Burullus>Bardawil>Manzala. Mn of the northern lagoon showed the following descending order: Edku>Burullus>Manzala>Mariute>Bardawil. Zn average concentrations of the northern lagoons showed the following descending order: Mariute>Edku>Bardawil>Burullus>Manzala. Mean concentrations of Cu in the northern lagoons were showed the descending order as follows: Mariute>Bardawil>Manzala>Burullus>Edku. Mean concentrations of Ni in the northern lagoons were showed the descending order as follows: Edku>Mariute>Burullus>Manzala>Bardawil. Mean concentrations of Cr in the northern lagoons were showed the descending order as follows: Burullus>Edku>Bardawil>Manzala>Mariute. Mean concentrations of Pb in the northern lagoons were showed the descending order as follows: Mariute>Burullus>Bardawil>Edku>Manzala. Mean concentrations of Cd in the northern lagoons were showed the descending order as follows: Bardawil>Manzala>Mariute>Edku>Burullus.

The average degree of contamination and modified degree of contamination of the northern lagoons were in the following descending order Bardawil>Mariute>Manzal>Edku>Burullus, while, the potential ecological risk index in the following descending order Bardawil>Manzal>Mariute>Edku>Burullus.

Table.(11): The heavy metals pollution indices of the bottom sediments of the northern lagoons.

Samples	Bardawil Lagoon			Manzal Lagoon			Burullus Lagoon			Edku Lagoon			Mariute Lagoon		
	Dc	mDc	RI	Dc	mDc	RI	Dc	mDc	RI	Dc	mDc	RI	Dc	mDc	RI
1	21.04	2.63	568.07	5.85	0.73	125.78	7.14	0.89	27.49	9.20	1.15	122.93	7.61	0.95	119.53
2	84.27	10.53	2355.42	9.26	1.15	216.11	4.66	0.58	25.04	7.36	0.92	115.83	6.16	0.77	42.85
3	24.80	3.10	660.30	7.35	0.91	156.88	4.27	0.53	22.19	4.67	0.58	14.80	4.88	0.61	18.53
4	75.16	9.39	2136.59	9.19	1.14	213.11	10.06	1.25	71.88	8.35	1.04	38.44	8.81	1.10	55.17
5	28.97	3.62	762.69	10.63	1.32	209.79	3.16	0.39	18.31	8.78	1.09	23.52	10.01	1.25	78.20
6	93.28	11.66	2677.76	10.61	1.32	202.49	5.46	0.68	32.37	11.28	1.41	104.65	11.99	1.49	139.45
7	46.41	5.80	1248.25	8.80	1.10	183.93	6.84	0.85	45.62	4.73	0.59	16.24	13.10	1.63	132.25
8	67.50	8.43	1931.17	7.86	0.98	132.06	5.40	0.67	24.05	11.45	1.43	109.02	12.57	1.57	94.82
9	40.29	5.03	1065.20	6.59	0.82	118.37	5.20	0.65	31.85	5.35	0.66	30.16	9.62	1.20	92.31
10	88.99	11.12	2538.41				5.51	0.68	24.92				7.85	0.98	66.31
11							8.42	1.05	49.65						
12							5.22	0.65	24.06						
Average	57.071	7.13	1594.38	8.46	1.05	173.16	5.94	0.73	33.11	7.90	0.98	63.95	9.26	1.15	83.94

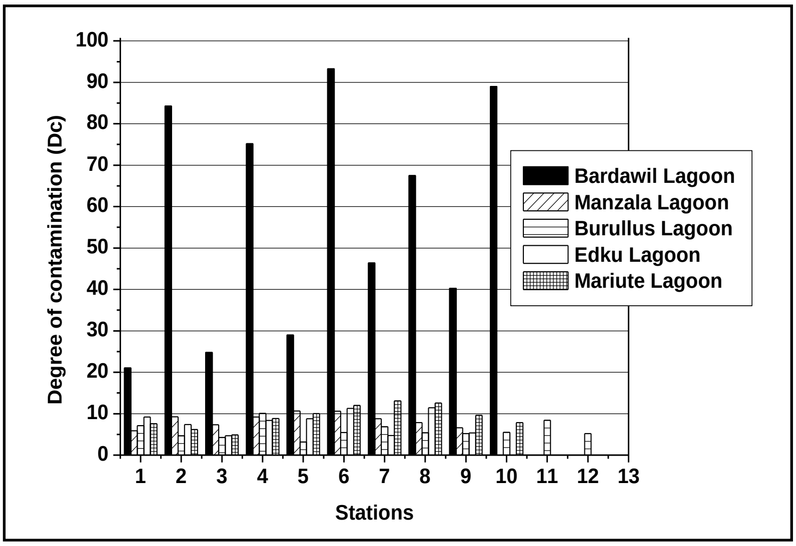

Fig. (3): Degree of Contaminations in The Egyptian Northern Lagoons

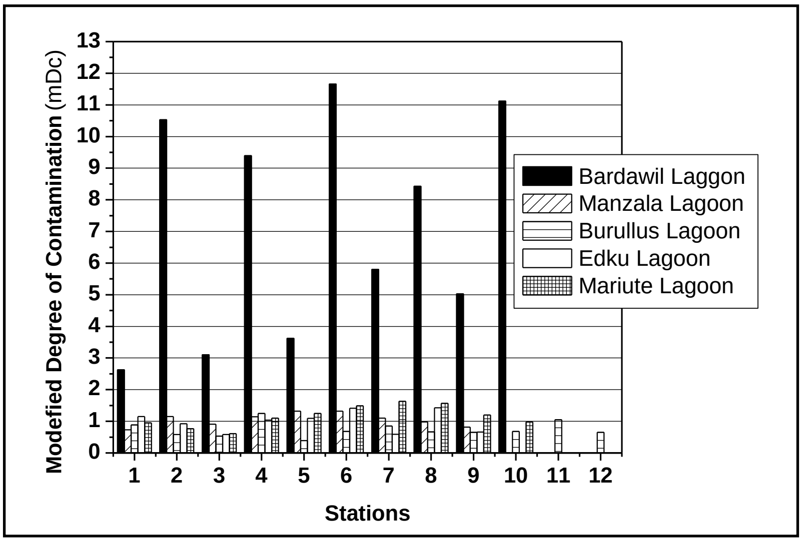

Fig. (4):Modified Degree of Contaminations in The Egyptian Northern Lagoons

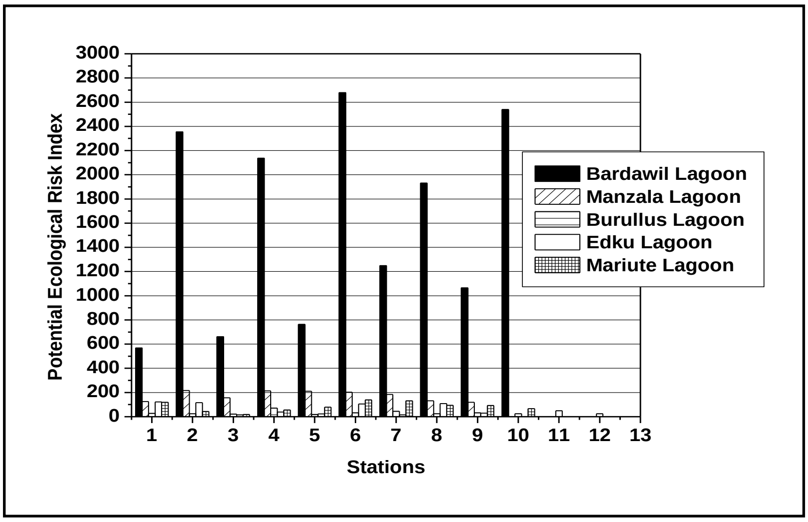

Fig. (5): The Potential Ecological Risk Index in The Egyptian Northern Lagoons

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