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Liver toxicity and geospatial analysis as integrated indices of water quality deterioration in Idku Lake, Egypt

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ABSTRACT

Idku Lake is one of the northern coastal lakes in Egypt which receives huge amounts of wastewater from two main drains. This study was carried out to assess some water quality parameters of Idku Lake, using fish liver condition as a biomarker of water quality. Eleven parameters were measured in 10 stations of Idku Lake and evaluated by spatial distribution map using GIS analysis, in addition to the Eutrophication Index (E.I.). Investigated parameters unlikely distributed throughout the different regions of the lake with most parameters exhibited the highest levels near drains discharge regions and the minimum near El Boughaz. Adversely, phosphate reached the maximum level at El Boughaz. Salinity, electric conductivity and TDS drew nearly the same pattern of distribution which hit the maximum at the W and S parts and gradually decreased toward the N and E parts. Ammonia was recorded at a very low concentration while nitrate was at a high concentration compared to previous investigations. Consequently, the lake was recorded to be dystrophic in terms of the abundance state. Anthropogenic activity is the primary factor enhancing the inputs of nitrogen, phosphorus and other compounds to lakes, causing widespread eutrophication which affects aquatic food webs and ecosystem sustainability. A histopathological study was conducted on fish species (*O. niloticus*, *O. aureus T. zillii*, *Clarias gariepinus* and *Dicentrarchus labrax*) collected from Idku Lake. The most observed alterations were mononuclear cell infiltration, vacuolated hepatocytes, dilated central vein, compressed blood sinusoids, cytoplasmic vacuolations, hepatocytes necrosis, blood vessel congestion, patchy degeneration and low accumulation of mucopolysaccharide that indicates the remarkable toxic effect of Idku Lake water environment.

INTRODUCTION

The Mediterranean basin in Egypt includes five northern lakes arranged from west to east as follows: Mariout - Idku - Burullus - Manzala and Bardawil. These lakes have an economic importance in terms of fish production that amounts more than 75% of total fish production in Egypt. The lakes face a range of challenges, which includes diminution of its area and problems resulting from the expansion of agricultural and industrial activities and fish farms.

Idku Lake is one of the most threatened aquatic wetlands in Egypt due to anthropogenic activities and pollution. Drainage water decreased the annual mean salinity levels in Idku Lake during the past three decades. This decrease is attributed to the restriction of water flow from the sea to the lake through the lake sea connection due to the increase of the rate of drainage water discharge to the lake from one year to the next **(Shakweer, 2006)**. Moreover, the northeastern part of the lake is intersected by the international coastal road which runs inside the lake for about 4.5km in a general NE-SW direction, which to some extent lowered the flow of sea saline water to most of the sea area **(Moufaddal *et al.*, 2008)**.

Water quality is a term used to describe the physical, chemical, and biological characteristics of water. The continuous wastewater disposal to the water body causes a serious impact on the water quality. Deteriorating water quality of lakes has both environmental and socioeconomic consequences. Dumping wastewaters into natural water bodies without an appropriate treatment results in an increase in organic matter and oxygen depletion **(Gupta *et al.*, 2014)**. This have caused eutrophication and adversely affected the fishery **(Soliman *et al.*, 2006; Chen *et al.*, 2010)**. Thus, the eastern side of the lagoon where drains discharge is heavily vegetated and less than 1m depth **(Al Sayes *et al.*, 2007)**.

Fish are one of the most important and the largest groups of vertebrates in the aquatic system and have been considered good indicators because they occupy different trophic levels with different sizes and ages **(Burger *et al*., 2002)**. Meanwhile, fish are widely consumed in many parts of the world by humans, and polluted fish may endanger human health. Tilapia species including *Oreochromis niloticus*, *Oreochromis aureus*, *Sarotherodon galilaeus* and *Tilapia zillii* is ranked the first, followed by *Clarias gariepinus* in the fish production of the Idku Lake, while most other species have almost disapeared **(Saeed & Shaker, 2008; Zahran *et al*., 2015)**. This study was conducted on the lake ecosystem to identify its water quality and investigate the probability of liver toxicity of fish inhabiting such water, using an integrated system of lab and remote sensing data analysis.

MATERIALS AND METHODS

1. Study area

Idku Lake is located in the northwest of the Nile delta, parallel to the Mediterranean Sea at about 36km east of Alexandria, with an area of about 127.37 km^2 **(Moufaddal *et al.*, 2008)**, of which 22 km^2 of the total surface area is open water; whereas, the rest is covered by aquatic vegetation and islands. In 2017, the lake's water surface area (Fig. 1) reached 16.8 km^2 (about 4000 feddan) **(EEAA. 2017)**. It is located between latitudes °31 ´10 and °31 ´18 N and longitudes °30 ´23 and °30 ´8 E. The total fish production of the lake was 8070 tons in 2019 **(CAMPAS. ٢٠١٩)**, constituting 3.9% of fish production from the Egyptian lakes or 5.2% from the production of the northern lakes.

The lake depth ranges between 0.1 and 1.40m, with the maximum depths in the middle and the eastern regions **(El Kafrawy *et al.*, 2019)**. It receives saline water from the sea through Buoghaz El-Maadyah at the northern part **(Ramdani *et al.*, 2001)** and receives drainage freshwater from two main drains; namely, Kom-Belag and Barsik drains. Kom-Belag drain receives annually about 592 × 106 m^3 of drainage water **(Badr & Hussein, 2010)** from El-Bousely, Idku, El-Khairy, and Damanhur sub-drains transporting domestic, agricultural, and industrial wastes, as well as effluents from more than 300 fish farms **(Khalil & Rifaat, 2013)**. Whereas, Barsik drain transports annually about 348 × 106 m^3 of drainage water, mainly agricultural, to the southern basin of the lake **(Badr & Hussein, 2010)**. These drainage waters mostly give rise to water movement through the lagoon from both the east and the south to the north **(Khalil & Rifaat, 2013)**.

Idku Lake administratively belongs to Idku district, Kafr Al Dawar district, Abo-Homos district, Behira Governorate, while most of the lake belongs to Idku district. The average water temperature is 23.54 ±5. 84°C, and average salinity is 2.24 ± 2.12PSU **(Zaghloul & Hussien, 2017)**.

2. GPS positioning

Satellite data were required for accomplishing the objectives of the current study. Thus, satellite image of sentinel-2A 2021 at Path/Row 176/38 was selected with nearly 0% of cloud covering then downloaded using **USGS**. Ten stations covering the major sectors of the Lake were geographically positioned using GPS, and their distribution was plotted as shown in Fig. (1). A list of the stations and their geographical position is given in (Table 1). The monitoring program was undertaken in recording hydrological changes and field sampling. The GPS system used in the survey was tested and verified at two different points before and after the survey.

3. Sample collection

3.1. Water sample collection

Three water samples were collected from each site in polyethylene bottles, labeled and preserved in icebox before being transferred to the laboratory for further water quality determinations.

3.2. Fish sample collection

Total of 15 fish samples were collected, 3 fish individuals from *Dicentrarachus labrax, Clarias gariepinus, Oreochromis aureus, Tilapia zilli* and *Oreochromis nilotica.* Each fish was dissected for liver isolation. The isolated liver samples were immediately fixed in 10% of formalin until transferred to laboratory for histopathological investigation.

4. Water quality analysis

The investigation sites were measured *in situ* for seven parameters using Hydrolab HL7 Multiparameter Sonde. Parameters measured were pH, (Specific Conductance) SpCond, (Chromophoric Dissolved Organic Matter) CDOM, salinity, (Total Dissolved Solutes) TDS, turbidity and chlorophyll-a. Water samples transferred to laboratory were analyzed for nitrate, nitrite, ammonia and phosphate using Ion Chromatography (C1100).

5. Eutrofication index

Eutrophication status of Idku lake was assessed by the eutrophication index (E.I.) proposed by **Primpas *et al.* (2010),** based on five-point scales.

$$\mathbf{E.I.= 0.279C_{PO4} + 0.261C_{NO3} + 0.296C_{NO2} + 0.275C_{NH3} + 0.214C_{chl\text{-}a}}$$

Where, C is the measured concentration of the nutrient. The calculated E.I. values classify the trophic status as follows:

Ultratrophy	< 0.04 (high)
Oligotroph	0.04- 0.38 (good)
Mesotrophy	0.37-0.87 (moderate)
Eutrophy	0.83-1.51(bad)
Dystroph	> 1.51(poor)

6. GIS and interpolation

The downloaded satellite image was pre-processed, enhanced then lake boundary was digitized using 1:50,000 scale by the polygon shapefile in the ArcGIS software version.

In GIS applications, interpolation uses vector points with known values to estimate values at unknown locations to create a raster surface covering an entire area. Spatial interpolation is therefore a mean of creating surface data from sample points. All investigated points have been used, covering the whole lake area for interpolation process of water parameters in Idku Lake.

7. Statistical analysis

Microsoft Excel software version 2010 was used to determine the descriptive statistics (mean, standard error, median, standard deviation, minimum, maximum and range) of parameters' values in water samples.

8. Histopathological study

Liver samples of the collected fish were fixed with 10% of neutral formalin for 24 hours. Afterward, tissues were preserved in 70% of ethyl alcohol. Tissues were dehydrated in ascending ethanol series, cleared with xylene, then embedded in paraffin. Tissues were sectioned at 5µ and stained with haematoxyline and eosin (H&E) for general histological examination based on the method of **Bancroft and Stevens (1996)**. Slides were examined using a light microscope (Zeiss) model 25 and photographed using microscope-computerized camera. This examination was done to evaluate the impact of pollution on liver tissues. In addition, tissues were stained by Acid-Schiff (PAS) reaction stain for the investigation of mucins content **(McManus, 1948)**.

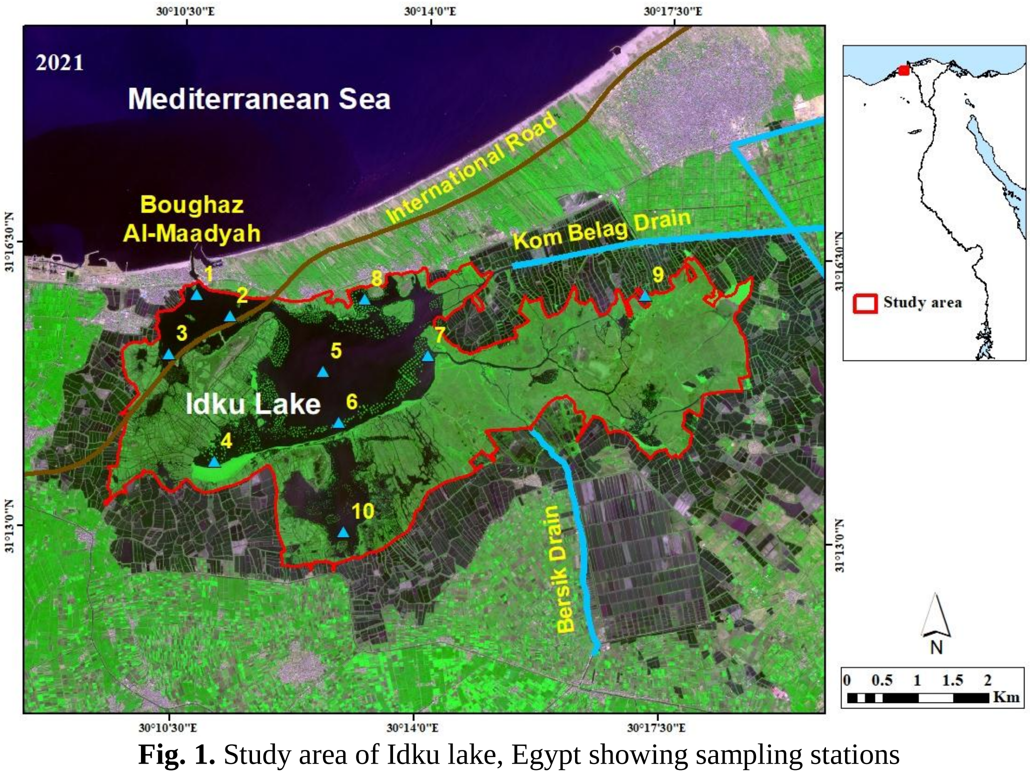


Fig. 1. Study area of Idku lake, Egypt showing sampling stations

Table 1. List of water sampling stations and their geographical positions

Station	Longitude	Latitude	
1	30°17'90.13"E	31°26'49.85"N	El Boughaz region
2	30°17'27.72"E	31°25'27.01"N	
3	30°18'71.12"E	31°26'07.40"N	
4	30°18'41.98"E	31°23'08.11"N	The western- southern region
5	30°20'98.44"E	31°24'98.97"N	Middle of the lake and free water area
6	30°21'38.64"E	31°23'93.32"N	
7	30°23'46.53"E	31°25'35.92"N	Drain water disscharge region
8	30°21'92.03"E	31°26'48.78"N	
9	30°21'56.28"E	31°21'68.28"N	The eastern- northern region
10	30°28'64.01"E	31°26'70.21"N	The southern side

RESULTS AND DISCUSSION

1- Water quality and physico-chemical parameters

Physical, chemical and biological characteristics are limiting factors of water quality in relation to the environmental and human activity. Thus, the quality of water is preindicated by the current activities and their probable impacts on it **(El-Halag *et al.*, 2013)**. Table (2) summarizes the descriptive statistics of the investigated physico-chemical parameters measured in water samples, collected from the 10 sampling sites along Idku Lake during 2021. The mean concentration (± SD) of nitrogenous compounds were observed to follow the order of: nitrate (3.3 ± 1.4 mg/l) > nitrite (0.47 ± 0.30 mg/l) > ammonia (0.22 ± 0.03 mg/l). The range between the minimum and maximum values for the three parameters concentrations was 4.8, 1.09 and 0.36 mg/l, respectively.

Table 2. Statistics of some water quality parameter values from the investigated stations in Idku Lake , Egypt (2021)

	pH (Units)	CDOM (mg/l)	SpCond (mS/cm)	Salinity (PSU)	TDS (g/l)	Turb (NTU)	No_2 (mg/l)	No_3 (mg/l)	Po_4 (mg/l)	NH_3 (mg/l)	Chl. A (µg/l)
Min.	7.53	95.22	1.87	0.95	1.19	6.01	0.11	1.8	1.32	0.06	19.5
Max.	8.21	415.7	6.02	3.61	3.85	87.5	1.20	6.6	5.58	0.42	100
Range	0.68	320.4	4.15	2.66	2.66	81.5	1.09	4.8	4.26	0.36	81.1
Med.	7.91	152.8	3.93	2.36	2.52	21.1	0.42	3.2	3.09	0.22	47.7
Mean	7.89	172.9	3.85	2.31	2.46	27.5	0.47	3.3	3.32	0.22	53.4
±SD	0.20	82.37	1.31	0.90	0.84	24.9	0.30	1.4	1.31	0.03	32.8
±SE	0.05	23.78	0.37	0.26	0.24	7.19	0.08	0.4	0.37	0.13	10.3

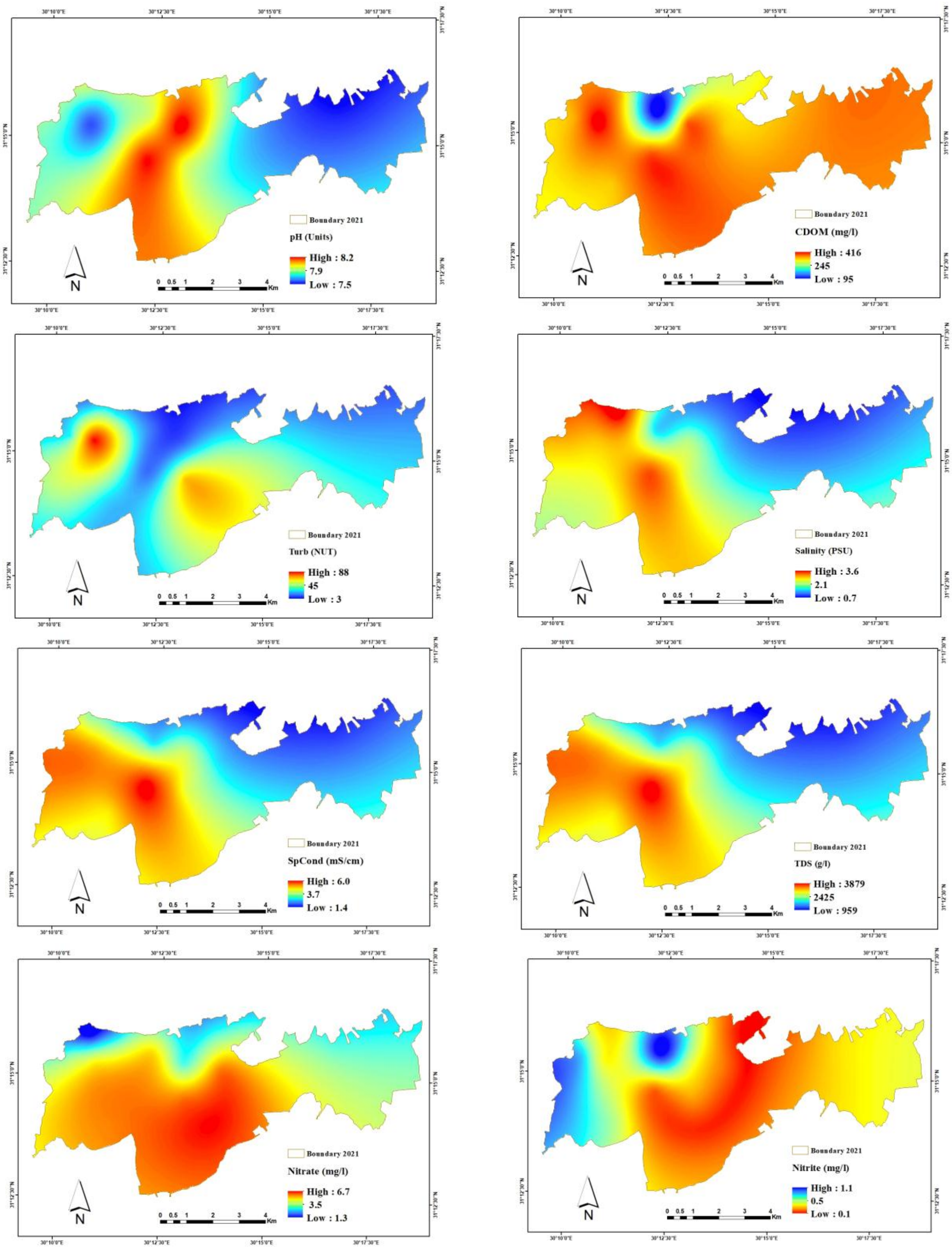
Results in Table (3) present the same parameters in some previous studies. In Idku Lake, the mean concentration of electric conductance in water, total dissolved solids are higher in value than previous studies. The mean of pH value agrees with that of **Masoud *et al.* (2004)**, and it was lower than that recorded in more recent studies. The mean concentration of No_2, No_3 and Po_4 are of higher values compared to recent studies **(Saeed, 2013; Sherif *et al.*, 2018)**. Chlorophyll-a content is lower than most previous studies except for the study of **Saeed (2013)**.

Table 3. Data of physico- chemical parameters in some previous studies in Idku Lake, Egypt

Reference	Year	pH (Units)	CDOM (mg/l)	SpCond (mS/cm)	Salinity (PSU)	TDS (g/l)	Turb (NTU)	No2 (mg/l)	No3 (mg/l)	Po4 (mg/l)	NH3 (mg/l)	Chl. a (µg/l)
Masoud *et al.* (2004)	**2004**	7.98	----	----	----	1.87	----	0.34	3.59	2.5	0.4	----
Saeed and mohamed (2012)	**2012**	8.71	----	2.13	----	----	----	----	----	----	----	69.50
Saeed (2013)	**2013**	8.31	----	----	----	----	----	0.15	0.71	0.33	1.76	23.59
Sherif *et al.* (2018))	**2018**	8.4	----	3.5	----	2.3	----	0.08	0.16	0.7	4.5	70.3
Shetaia *et al.* (2020)	**2020**	8.21	----	----	3.4	----	----	0.12	0.47	0.38	1.5	84.31
Present study	**2021**	**7.89**	**172**	**3.85**	**2.31**	**2.46**	**27.5**	**0.47**	**3.3**	**3.32**	**0.22**	**53.04**

Fig. (2) exhibits the spatial distribution map of the physico- chemical parameters in Idku Lake water which indicates that:

- pH of water hit the 8.2 units at the N and S regions while the lowest degree (7.5 Units) was recorded at the W and E regions, with an average value of (7.9 Units).
- Chromatophoric organic matter (CDOM) showed heavy distribution (at 416 mg/l as maximum) along the whole lake, except the area near El Boughaz connection that recorded the lowest distribution (at 93 mg/l as minimum).
- Turbidity of water reached the highest degree (88 NTU) at El Boughaz and drains regions and the lowest degree (3 NTU) at the N and S regions.
- The salinity, specific conductivity and TDS recorded the maximum level at the N-W and S-W regions near the Boughaz link (3.6 PSU, 6 mS/cm and 3879 g/l, respectively) and decreased gradually reaching the minimum level (0.7 PSU, 1.4 mS/cm and 959 g/l, respectively) at the E and N-E regions near the drains. In addition the salinity, spCond and TDS levels appeared to be higher at Bersik drain than Kom Belag drain. The three parameters were nearly configured at the same distribution pattern.
- Nitrate exhibited the highest conc. (6.7 mg/l) near drains regions while the lowest conc. (1.3 mg/l) was recorded at El Boughaz region and at the extreme western area. Nitrite exhibited the highest conc. (1.1 mg/l) near drains regions and at western side while it showed the lowest conc. (0.1 mg/l) at El Boughaz region.
- Ammonia displayed the highest conc. (0.44 mg/l) near drains and western region, while it exhibited the lowest conc. (0.025 mg/l) near El Boughaz and at southern regions, with an average value of (0.23 mg/l).
- Phosphate recorded the highest conc. (6 mg/l) near drains and El Boughaz regions, while it exhibited the lowest conc. (0.8 mg/l) at western side, with an average value of (3.1 mg/l).
- Chlorophyll-a exhibited the highest conc. (100 µg/l) near drains and eastern side, while the lowest conc. (19 µg/l) was recorded at El Boughaz and western regions, with an average value of (47 µg/l).


Boundary 2021
pH (Units)
High : 8.2
7.9
Low : 7.5
Boundary 2021
CDOM (mg/l)
High : 416
245
Low : 95
Boundary 2021
Turb (NUT)
High : 88
45
Low : 3
Boundary 2021
Salinity (PSU)
High : 3.6
2.1
Low : 0.7
Boundary 2021
SpCond (mS/cm)
High : 6.0
3.7
Low : 1.4
Boundary 2021
TDS (g/l)
High : 3879
2425
Low : 959
Boundary 2021
Nitrate (mg/l)
High : 6.7
3.5
Low : 1.3
Boundary 2021
Nitrite (mg/l)
High : 1.1
0.5
Low : 0.1

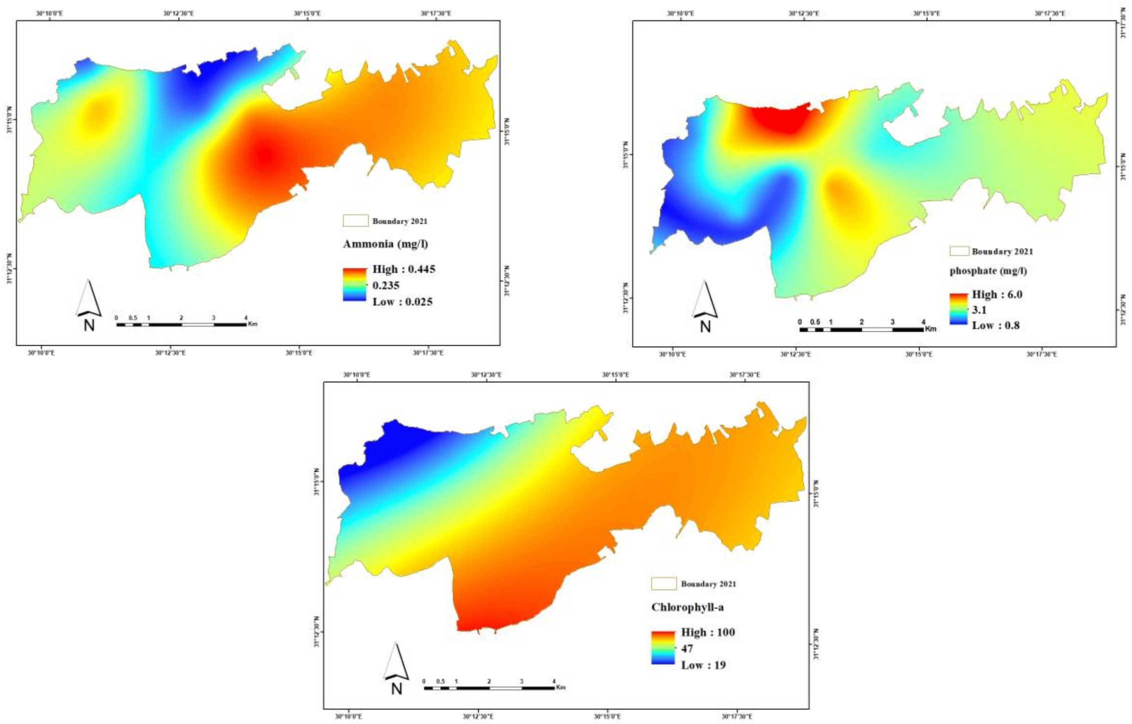


Fig. 2. Spatial distribution map of physico- chemical parameters in Idku Lake 2021

The alkalinity of water near the drains effluents can explain the richness of drainage water with organic matter and heavy growth of phytoplankton and hence maximum carbon uptake **(Kemdirim, 2001). This finding coincides with that of** with **Sherif *et al.* (2018).** Increased organic matter decreases the amounts of dissolved oxygen during decomposition causing hazardous effects to the aquatic life. In addition, the organic pollution causes various changes such as pH, turbidity, sedimentation rates, decomposition products, salinity and other biologically active materials **(Ezzat *et al.*, 2012)**. Colored dissolved organic matter concentration CDOM appeared to be correlated to pH level, specifically around El Boughaz enterance. The richness in organic matter and alkalinity at large areas of Idku Lake is a result of drain effluent discharge from different resources.

Richness of particles suspended or dissolved in water causes turbidity which scatters light, and causes water to appear cloudy. Particles can include sediment, especially clay and silt, organic and inorganic matter, algae, and microscopic organisms **(MPCA, 2008)**. Based on this, turbidity of Idku Lake water could be attributed to the increaseD values of TDS and nutrients, specifically near El Boughaz and drain discharge regions. The shallowness of the lake and richness of phytoplankton can be considered an important factor in decreasing the transparency of the lake.

Increasing values of TDS and salinity at the eastern part compared to that at the western part of the lake can be attributed to the discharge of drain water at this part, with most corporation from Kom Belag. On the other hand, the inflow of Abu Qir Bay water during the low tide periods can be a main reason for increasing the TDS values of the western part. In addition, the increased values of TDS at Bersik drain compared to Kom Belag drain can be due to the discharge of agricultural wastes in various parts of this drain before it reaches the lake. These wastes are supposed to contain more soluble salts used mainly as fertilizers. The present results agree with those of **Shakweer (2006)**. Moreover, The TDS values recorded are correlated with the results of water salinity and water electric conductivity, in which the highest EC reading recorded could be attributed to the increased

TDS in the western side of the lake near El Boughaz as previously mentioned by **Thompson *et al.* (2012)** who revealed that, electric conductivity reflects the quantities of dissolved salts and salinity. Decreased salinity at the eastern side reflects the effect of drainage water inflow in these regions. Drainage water also caused annual mean salinity levels in Idku Lake to decrease along the past three decades. This decrease is attributed to the restriction of water flow from the sea to the lake through El Boughaz connection due to the increase of the rate of drainage water discharge to the lake from one year to the next **(Shakweer, 2006)**. Water salinity in the area near the lake sea connection was 14.89 ‰ during the early 70's **(El-Samra, 1973)**. Now, this value decreased more than 5 folds in 2021. Moreover, the northwestern part of the lake is intersected by the international coastal road, which runs inside the lake for about 4.5km in a general NE-SW direction, which to some extent, lowers the flow of sea saline water to most sea area **(Moufaddal *et al.*, 2008)**.

The dissolved inorganic nitrogen comprises ammonia, nitrite and nitrate. Through the nitrification process, ammonia is oxidized to nitrite then to nitrate **(Hovanec & Delong, 1996)**. Based on this fact and probably due to the consumption and assimilation of ammonia by aquatic plants, ammonia is found at a very low concentration and nitrate at high concentration compared to previous studies. In addition, a decrease in ammonia was accompanied by the richness in phytoplankton **(Samiha & Soliman, 1998)**. Moreover, **Shetaia *et al*., (2020)** explained that, the distribution of ammonia in the lake water is affected by several factors such as temperature, dissolved Oxygen, decomposition of organic matter and assimilation by plant organisms. Generally, the highest value is concentrated at drains region and less near El Boughaz due to its organo-riched effluents of drains.

Nitrites and nitrates are important specific compounds to water fertility as sources of ammonia nitrogen for algae and aquatic plants; however, their level could be serious if they exceed the required limits **(El-Halag *et al*., 2013)**. Water nitrite and nitrate exceeded the maximum acceptable limits (2.9 and 0.06 mg/l respectively) of **CCME (2007)** standard. Their increased values near drains can also be due to sewage effluents, which are more fertilized with nitrogenous compounds, especially near Bersik drain which is mainly composed of agricultural wastes. It was observed that, the nitrates concentrations were higher than nitrites at all sites since nitrate is the final stable form of nitrogen and the only thermodynamically stable form of nitrogen occuring in the presence of oxygen. Nitrate and nitrite are dependent on each other when nitrite decreases, nitrate increase due to the oxidation of nitrite into nitrate **(Abdo, 2013)** and hence, nitrite is very low compared to nitrate. Continuous transformations among the different forms of nitrogen were detected by several investigators due to biological, chemical or physical agents.

Phosphorus is an important nutrient in the aquatic habitat and is one of the limiting factors controlling the growth and reproduction of phytoplankton. Increasing phosphate content at the eastern part in addition to drain discharge regions at the middle and southern part can be due to agriculture and industrial drains that may contain large amounts of phosphate **(Edwards & Withers, 2008; Manssour & Al-Mufti, 2010)**. While, the highest level near El Boughaz can be a result of the heavy sedimentation during the international road construction. In addition, the variations of water temperature, dissolved oxygen and pH play an important role in the distribution of phosphorus along the lake area **(Coldman & Horn, 1983)**.

Chlorophyll-a is the main factor and indicator for algae content and eutrophication state assessment and thereby the level of water pollution **(Zhou *et al*., 2004; Hakanson *et al*., 2007)**. The most factors related to algae density and chlorophyll-a content are phosphorus, pH, DO and nitrogen concentration **(Scholz, 2006)**. Thus, concentrations of such parameters detected can be key factors in increasing chlorophyll-a and algae content. The highest values recorded in the middle, southern and eastern regions can be due to the waste water discharge and increased organic nutrients in those regions.

2- Eutrophication state

Data in Table (4) and Fig. (3) describe the eutrophic state of Idku Lake and subsequent water quality at all investigated sites. The calculated values of E.I. varied between 0.96 and 2.86. Consequently, the average state of the lake recorded dystrophic state, where the water exhibit poor class of ecological quality according to the E.I. scale proposed by **Primpas *et al.* (2010)**. This state recorded less intensity of eutrophy at site 1 and 2 of El Boughaz region.

In addition, the spatial distribution map of eutrophication index showed that the middle, eastern, southern and El Boughaz regions of Idku Lake exhibited the highest values, while the northern and western regions exhibited less values (Fig. 3).

Table 4. Eutrophication index (E.I.) of investigated stations and its descriptive statistics

Station	(E.I.)	Status	Water quality class
Min.	0.96	Eutrophic	Poor
Max.	2.86	Dystrophic	Bad
Mean	2.08	Dystrophic	Bad
1	0.96	Eutrophic	Poor
2	1.37	Eutrophic	Poor
3	2.05	Dystrophic	Bad
4	2.61	Dystrophic	Bad
5	1.90	Dystrophic	Bad
6	2.64	Dystrophic	Bad
7	1.89	Dystrophic	Bad
8	2.86	Dystrophic	Bad
9	2.28	Dystrophic	Bad
10	2.25	Dystrophic	Bad

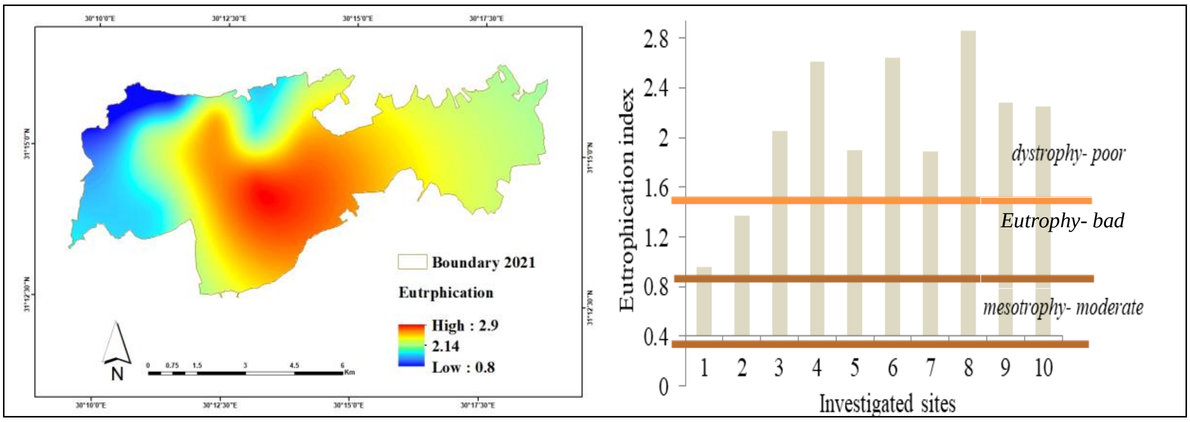


Fig. 3. Spatial distribution of Eutrophication index (E.I.) in Idku Lake

Dystrophic state of Idku Lake is in accordance with the highly trophic state of Manzala Lake recorded in the studies of **El-Amier *et al.* (2016)** and **Alprol *et al.* (2021)** and it concurs with the general state of eutrophication reported in the study of **Shetaia *et al.* (2020)**. Nevertheless, the previous studies recorded a less degree of eutrophication state ranging from eutrophic to mesotrophic. In addition, the increased distribution of eutrophication in the middle and the east of the lake may be related to the drain discharge in these regions loaded by organic content. The spatial distribution of eutrophication is associated with estimated distribution of nitrate, nitrite, phosphate, ammonia and chlorophyll-a, which are affecting eutrophication with phosphorus, the rate-limiting nutrient in the eutrophication of most freshwater ecosystems **(Mainston & Parr, 2002)**. Anthropogenic activity is the primary factor enhancing the inputs of nitrogen, phosphorus and other compounds to lakes, causing widespread eutrophication **(Sackett, 1975)**. The state severity could change through the recent years alarming ecosystem and water body degradation.

Generally, results indicate less salinity, high turbidity, richness with nitrogen and other organic compounds and bad water quality with dystrophic state nearly along the whole lake. This change of lake water can greatly affect sustainability and productivity of its ecosystem.

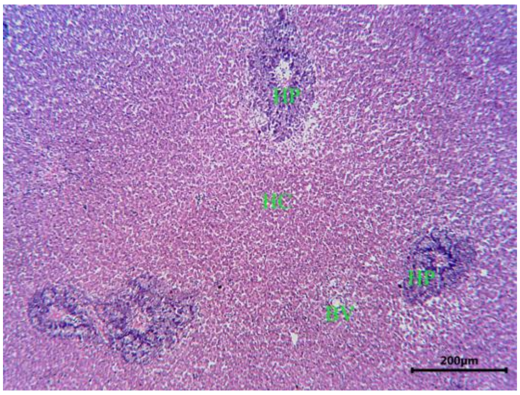
3- Histopathological changes

Results of liver histopathology showed the most alterations in liver tissues of fishes (*Oreochromis nilotica, Oreochromis aureus, Tilapia zilli, Clarias gariepinus* and *Dicentrarachus labrax*) which revealed the structural and functional alterations in respone to their environmental quality state.

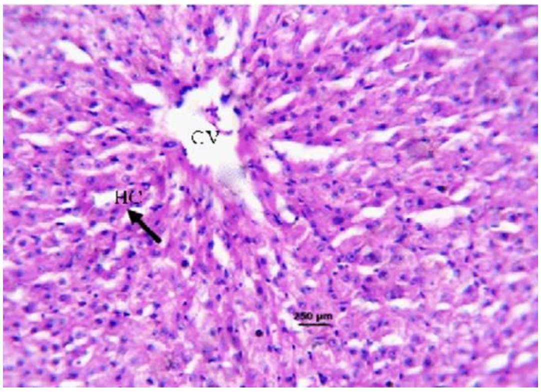
Histological changes of fish tissues serve as a biomarker of water pollution and provide information about the environmental conditions; liver tissues are more sensitive and its changes occur earlier. Sever decomposition detected in liver tissue structure and muco-polysaccharide content in all species under study is synergetic with the increased rates of water quality alteration rather than histopathological and biochemical changes confirmed by other studies **(Saeed & shaker, 2008; Saeed *et al.*, 2012; Saeed, 2013;Farouq, 2018 ;Farouq *et al.*, 2020; Haredi *et al.*, 2020)**. However, the investigated fish species are the most traditional ones in Egypt; the alterations detected could be merely a mirror image of the contamination levels in the environment **(Soliman *et al*., 2020)** that worsen the future risk without a probable effect on human health at the current level. That is because the muscle is the most edible part consumed by human with a non-carcinogenic effect on human health, based on our estimation according to hazard quotient value.

Regardless of human health risk, results indicate deterioration of fish health and their inability to remain within its environment that can greatly affect productivity, fish quality and biodiversity. In addition, liver toxicity detected indicates the effects of pollution on each biochemical parameter, which integrates with the impact of various stressors, such as microbial pathogens, toxic compounds, nutritional and adverse environmental conditions **(Marchand *et al.*, 2009)**. The high pH value detected could impact the biological and chemical reactions and controls the metal ions solubility **(Ibrahim** & **Ramzy, 2013).** Low salinity detected could affect the growth, survival, and allocation of numerous aquatic organisms **(Chand *et al.*, 2015)**. Increased nitrate levels investigated can induce oxidative stress through the generation of free radicals **(Manassaram, *et al*., 2006)**; the nitrate may react with amines of the foods in the stomach and produce nitrosamines and free radicals; such products may increase lipid peroxidation, which can be harmful to different organs including liver and kidney **(Choi *et al*., 2002)**.

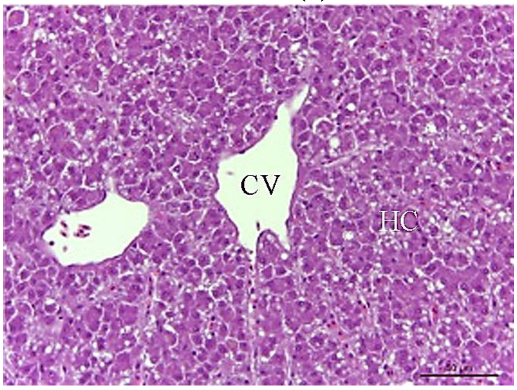
Control$_{(1)}$



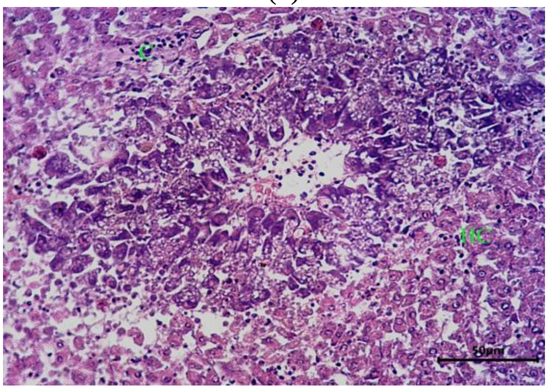
Control$_{(2)}$



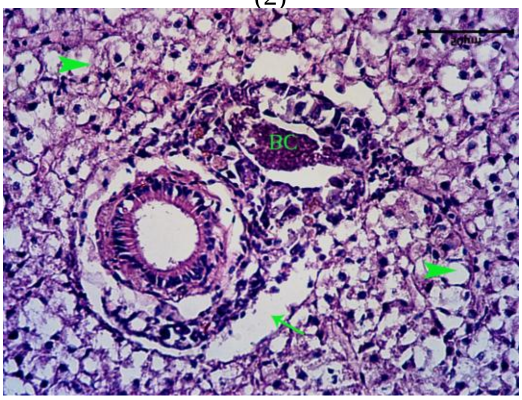
Control$_{(3)}$



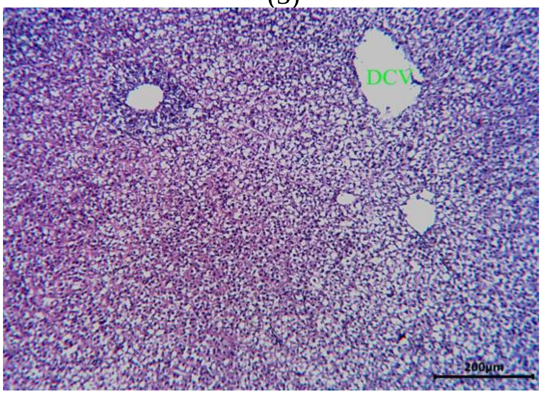
a$_{(1)}$



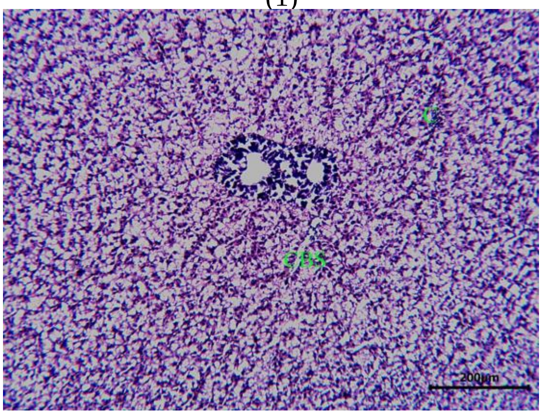
a$_{(2)}$



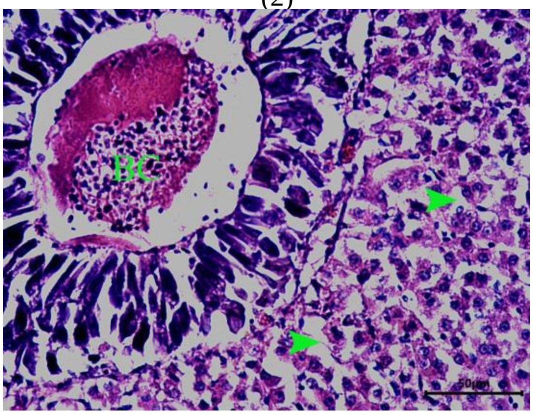
a$_{(3)}$



b$_{(1)}$



b$_{(2)}$



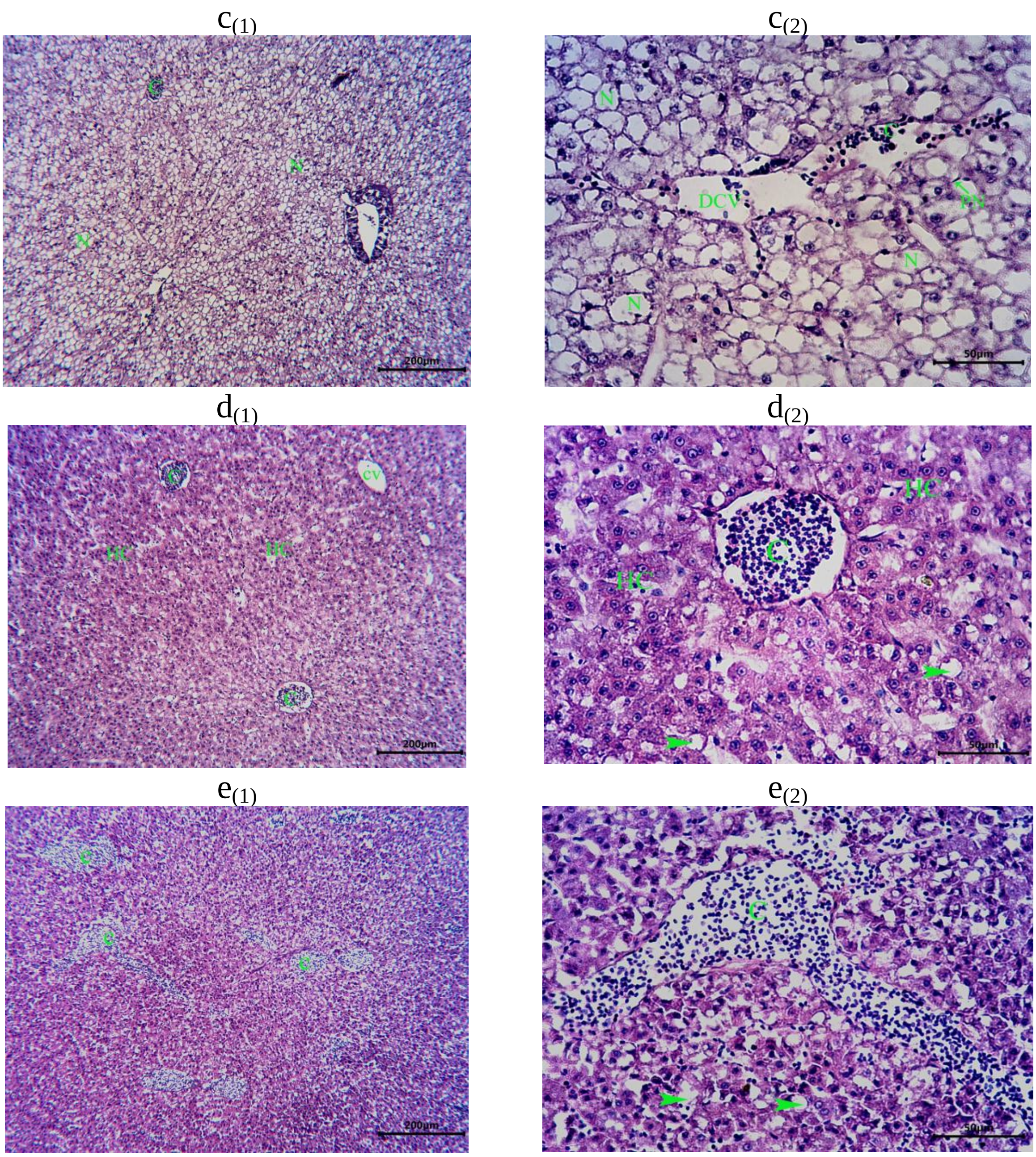


Fig. 4. Photomicrograph of liver showing **Control$_{(1)}$:** normal hepatic tissue architecture, hepatocytes (HC), hepatopancreatic ducts (HP) and blood vessels (BV) ; **Control$_{(2)}$:** normal hepatic tissue architecture; normal hepatocyte clusters (HC) and blood vessels (BV) ; **Control$_{(3)}$:** normal hepatic tissue architecture; normal hepatocytes (HC) and blood vessels (BV) ; **a$_{(1)}$:** normal hepatocytes (HC) with scattered mononuclear cell infiltration (C) ; **a$_{(2)}$:** hepatocytes cytoplasmic vacuolations (arrow heads), patchy degeneration (arrow) and congestion blood vessel (BC) ; **a$_{(3)}$:** vacuolated hepatocytes with dilated central vein (DCV) ; **b$_{(1)}$:** scattered mononuclear cell infiltration (C) and compressed blood sinusoids (CBS) ; **b$_{(2)}$:** cytoplasmic vacuolations (arrow heads) and congestion blood vessels (BC) ; **c$_{(1)}$:** hepatocytes necrosis (N) and mononuclear cell infiltration (C) ; **c$_{(2)}$:** hepatocytes necrosis (N), mononuclear cell infiltration (C) and dilated central vein (DCV) ; **d$_{(1)}$:** normal hepatic tissue architecture; hepatocytes (HC), central vein (CV) with mononuclear cell infiltration (C) ; **d$_{(2)}$:** normal hepatic tissue architecture, hepatocytes (HC), with scattered cytoplasmic vacuolations (arrow heads) and mononuclear cell infiltration (C) ; **e$_{(1)}$:** mononuclear cell infiltration (C) ; **e$_{(2)}$:** mononuclear cell infiltration (C) and moderate cytoplasmic vacuolations (arrow heads). **(H&E)**

Control$_{(1)}$: *Oreochromius and Tilapia sp*.; **Control$_{(2)}$:** *Clarias gariepinus* ; **Control$_{(3)}$:** *Dicentrarachus labrax* ; **a:** *Oreochromius niloticus* ; **b:** *Oreochromius aureus* ; **c:** *Tilapia zilli* ; **d:** *Clarias gariepinus* ; **e:** *Dicentrarachus labrax.*

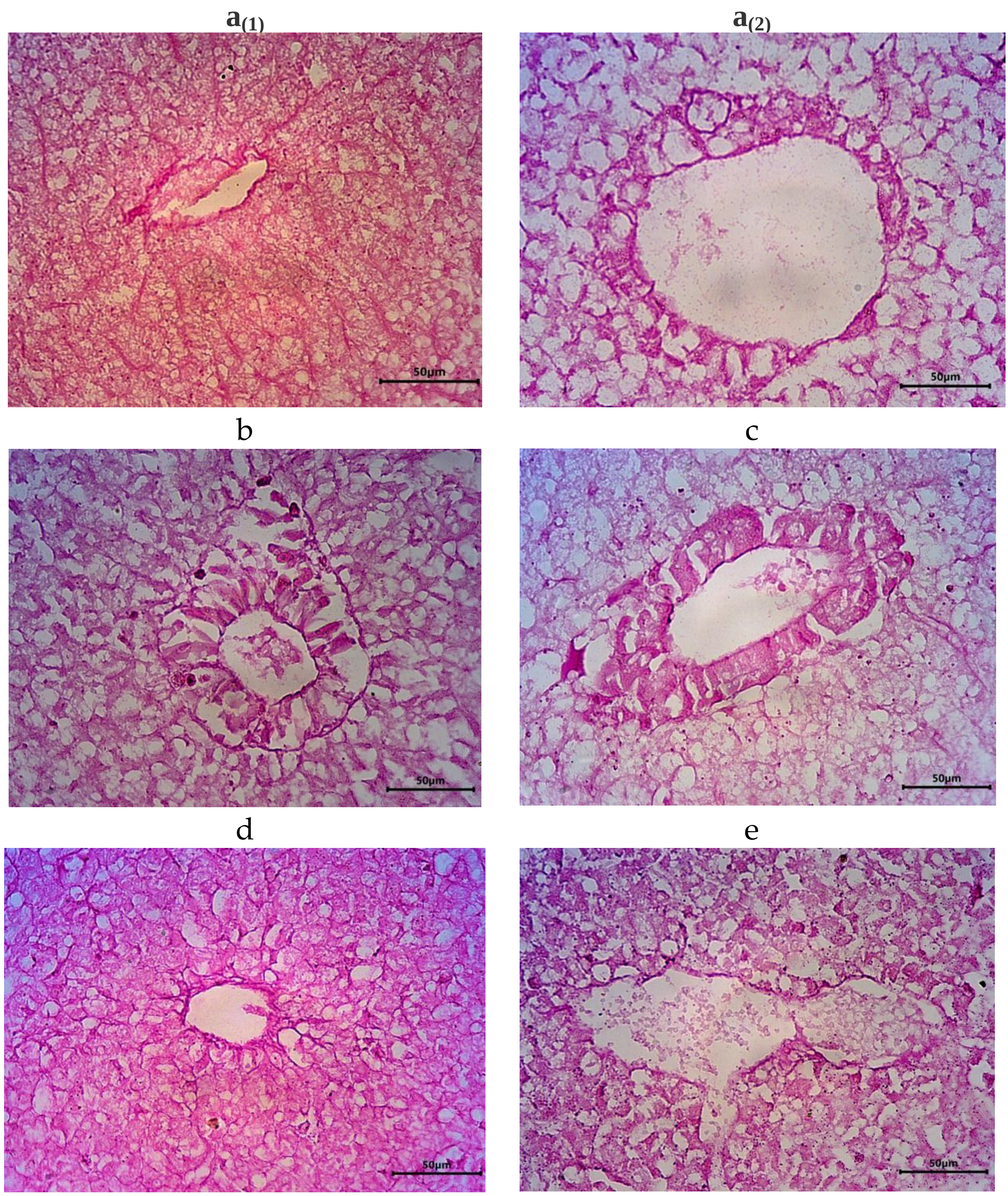


Fig. 5. Photomicrograph of liver showing **$a_{(1)}$, b:** moderate accumulation of mucopolysaccharide ; **$a_{(2)}$, c, d, e:** faint accumulation of mucopolysaccharides. **(PAS)**

a: *Oreochromius niloticus* ; **b:** *Oreochromius aureus* ; **c:** *Tilapia zilli* ; **d:** *Clarias gariepinus* ; **e:** D*icentrarachus labrax.*

CONCLUSION

Data previously reported together with the current results reveal that Idku Lake have been negatively affected by drainage water discharge and other sources of pollution rather than different other human activities. This is clearly deduced from results confirming less or more deterioration of water quality in addition to histopathologial alterations of fish liver as biomarker and indicating that water quality is a large contributor to oxidative stress that sfish could face in habitat with untreated sewage runoff.

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