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Monitoring and Assessing the Quality of Water in Lake Edku Using Remote Sensing Technology and Geographic Information System (GIS)

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ABSTRACT

Egyptian Northern Lakes are highly dynamic aquatic system that have undergone considerable physical, chemical and biological changes during the past century. Using Data Fusion Techniques of Remote sensing data and Geographic Information Systems can be used as a tool to detect, monitor and evaluate changes in ecosystems and develop management strategies for maintaining the lakes resources. Coastal lakes in the Mediterranean region constitute a major aquatic Resource. Northern Egyptian lakes are all impacted by a variety of environmental change processes, but direct human activities have had the greatest effect during the 20th Century. Using different satellite images from 1973 to 2018 for monitoring and assessing the pollution problem of Lake Edku by mapping water properties (water transparency, salinity, PH, TSM, Phosphors), Lake Eutrophication (Nitrites, Nitrates, Ammonia, Water Organic Matter), Heavy Metals (Cadmium, Chromium, Copper, Iron, Nickel), also mapping the sediment parameters (PH, TDS, OM, Fe, Cd, Pb, Cr, Ni), all of this for monitor and analyzing the Water Quality of Lake Edku in 2019 in order to study its ecology and estimating the spatial temporal changes occurred in both water body of the Lake. By comparing the study results with other pervious results, it was found that the percentage of some elements as Cadmium, Nickel, increased, while others appeared as Chromium, Ammonia, Iron, where the percentage of the Copper and PH were within the range.

INTRODUCTION

Coastal Lakes are characterized with distinctive environment and water quality status that make them host of rich aquatic populations as well as migratory birds. However, lakes are susceptible to deteriorating conditions that threat sustainability of such promising ecological role **(Elshinnawy, 2002).** With growing concerns of climate change and possible impact on environmental systems, human intervention and progressive development processes have had undeniable adverse fingerprints on

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environmental systems, human intervention and progressive development processes have had undeniable adverse fingerprints on maintaining healthy environment in coastal lakes of Egypt **(Abayazid and Al-Shinnawy, 2012).** Water is one of the most important natural resource available to mankind. The need for conservation of water bodies especially the fresh water bodies is being realized everywhere in the world **(Gupta *et al.,* 2011).** Industrial and agricultural wastewater causes pollution of surface water (rivers and lakes) with chemicals and excess nutrients **(USEPA, 2000)**. lakes are indicators of climate change and environmental deterioration **(Woolway, 2020)** water demands will most likely increase by 20%. Water quality is a description of physical, chemical and biological characteristics of water **(El Gohary, 2015).** Since all water uses require that water quality falls within a range suitable for that use. Thus, the present rate of deterioration of quality will certainly increase the severity of the water scarcity problem **(Ministry of Water Resources and Irrigation, 2014).** The northern lakes (Bardawil, Manzala, Berlus, Edkuu and Mariout) are of great economic importance, with fish production accounting for 77% of the total production of all Egyptian lakes. Due to its shallow depths, quiet water movement and high fertility, it is considered a natural nursery for various types of economic fish, not only in these lakes but also in the Egyptian coasts of the Mediterranean Sea. Due to the continuous exposure of these lakes to various types of industrial, health and agricultural pollutants, which affects both the quality of these lakes and their fish production. Due to the absence of a regular follow-up program for the environmental status, their condition deteriorates over time, remote sensing techniques and a geographic information system is used to analyze different satellite images to monitor the changes in the volume of water **(Salama *et al.,* 2022).** affecting the health, economic and social situation as these lakes represent the sources of livelihood and food for millions of Egyptians. Therefore, the current program of environmental monitoring of the Northern Lakes aims at periodic monitoring of these lakes to identify the environmental conditions and pollutants affecting them at different times and places in order to develop a national program to reduce the impact of these pollutants and stop the continuous deterioration of lakes and develop future plans to protect them and solve their problems for sustainable development. The province of Edku lake is one of the major provinces in the field of fish production due to the possession of many components of production such as Lake Edku which is located on the Mediterranean Sea. The study presented aspects of changing structure and aquatic environment in coastal lakes in Egypt, with reference to development process and pollution impact. the future goal is to implement large-scale, intelligent remote sensing technology for the observation of water quality in lakes and rivers **(Luo *et al.,*2022).**

AIM OF THE STUDY

This study presented the use of Earth Observation techniques summarized in the Remote Sensing techniques and the GIS in monitoring and assessing aspects in environmental conditions pollution impacts within the lake.

TOOLS OF THE STUDY

A- Field studies: To collect data and carry out.

hydrologic field measurements such as water levels and water quality parameters.

B- Satellite images: different Satellite data.

C- Topographic maps and land cover maps.

STUDY AREA

Northern Lakes of Egypt

The natural lakes of Egypt have a unique combination of physical and chemical features. They are bodies of fresh, brackish and saline or hypersaline water. These habitats are highly environmentally structured and they provide a gradient from extremely inundated to relatively mesic. Chemical and hydro-physical characteristics of water and sediments affect the diversity and structure of the vegetation of these lakes **(El-Bana, 2003).**

Fig.1. Locations of the Egyptian northern coastal lakes 2017 (NARSS)

Lake Edku

Lake Edku is situated approximately 35 km east of Alexandria. It is a shallow eutrophic lake rarely exceeding 1.5 m in depth, The mean annual fish production from the lake is 9,000 ton **(GAFRD, 2017).** It is located west of the River Nile Delta between longitudes 30803000 and 30230 E and latitudes 31100 and 310180 N. The lake is connected to the adjacent Abu Qir Bay through Boughaz El-Maadia. The actual surface area of the lake has been decreased since 1964 due to the reclamation of a large area from the eastern side for cultivation purposes. Water depths in the lake vary from 10 to 140 cm, the maximum depths being in the central and eastern parts **(El Kafrawy *et al.,* 2017).** The lake receives large quantities of drainage water released from the agricultural lands of the Beheirah. Lake Edku outlines province, through the Barsik, Edku, and El-Bosely drains, where the last two drains meet together before entering the lake and discharge their water through the extension of Edku drain **(El Kafrawy *et al.,* 2017).**

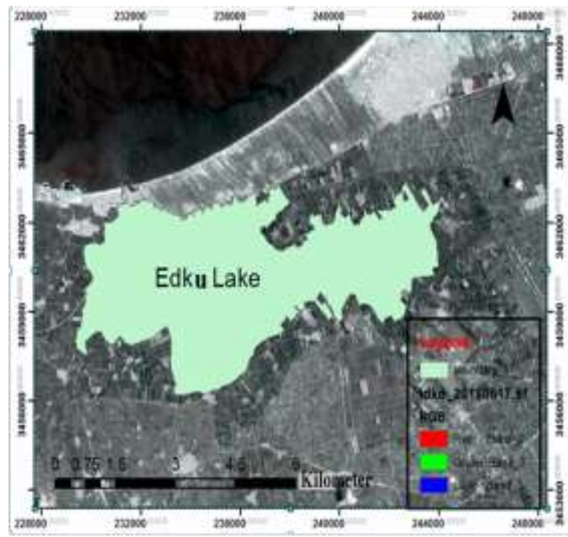

Fig.2 Determined Lake Edku Location Map 2018

Located 35 km from the city of Alexandria at the latitude and longitude 30 ° N longitude 31 ° E, respectively, and Lake Edku, like the lakes of northern Egypt, get its water supply from a main source, which is the banks where it meets and pours the resulting agricultural drainage water from the cultivated areas around it. In addition, Edku Lake shares some of its waters with the waters of Abu Qir Bay through the Bugaz, a 20-meter hole connected to the Mediterranean Sea, which allows for the passage and diversity of fish in the lake and is no more than 1.5 meters deep. The city produces more than one million cubic meters of sewage waste every day, mixed with industrial waste, hospital waste and gas stations. Almost half of this amount is received without treatment in water bodies.

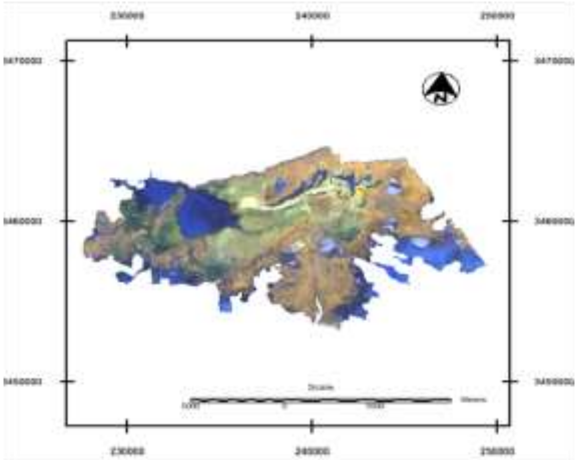

Fig.3. Satellite image of Lake Edku 1973

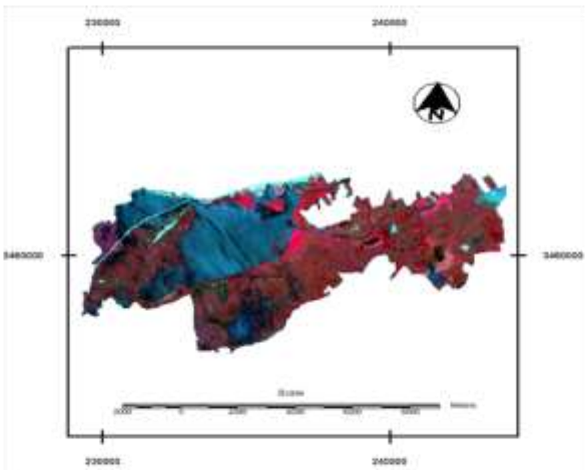

Fig.4. Satellite image of Lake Edku 1973

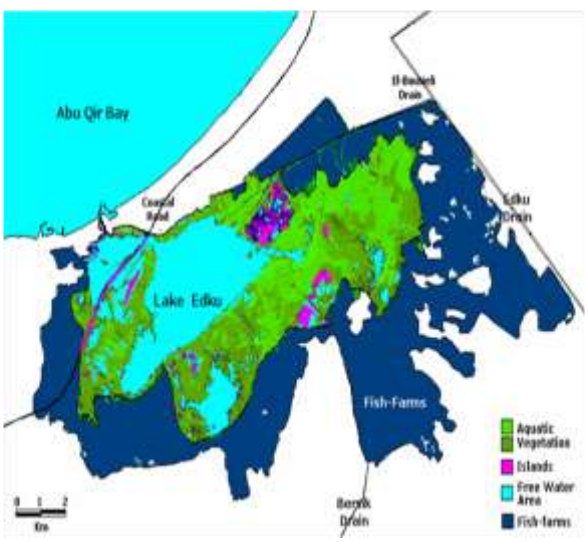

Fig.5. The main features of Lake Edku, as revealed by remote sensing mapping (Abdel Halim *et al.,* 2013).

MATERIALS AND METHODS

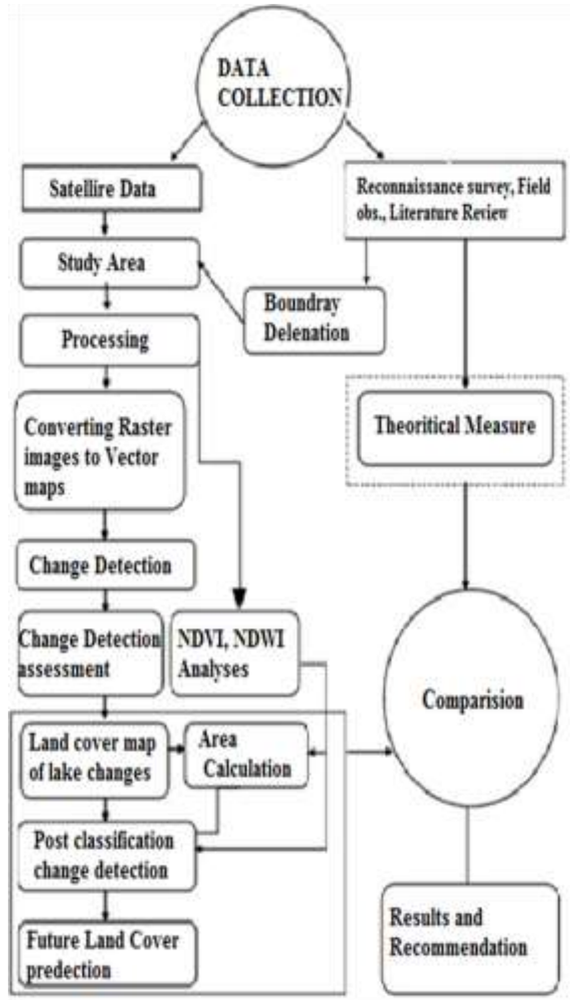

Fig.6. The Methodology of the study work steps

DATA AQUASITION

FIELD OBSERVATIONS

Field surveys in the study area were used to help interpret the remotely sensed data. The monitoring programs were undertaken in several ways; record hydrological and water changes and regular field sampling for water quality during as shown in the Figure.

THE USED MATERIALS

SATELLITE DATA

Satellite data required accomplishing the objectives of remote sensing activities and consequently achieving the current study as follow: (1) Land sat Thematic Mapper ™ 1973, 1985, 1990, 2003, 2015, and 2018. All images were geometrically rectified to the Universal Transverse Mercator projection (WGS-84) zone 36. The satellite images were covered the study area were collected and used for the purpose of establishing a comprehensive GIS database. Satellite data required fulfilling the study objectives of acquired from NARSS archived scenes.

Table 1. The satellite images data

Satellite Data	Date of acquisition	Resolution (m)
Landsat 1	1973	60 m
Landsat 5	1985	30 m
Landsat 5	1990	30 m
Landsat 5	2003	30 m
Landsat 7 ETM	2009	30 m
Landsat 7 ETM	2015	30 m
Landsat 8 OLI	2018	30 m
Blanet lab	2018	7.5 m

THE USE OF DIFFERENT SENSORS

Before the individual management applications of remote sensing are discussed in further detail, it is useful to make some general comparisons between each of the sensors. Landsat Multispectral Scanner. The most widely used sensor employed for coastal applications is Landsat Multispectral Scanner (MSS). This does not necessarily suggest, however, that MSS has been found to be the most desirable sensor. Landsat MSS has been available since 1972 and has supported much fundamental remote sensing work.

The Landsat Thematic Mapper (TM) is a scanner carried on Landsat 4 & 5 satellites. It records 256 radiance levels in seven wavebands, operating in the range from blue to thermal infra-red. The spatial resolution of all bands is 30 m apart from the thermal band which is 120 m. A Landsat TM imagery was used to estimate chlorophyll a, total phosphorus, suspended solids, salinity and temperature **(Baban, 1993a; 1993b; 1993c).**

THE BASIC CONCEPTS OF WATER QUALITY IN REMOTE SENSING

The main objective of remote sensing, in terms of lake studies, is to record images of lakes and their catchment area by using electromagnetic radiation energy sensors mounted on satellites or aircraft. The wavelengths that are of most interest to lake studies is the visible (0.4–0.7 m), where in pure water the majority is transmitted, the near infra-red (0.7–2.0 m), where the majority is absorbed and thermal infra-red (3.–50 m) **(Curran, 1985).**

IMAGE PROCESSING TECHNIQUES

The image processing is an analyzed and manipulation of a digitalized image, especially in order to improve the quality of image processing **(Prabhu, 2016).**

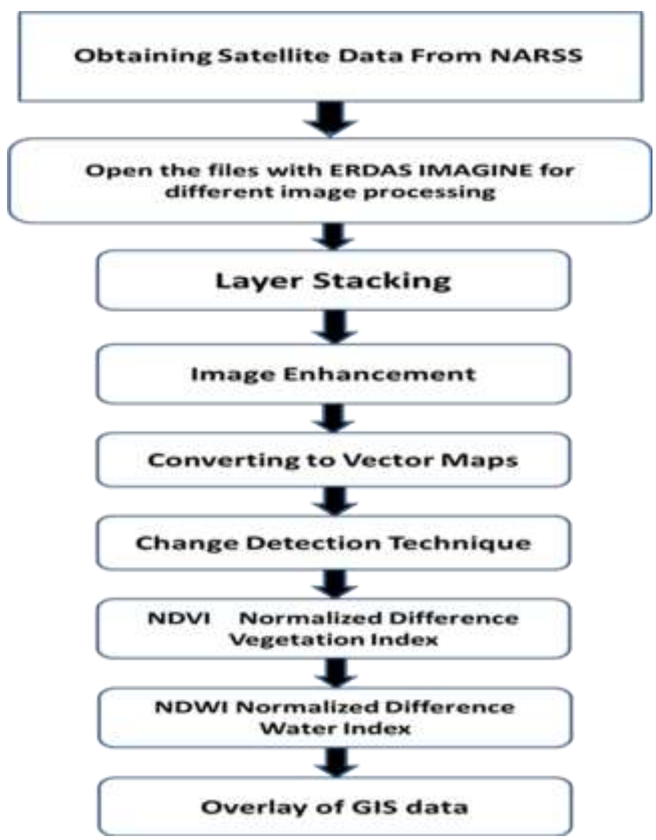

Fig.7. Image processing techniques for monitoring water quality

WORK STEPS FOR SOLVING THE PROBLEM

POLLUTION PROBLEM IN LAKE EDKU

The main cause of pollution in Lake Edku is the spread of, weeds and aquatic plants heavily in large areas of the lake in addition to the spread of the Nile, which leads to stagnation of water in these areas and the creation of places of detention and this stagnation and lack of movement of water circulation in these areas to change water properties and pollution.

The agricultural drainage water containing pesticides, fertilizers and effluents of industrial activities and runoffs in addition to sewage effluents supply the lake water body and sediment with huge quantities of inorganic anions, such as phosphates, nitrates, and ammonia, combined organic nitrogen and/or heavy metals **(Shaltout and Khalil, 2006; Khan and Ansari, 2005).**

Since, many water quality monitoring studies have focused on mapping different water quality parameters using remote sensing technologies, with varying purposes **(e.g., Serrano *et al.,* 1997; Härmä *et al.,* 2001; Peña *et al.,* 2004; Duan *et al.,* 2006; Allan *et al.,* 2011; McCullough *et al.,* 2012).** Landsat imageries were extensively used in those studies because of its relatively high spatial resolution of 30 m and its long period of archived data, which allows one to conduct multitemporal change detection of targeted water bodies (**e.g., Mayo *et al.,* 1995; Alle and Johnson, 1999; Olmanson *et al.,* 2008).**

SAMPLING STRATEGY

Water samples were collected seasonally using plastic bottles during 2019 through the field trip from twelve locations in Lake Edku and its drains. Sampling stations covered different basins of the lake, representing the different habitats. Twelve samples were directly collected from the stations. This sampling protocol has been chosen to assess the impacts of water discharge on the lake water (as three sectors) and to correlate their water quality with the water quality of each drain.

Table 2. The locations of samples collected from Edku Lake

	Longitude	Latitude	x	y	x_utm	y_ut
1	30 10 47.48	31 15 54.13	30.179722	31.265	231555.3474	3462
2	30 11 26.95	31 15 47.20	30.27222222	31.265	240363.603	3462
3	30 10 22.82	31 15 19.70	30.17972222	31.25555556	231528.4705	3461
4	30 10 54.86	31 15 15.70	30.18222222	31.25444444	231763.397	3461
5	30 12 17.94	31 15 28.87	30.205	31.25805556	233942.8254	3462
6	30 12 53.34	31 15 9.32	30.215	31.25277778	234880.3137	3461
7	30 12 16.28	31 14 29.81	30.20472222	31.24166667	233870.1665	346
8	30 11 15.82	31 14 3.20	30.18777778	31.23416667	232234.9707	3459
9	30 13 5.93	31 14 31.86	30.185	31.24222222	231993.2361	3460
10	30 13 50.59	31 15 14.49	30.23277778	31.25416667	236577.2905	3461
11	30 13 57.18	31 15 57.60	30.2325	31.26611111	236584.1823	3462
12	30 16 19.96	31 15 41.05	30.27222222	31.26138889	240353.6673	3462

The main parameters analyzed are: air temperature surrounding the lake (AT), water temperature (WT), water pH, salinity (TDS), conductivity (COND), chemical oxygen demands (COD), biological oxygen demands (BOD), dissolved oxygen (DO), water depth (WD), turbidity (SD), ammonia (NH4), nitrate (NO3), nitrite (NO2) , total phosphorous (TP).

Fig.8. The sampling sites and main banks of Lake Edku during 2018

RESULTS AND DISCUSSION

A field study aimed to record the current development activities along the study area and collect samples of water, different natural and anthropogenic environmental features that occurred along the study area due to the coastal changes.

Comparison between the results obtained from the project of a program of cooperation between the EEAA and the National Institute of Oceanography and Fisheries presents the environmental status of Lake Edku that was carried out during the period of 2012 - 2013.

The interpretation of the project output will be discussed. The interpretation between results will lead to proposing the management plan for Edku Lake, also will be recorded and compared between the old, present and expected near future impact.

The degree of transparency in Lake Edko between (60-100 cm) in 2003**. (Shakweer, 2006)** the current study showed that the values of water transparency ranged between the lowest value of the transparency degree 10 cm in the western part of the lake in stations 1, 2, 3, 4, 8, where the highest value of the transparency

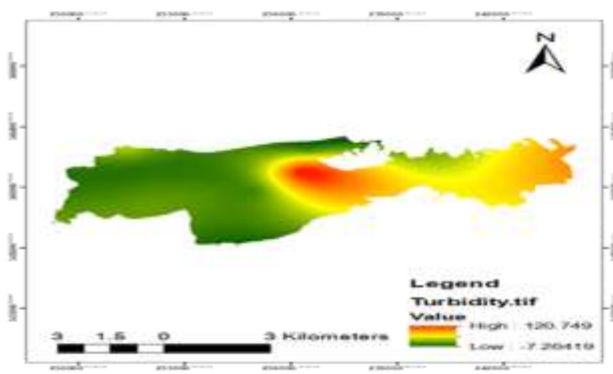

Fig.9. Water transparency distributions

Table 3. The results of water analysis obtained from Lake Edku during 2019

	TDs	Fe	Cd	Pb	Cr	Ni	Nitrite	Nitrate	Phosphate	Ammonia	omw	salinity	pH_w	Turbidity	Cu
1	42409	0.46	0.08	0.54	0.08	0.26	0.06	7.14	3.63	0.03	0.87	16.33	7.3	38.8	32.1
2	32840	0.35	0.04	0.4	0.06	0.026	0.1	2.75	3.6	0.15	0.562	13.11	7.7	18.2	36.8
3	30747	0.36	0.02	0.32	0.04	0.19	0.09	6.79	3.57	0.12	0.5386	11.57	7.8	13.3	7.6
4	11051	0.11	0.02	0.23	0.02	0.09	0.1	11	3.6	0.19	0.1778	3.56	8.4	10.1	13.5
5	4564	0.17	0.03	0.19	0.02	0.13	0.12	3.86	3.72	0.05	0.059	1.68	7.8	14.5	17.8
6	5870	0.49	0.03	0.15	0.02	0.22	0.07	4.33	3.83	0.03	0.088	2.85	8.2	25.7	26.1
7	5702	0.16	0.02	0.14	0.02	0.21	0.1	4.56	3.6	0.07	0.0808	2.95	7.4	19.4	20.
8	10373	0.2	0.03	0.18	0.03	0.05	0.07	6.32	3.63	0.1	0.1656	7.04	7.6	24.8	23.5
9	4259	0.29	0.02	0.21	0.02	0.07	0.16	5.38	3.69	0.17	0.061	1.94	8.6	19.1	40.8
10	2770	0.28	0.02	0.2	0.03	0.04	0.06	13.63	3.55	0.21	0.05	1.42	7.8	120	13.2
11	1517	0.39	0.02	0.16	0.03	0.02	0.09	4.74	3.86	0.06	0.0266	0.73	7.7	17.9	29.4
12	1438	0.25	0.03	0.14	0.02	0.02	0.19	8.89	3.57	0.19	0.0296	0.68	8	38.3	20.0

WATER TRANSPARENCY

The degree of water transparency reflects the ability of light to penetrate through the water, making the degree of transparency an important factor affecting the biological processes within the bodies of water. The degree of transparency is affected by the number of suspended materials present in water, where there is always an inverse relation between the degree of transparent water and the amount of suspended matter **(Verduin, 1964).**

SALINTLY

The salinity of water (Total Dissolved Salts TDS) is mainly composed of super cautions (sodium, potassium, calcium and magnesium) and super anions (chlorides, carbonates, bicarbonates and sulfates), in addition to some trace elements and salts **(Eaton *et al.,* 1995).** The salinity of the lake in front of the pogas from 14.84 in 1971 to 2.9 in 2001 and in 2003 salinity ranged from 0.66 to 4.78.

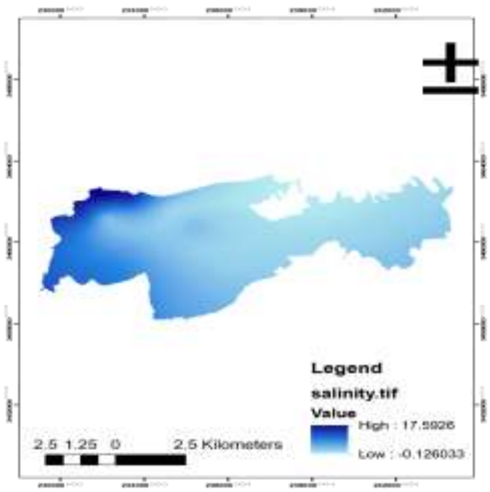

Fig.10. Distribution of water salinity of Edku water body 2019

HYDROGEN ION CONCENTRATION (pH)

Hydrogen ion concentration is one of the most important factors affecting the aquatic environment, which has a significant effect on all biological processes within the water bodies. Hydrogen ion concentration plays an important role in the deposition or melting of heavy metals in water bodies. The value between 6.5-8 is the ideal value for the life and growth of fish. The concentration of the hydrogen ion is less than 4 and higher than 11 mm for most species of fish **(Delince, 1992).**

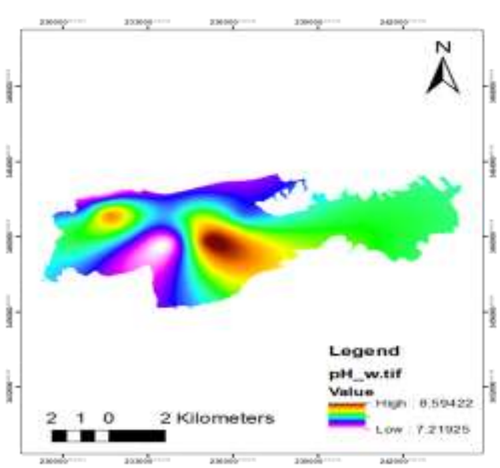

Fig.11. Distribution of pH of lake Edku

TOTAL SUSPENDED MATERIALS TSM

Concentrations of the total suspended matter in Lake Edko vary widely, with the lowest value of 1.4, 1.5, 2.7 mg / L in the northern east of the lake in stations 11, 10, 9 respectively, while the highest value of 42, 32 mg / L in the northern west of the lake in stations 1, 2.

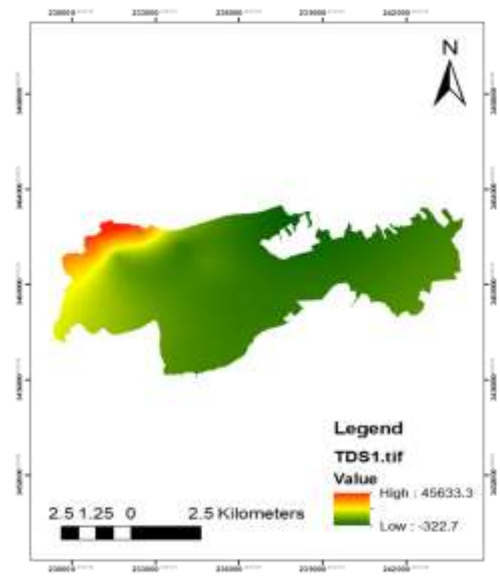

Fig.12. Distribution of TSM of the surface water of Lake Edku in 2019

PHOSPHORUS

Phosphorus is an essential component of aquatic organisms and their growth. Because phosphorus is a non-gaseous element and is present in natural form of insoluble phosphoric salts, it is by nature a low concentration in the aquatic environment. The concentration of phosphorus in the water bodies is increased as a result of sanitary drainage or industrial or agricultural drainage, leading to many environmental problems. Phosphate concentrations in the lake ranged between the lowest of 0.14 and 0.15 µg / L in the middle of the lake, in station 6 and 5 respectively, while the highest of 0.54 µg / L in the northern west of the lake in station 1.

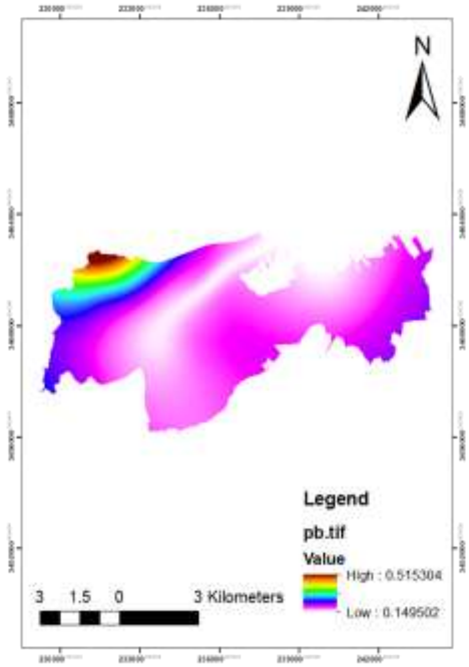

Fig.13. Distribution of Phosphorus in water of Lake Edku in 2019

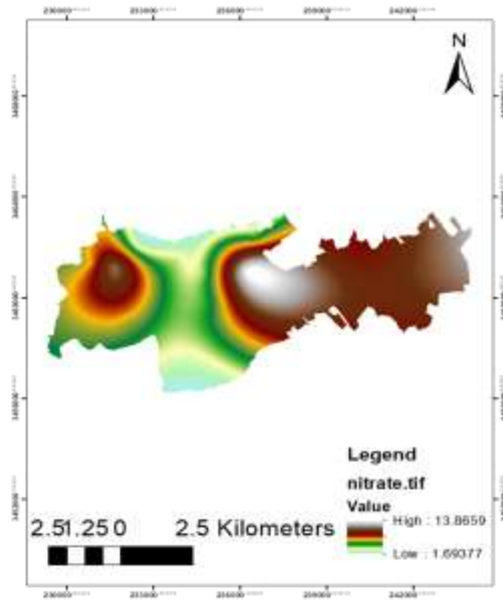

Fig.14. Distribution of Nitrites in water of Lake Edku in 2019

NUTRITIOUS SALTS

Nitrites (NO2-N)

Nitrite increases as a result of bacterial oxidation of inorganic materials to obtain energy. This gas in turn is unstable. It is oxidized to nitrate by a specific bacterium or reduced to ammonia by other bacteria opposite to the first. Nitrite gas is toxic gases and its presence at high concentrations confirms the presence of source of pollution.

Nitrite was the least concentrated in nitrogen images in lake water, but the change in nitrite concentrations in lake water was observed in a wide range ranging from the lowest 0.06, 0.07 µg / L in the northern and southern middle part of the lake in stations 1, 5, 7 respectively, while highest 0.16, 0.19 µg / L in the eastern part of the lake in stations 8, 11, 12 respectively.

Nitrate element (NO3-N)

Nitrates are nitrogen images in the aquatic environment and are the main food for many phytoplankton and algae

. Nitrate ion contributes significantly as a source of nutritious salts necessary for the growth of aquatic plants in water bodies, especially those that contain a limited amount of nitrogen. Nitrate ion produces nitrite and urea oxidation by oxidizing bacteria and can produce nitrate of nitrate due to melting nitrogen gas in the atmosphere and pouring it into rain water in the form of nitrate.

The values of nitrates in the lake water ranged between the lowest value of 2 mg / L in the northern and eastern middle parts of the lake in stations from 1, 2, while the highest value of 13.6 mg / L in the western middle part of the lake in station 9. These factors are all sporadic or combined that work to fold the vitality of the fish or crustaceans and reduce their immune capacity in addition to the continuous bioaccumulation of sources different pollution.

CONCULUSION

Edku Lakes are under the direct threat of environmental degradation. Lake Edku was subjected to all kinds of encroachments and turned into a polluted pool that caused the deaths of fish and the destruction of the fishermen's houses.

Proposed solution for the Pollution problem

a. Establish a purification plant for industrial, agricultural and agricultural wastewater in the lake, and obligate the companies, factories and villages that have drainage outlets on the sea and the lake to make drainage networks and connect them to the purification plant to be constructed.

b. An innovative solution to the problem of Pollution: 1.Making a survey of all sources of industrial, agricultural and health drainage and the establishment of a database that includes information about each of the banks of the lake and the name and type of production of the plant, which casts its industrial waste and determine the type and size of waste and degree and quality of polluted and also for agricultural drainage and Fertilizers, Chemicals, Fertilizers used and their residues which are given in the bank, which enable us to periodically monitor the waste of factories and agriculture by following the analysis of water samples.

c. The work of treatment plants for drainage before entering the lake with the work of masts and channels for communication channels and irrigation of agricultural land to drain the Nile water.

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