

## Relation of Some Hydrochemicals with Hydrogen Sulphide Levels in Sediments of Lake Burullus, Egypt

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### Authors' contributions

*This work was carried out in collaboration between all authors. Authors FTT and AMR designed the study, wrote the protocol and first draft of the manuscript. All authors managed the literature searches and performed the statistical analysis. Author MAE made the distribution maps. All authors read and approved the final manuscript.*

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### ABSTRACT

Lake Burullus, as one of the northern deltaic lakes in Egypt, is an important economic, recreational and Fish breeding reservoir. The study used nine georeferenced stations to assess hydrogen sulphide (H<sub>2</sub>S) levels, its relationship with some selected hydrochemical parameters, and the implication on this lake's biota.

The study reveals that areas mostly affected by drainage water with high load of organic matter, aid to the production of H<sub>2</sub>S into sediments and dispersion to water. The results indicate that H<sub>2</sub>S levels

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in lake sediments increase with increasing water temperature, biological oxygen demand (BOD) and load of organic matter (OM) in water. On the other hand, clear water areas with high oxygen levels aid in reducing levels of H<sub>2</sub>S in sediments as proved from correlation analysis. The positive correlation between variables as OM and BOD with H<sub>2</sub>S was observed using the distribution maps. The amount of different wastes, particularly in large quantities, increase the level of H<sub>2</sub>S, and therefore affected biota so it is highly recommended to treat wastewater to conserve the biodiversity of this lake.

**Keywords:** Lake Burullus; pollution; hydrochemicals; hydrogen sulphide.

## 1. INTRODUCTION

The drainage water transports huge amounts of deposits to the Lakes. These deposits are distributed by currents, flows and water movements along these Lakes. They are deposited on the bottom sediments of the Lakes [1]. These sediments are being carried annually into the lake through the drained water, sea water and wind. The soil texture of lake's bottom along the northern shores is mainly clayey-sand; silty sand with some patches formed molluscan shells. The eastern and western regions of the lake are silty clay. Lake sediments along the southern shore form from clay and silt with small areas covered with molluscan shells [2].

Abdo [3] explains that the total organic matter in sediments plays an important role in the accumulation and release of pollutants in lake water, and is a source of nutrient for the living fauna in the lagoon.

Hydrogen sulphide concentration in water and sediment in aquatic system is considered good indicator of oxygen levels in the water and sediment as regards assessing the lake's water suitability for supporting biota [4]. Naturally, hydrogen sulfide occurs in the process of decomposing organic substances containing sulfur used by bacteria in anaerobic conditions [5]. Also, Berner [6] stated that surface sediments, which contain large amounts of the freshly deposited planktic organic compounds, are very important in the production of H<sub>2</sub>S by sulfate reducing bacteria.

H<sub>2</sub>S is an extremely potent metabolic poison, lethal at low concentrations (<1 ppm) to most vertebrates [7-10].

The toxicity of hydrogen sulphide for some fauna i.e. *Tilapia gallilae*; Nauplii larvae of *Artemia*

*salina* (*Ocenebra erinacea*) and *Idotea baltica* has been recorded by Tayel and Shriadah [11]. The aim of this research is to study the interrelationship between selected hydrochemical variables and H<sub>2</sub>S level in the sediments of Lake Burullus in Egypt.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Lake Burullus is located in Kafr El-Sheikh Governorate (30° 22' - 31° 35'N; 30° 33' - 31° 08'E) with an area of about 460 km<sup>2</sup>. It is situated on the eastern side of Rosetta branch of the River Nile. It occupies a central position along the Mediterranean coast of the Nile Delta. It is the second largest natural lake in Egypt after Lake Manzala [12].

Lake Burullus is connected to the Mediterranean Sea through El-Burullus outlet (Boughaz El-Burullus) which is about 250 m wide and 5 m deep. The depth of the Lake varies between 40 cm in its middle sector and near the shores and 200 cm near the outlet to the sea [13].

The lake receives 4 milliard m<sup>3</sup>/y<sup>-1</sup> of drainage water from several drains which were considered the main source of pollution in the lake [14]. Drainage water is discharged into the lake through a group of pumping stations at the end tail of the drains except Gharbia drain which discharges its water freely without pumping [15]. The estuarine water of Rosetta mouth of the River Nile is mixed with the lake water through Brinbal canal [16].

Surficial sediment samples were collected from nine stations covering Lake Burullus; (Fig. 1). The description of these locations is shown in Table 1.

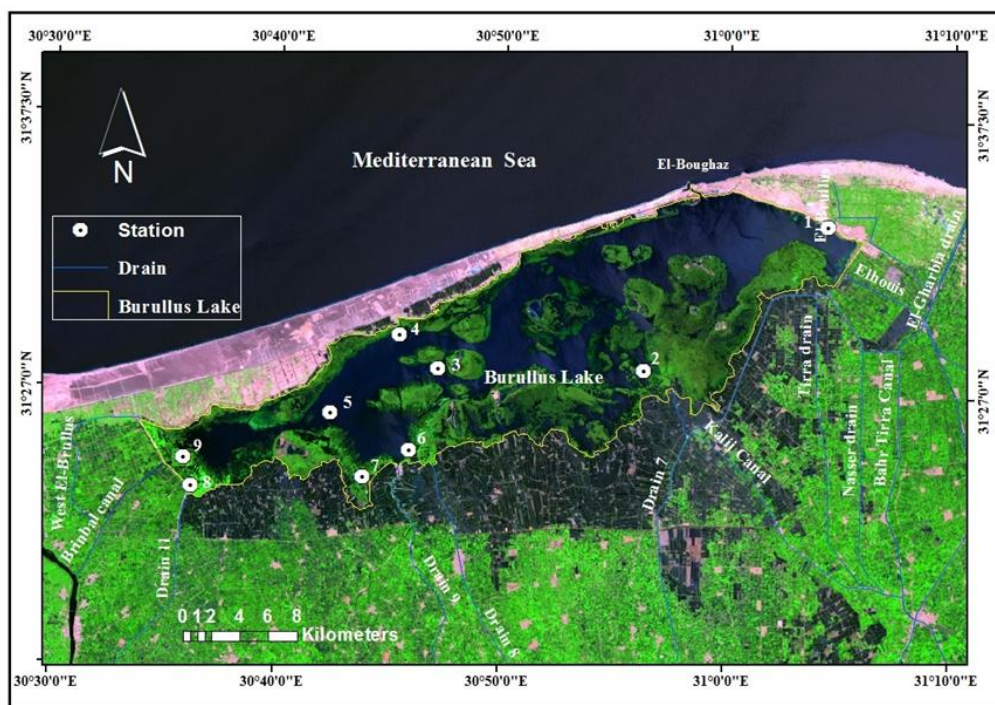


Fig. 1. Sampling stations at Lake Burullus, Egypt

Table 1. Latitudes and longitudes of the sampling stations at Lake Burullus

St. no	Station name	Latitude N	Longitude E
1	El-Burullus (east)	31° 33' 29.9"	31° 04' 25.3"
2	inf. of drain 7	31° 27' 56.1"	30° 56' 17.5"
3	El-Zankah	31° 27' 53.3"	30° 47' 10.0"
4	Mastarouh	31° 29' 09.0"	30° 45' 24.4"
5	Abo-Amer	31° 26' 07.0"	30° 42' 23.3"
6	El-Tawelah	31° 23' 43.8"	30° 43' 52.8"
7	inf. of drain 8 & 9 (Shakhlobah)	31° 24' 46.9"	30° 45' 54.9"
8	inf. of drain 11 (El-Hoksa)	31° 23' 15.5"	30° 36' 15.3"
9	inf. of Brimbah Canal	31° 24' 06.0"	30° 35' 00.4"

St= station    inf= infront

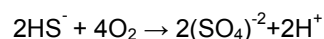
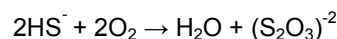
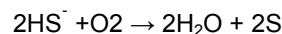
## 2.2 Analytical Methods

Nine geo-referenced water samples were collected within Lake Burullus. In the field, water temperature and dissolved oxygen (DO) were measured using DO meter (Lutron YK-22 DO meter). pH is measured using pH-meter (Model Lutron YK-2001, pH meter). EC was determined using EC-meter (Thermo, Orion 150 A+ advanced conductivity). The biological oxygen demand (BOD) determination was carried out using the conventional Winkler method [17]. Organic matter (OM) is determined by Permanganate oxidation method [18].

Hydrogen sulfide is a colorless, flammable and toxic gas smell like rotten eggs, even at low concentrations [19].

Oxidation of hydrogen sulphide in natural waters either produces or consumes hydrogen ions, depending on products and other conditions [11].

Thus



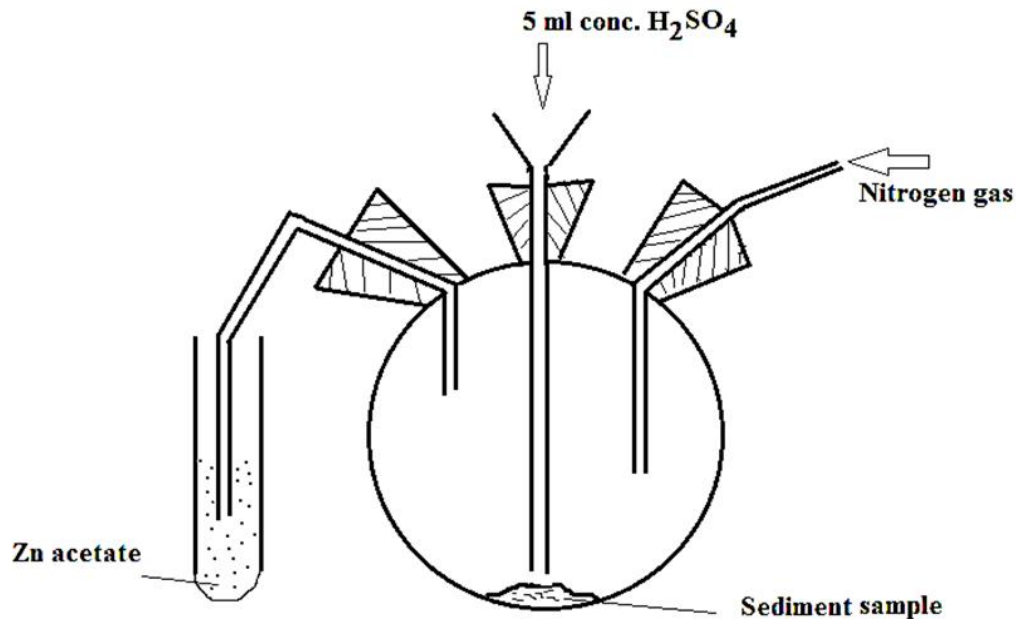


Fig. 2. The used apparatus for hydrogen sulphide estimation

In absence of biological activity, sulphide can be slowly oxidized to Sulphur which then combines with remaining sulphide to form polysulphide.

Estimation of hydrogen sulphide in sediment samples is occurred as follow: 0.1 –0.8 gm of wet acidified samples with nearly 5 ml Conc. H<sub>2</sub>SO<sub>4</sub> in closed system, (Fig. 2). The involved hydrogen sulphide gas was displaced with oxygen free nitrogen gas into zinc acetate traps. The recovery of sulphide in this manner is 99% efficient. Sulphide collected in the traps was measured calorimetrically using methylene blue method [20]. Results are expressed as mg/gm.

### 2.3 Statistical Analysis

The statistical analyses for the data were carried out to determine the correlation coefficient (r) using the formula

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where X is the concentration of H<sub>2</sub>S and Y is the corresponding concentration of variable and n is the number of data.

### 2.4 Geo-statistical Analysis

Inverse distance weight (IDW) is a deterministic interpolation procedure that estimates values

at prediction points (V) using the following equation

$$V = \frac{\sum_{i=1}^n v_i \left(\frac{1}{d_i^p}\right)}{\sum_{i=1}^n \left(1/d_i^p\right)}$$

Where d is the distance between prediction and measurement points, V<sub>i</sub> is the measured parameter value, and p is a power parameter [21]. The main factor affecting the accuracy of inverse distance interpolator is the value of the power parameter p, as well the size of the neighborhood and the number of neighbors are also relevant to the results accuracy [22].

## 3. RESULTS AND DISCUSSION

Results of hydrogen sulphide concentrations in sediments as well as concentrations of some related parameters in the water as organic matter, dissolved oxygen, biological oxygen demand and hydrogen ion concentration were shown in Table 2. Also, the spatial distribution maps of depth, pH, EC, BOD, DO, OM and H<sub>2</sub>S within water and sediments of Lake Burullus are as shown in Fig. 3 (A-G).

H<sub>2</sub>S concentration in sediments ranged between 4.3 at Abu-Amer and 7.7 at El-Tawelah and Brinbal canal with a mean value of 6.72 mg/g.

The highest value was recorded at Brinbal, and may attributed to the nature of sediment characteristics of clay and high content of organic matter that aid in the release of H<sub>2</sub>S in sediments. Radwan and Lotfy [23] estimated that sediments of Lake Burullus have a complex nature. More specifically, the sediments change from coarse particles-sand, usually abundant in the northern coast and at the coast of islets, whereas it's muddy in the southern parts of lakes.

Organic matter also takes the same distribution of H<sub>2</sub>S as its high percent content was found at Brinbal canal may attributed to agricultural wastes from different agricultural areas. High discharge of drained water in the southern part of the lake led to the consumption of DO due to oxidation of such OM. This is agreed with observations of El-Ghobashy [24] in Lake Manzala.

In Lake Burullus, the highest concentrations of organic matter and organic carbon were distributed at the western, southern and eastern parts of the lake; this agrees with Masoud [25] and El-Alfy [26].

The southern parts are described as having clayey sediments or fine particles which contain high amount of organic carbon not as sandy soils which are very poor with organic matters at the northern parts of the lakes [27].

The site at Brinbal canal is distinguished by high density of vegetation especially hydrophytes i.e. *Eichhornia crassipes* and other vegetative plants. So it's an important reason for high concentration of organic matter (OM) in these areas may due to sinking and decaying of dead aquatic plants on the bottom sediments [28]. These results are in agreement with Moussa et al. [29] and Khalil et al. [30] for Lake Edku where the content of OM in sediment was controlled by the amount of clay and silt in addition to the plant detritus from nearby vegetative areas.

Electrical conductivity (EC) fluctuated between 3.9 at Brinbal canal (source of fresh water from Rosetta Branch /River Nile) to 30.9 ms/cm at the eastern part of El-Burullus (nearby El-Boughaz area), may attributed to the sea water intrusion.

Hydrogen sulphide was produced in the anoxic part of the sediment, with reduction of sulphate. It's noticeable that, the reduction of sulphate in

sediments reaches a percent of nearly 13% of total organic matter in acidic conditions and to 50% in marine sediment [31]

pH is very significant parameter in the metabolic and physiological processes that is important in growth of aquatic organisms [32]. Values of pH changed within different sites. It was acidic especially in the outlets of drains, as a result of nutrients release like ammonia that responsible for acidification and decreasing of pH. This is in agreement with Koerkamp et al. [33] and Ibrahim et al. [34]. Also Abbas et al. [35] and Sayed [36] stated that low pH values are attributed to liberation of H<sub>2</sub>S during the decompositions of OM. The highest value of pH was recorded in site 5, may attributed to high density of hydrophytes where the increase of pH value is accompanied by a flourishing photosynthesizing organisms [37].

The excess of OM produced during photosynthesis process in the euphotic zone eventually sinks down through the water to the sediments where respiration processes dominate. The depth of the Lake does not exceed 1.5 meter, thus, a significant difference often exists between the oxygen rich euphotic zone and underlying oxygen-poor aphotic zone. The presence or absence of oxygen has significant effect on the oxidation-reduction chemistry, also attributed to the anaerobic bacteria where the biological oxygen demand is an empirical test used to determine the relative oxygen requirements needed for the biochemical decomposition and oxidation of OM and inorganic material. The highest concentrations of BOD were recorded in stations close to the point of discharges as pronounced at station 7 (drains 8&9), where huge amount of OM originated from drains led to more consumption to DO by the bacterial activities which leads to oxygen depletion and rise in H<sub>2</sub>S level in the sediment.

Sedimentary production of hydrogen sulphide can increase the oxygen demand rate of sediment leading to dissolved oxygen reduction in the overlying water. Utilizing combined oxygen in sulphate purification process that resulted from OM decomposition to hydrogen sulphide as an end product [38]. It's clear that the whole water body of the lake is well oxygenated during the time of sampling with a minimum value of 5.1 mg L<sup>-1</sup> at station 7 (in front of drain 8,9) to a maximum value of 10.6 mg L<sup>-1</sup> at station 5 in the middle sector.

**Table 2. Concentrations of Hydrogen sulphide (mg/g) in sediment and selected hydrochemicals in water of Lake Burullus**

Station	H <sub>2</sub> S mg/gm	OM %	DO mg/l	BOD mg/l	pH	T°C	EC ms/cm	Depth cm
1	6.9	1.8	8.5	3.8	8.67	22.7	30.8	70
2	7.2	3.1	5.8	6.5	8.78	23.0	9.11	60
3	7.2	2.4	9.1	5.7	8.55	23.0	10.1	90
4	6.8	2.9	8.1	11.4	8.78	22.8	9.29	110
5	4.3	1.6	10.6	7.3	8.83	22.1	9	120
6	7.7	3.6	5.9	13.5	8.0	25.0	8.61	100
7	6.8	2.9	5.1	18.3	7.86	24.0	4.52	70
8	5.9	2.1	7.4	10.6	6.88	25.0	4.1	80
9	7.7	4.4	6.0	21.4	6.37	25.7	3.9	90
σn	1.00	0.84	1.73	5.60	0.85	1.19	7.74	18.72
σn.1	1.06	0.89	1.83	5.94	0.90	1.27	8.21	19.61
X	6.72	2.75	7.38	10.94	8.08	23.70	9.94	87.77

H<sub>2</sub>S: hydrogen sulphide; OM: organic matter; DO: dissolved oxygen; BOD: biological oxygen demand; pH: hydrogen ion concentration; T°C: temperature and EC: electrical conductivity

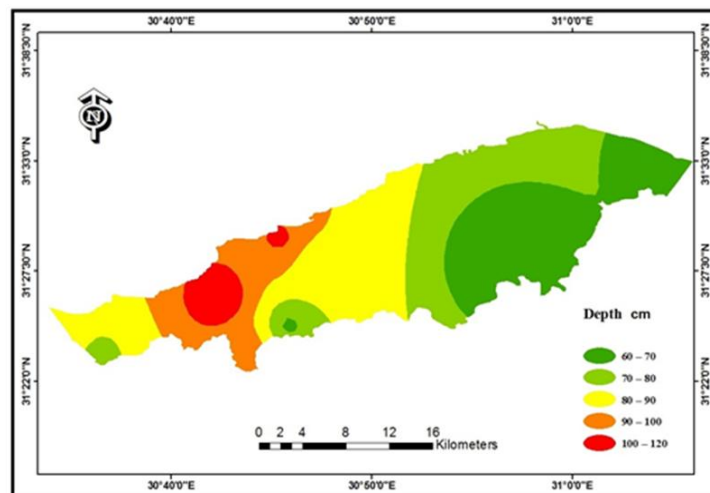
**Table 3. Pearson moment correlation matrix between some hydrochemical parameters and H<sub>2</sub>S in sediments**

Variables	H <sub>2</sub> S	OM	DO	BOD	pH	T°C
H <sub>2</sub> S	1					
OM	0.743*	1				
DO	-0.675*	-0.741*	1			
BOD	0.329	0.756*	-0.648	1		
pH	-0.246	-0.524	0.471	-0.734*	1	
T°C	0.48	.692*	-0.666	0.754*	-0.917**	1

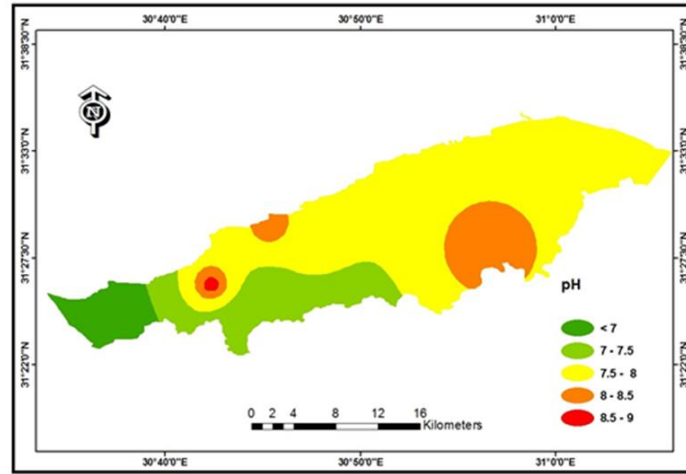
\*. Correlation is significant at the 0.05 level (2-tailed).

\*\* Correlation is significant at the 0.01 level (2-tailed).

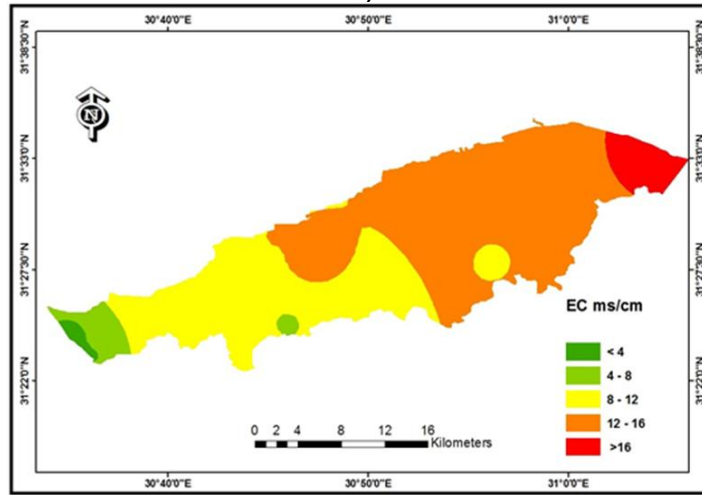
H<sub>2</sub>S: hydrogen sulphide; OM: organic matter; DO: dissolved oxygen; BOD: biological oxygen demand; pH: hydrogen ion concentration and T°C: temperature



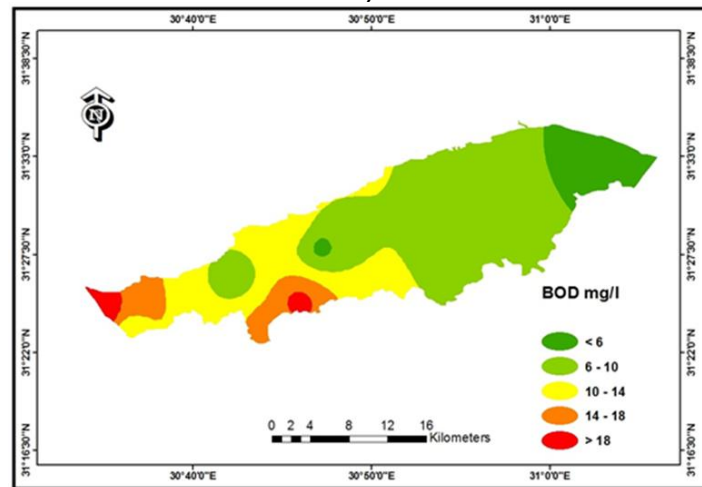
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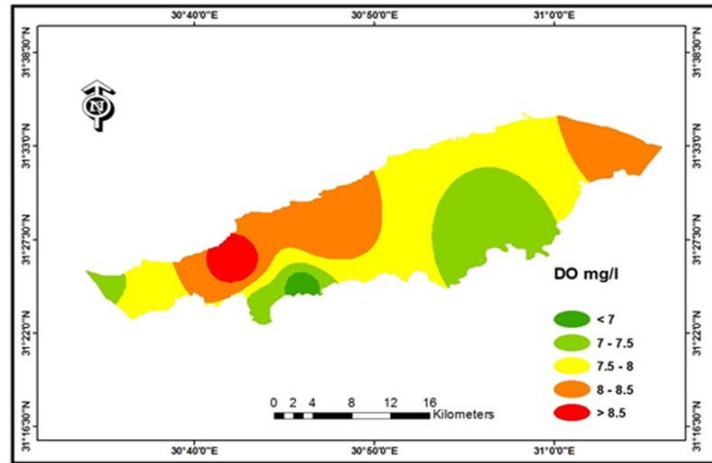
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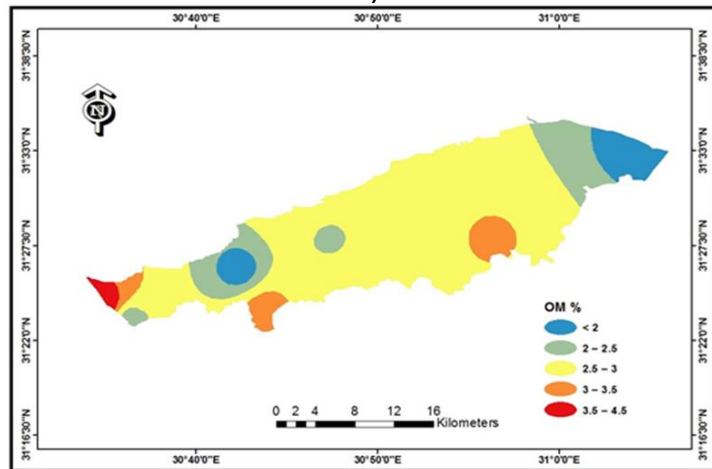
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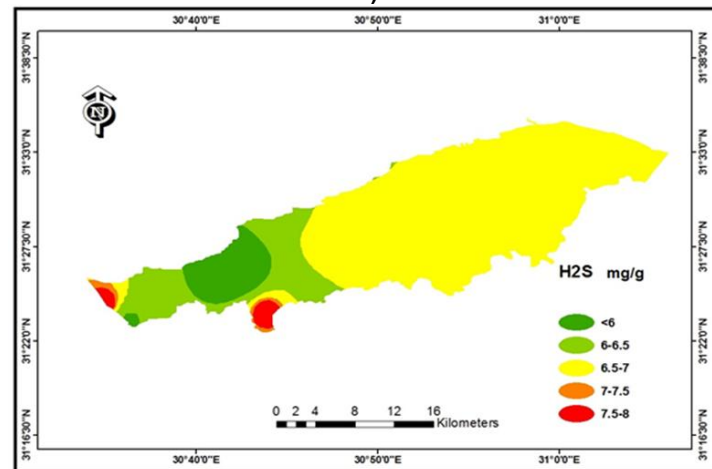
D)



E)



F)



G)

Fig. 3. (A-G) Spatial distribution of depth, pH, EC, BOD, DO, OM and H<sub>2</sub>S within water and sediments of Lake Burullus



From the statistical analysis (Table 3), it is obvious that high inversely significant proportion was observed between hydrogen sulphide and dissolved oxygen ( $r = -0.67$ ). Meanwhile, there was a positive significant correlation with organic matter ( $r = 0.74$ ). On the other hand, the relation was insignificant between hydrogen sulphide, BOD ( $r = 0.32$ ), pH ( $-0.24$ ) and with water temperature ( $r = 0.47$ ). The distribution maps of depth, pH, EC, BOD, DO, OM and H<sub>2</sub>S within water and sediment of Lake Burullus as shown in figure (3) proved the relation between the presences of different parameters within the H<sub>2</sub>S, which highly attributed to drainage waters from different drains. El-Amier et al. [39] and El-Alfy et al. [40] used geostatistical and deterministic methods for creating spatial distribution maps of different pollutants in Lake Burullus.

#### 4. CONCLUSION

It's concluded that drainage water areas recorded high levels of H<sub>2</sub>S. There are positive relations between drained water containing low concentrations of DO, high concentration of BOD and high levels of OM in sediments with the levels of H<sub>2</sub>S. Areas with acidic nature consider an indication for high levels of H<sub>2</sub>S in lake sediments. So it's highly recommended to reduce organic load to the lake by using different methods of remediation to reduce H<sub>2</sub>S levels in sediments for protection of the aquatic life. Also removal of invasive aquatic plants from Lake Burullus' water could aid to solve these problems.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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