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Study of the physico-chemical conditions and evaluation of the changes in eutrophication-related problems in El- Mex Bay

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El- Mex Bay is a relatively large coastal embayment west of Alexandria. The bay is an important fishery ground as well as recreation area. It includes both the Western Harbor and Dekhaila Harbor. It is one of heavily polluted areas on the Egyptian Mediterranean coast, receiving huge amount of agricultural, industrial, and sewage wastes from the adjacent Lake Mariut through El- Umoum Drain. According to different estimations in literatures the volume of the wastewaters varied between 7 × 10^6 and 8 × 10^6 $m^3 day^{-1}$, which is supposed to increase with the growing population density of Alexandria city. These conditions cause pronounced eutrophication and drastic changes. Eutrophication-related problems in El- Mex Bay of Alexandria were studied seasonally from autumn 2011 to autumn 2012. Geographical information system (GIS) and remote sensing techniques were used together with the ground-based surveys to assess the vulnerability of the most important physical and eutrophication parameters along El- Mex Bay coast. As a result of increasing population and industrial development, poorly untreated industrial waste, domestic sewage, shipping industry and agricultural runoff are being released to the bay. With the rapid increase in the industries and population, changes in water quality would have potential consequences for the large rapidly growing population of the Alexandria region. Recommendations for environmental recovery and restoration are proposed for preservation of El- Mex Bay and harbors in order to facilitate development of environmental and tourist activities.

Key words: El- Mex Bay, recreation area, El- Umoum drain, geographical information system (GIS, remote sensing, eutrophication, and restoration.

INTRODUCTION

The Egyptian Mediterranean coast receives huge volumes of wastewaters every year through the coastal lagoons and from other land-based effluents. These wastes are loaded by variable amounts and types of pollutants, in addition to great amount of nitrogenous and phosphorous compounds, which in turn cause high level of eutrophication along a significant part of the Mediterranean coast, particularly of both the Nile Delta region and Alexandria coast.

Eutrophication is an important problem to the Egyptian

Mediterranean coast, resulting in fundamental changes in the structure of the planktonic and benthic communities as well as fish mortality. Eutrophication was accompanied by the appearance of several harmful algal species at several hot spots along the coast. The level of eutrophic-cation demonstrated wide variation along the Egyptian coast relative to the variations in the volume and contents of discharged wastes. High nutrient levels and chlorophyll concentration are indication of Alexandria sea coast, like Mex Bay, Western Harbor, Abu Qir Bay, and others (Dorgham, 2011).

Eutrophication has become a persistent problem in El-Mex Bay of Alexandria and was recorded for the first time in 1985 (Dorgham, 2011). These problems came about as a result of the continuous enrichment of nutrients from different sources, including maritime activities, several land-based effluents consisting of mixed industrial, domestic and agricultural wastes as well as stored chemical fertilizers. Nutrient loads are directly dependent on human activities, which in turn depend on the growth of the world's human population. Consequently, human-induced eutrophication is in a way related to the increase in human population (De Jonge et al., 2002). In Alexandria City, the human population has just about doubled since the first record of eutrophication in El- Mex Bay in 1985 (Dorgham, 2011). This population increase has been associated with the intensive development of human activities, which directly or indirectly have led to the increase in nutrient enrichment in the bay and the consequent increase in the level of eutrophication during the past two decades.

Numerous studies have been conducted on the physical, chemical and biological characteristics of El-Mex Bay (Abuldahab et al., 1990; Soliman and Gharib, 1998; Gharib, 1998; El- Sherif, 2006; Dorgham et al., 2004; Hussein and Gharib, 2012; Hendy, 2013) and showed that, the continuous discharge of polluted water into the bay caused massive development of algal blooms and a gradual deterioration of water quality created (Zakaria et al., 2007; Mahmoud et al., 2009) identified four types of water in El-Mex Bay based on the salinity values: the mixed land drainage (L) of salinity < 10 ppt, mixed water (M) of salinity range 10 to 30 ppt, diluted sea water (D) of salinity range 30 to 38.5 ppt and Mediterranean Sea water (S) of salinity > 38.5. Youssef (2001) recorded the maximum average ratios of specific alkalinity at regions affected by the drainage water (El- Rayis, 1984; Abuldahab et al., 1986) and studied the levels of heavy metals in El-Mex Bay ecosystem including marine organisms of different trophic levels (Tayel and Shiradah, 1996; Halim et al., 1986) and also concentrations of heavy metals in fish tissues were studied. The majority of these studies were based on seasonal or bimonthly sampling. However, the rapid changes in water quality and biotic components require frequent follow-up at shorter time intervals. In the present work, the aim was to study the physico-chemical conditions and evaluate the changes in eutrophication-related problems in El- Mex Bay. Recommendations are presented to facilitate imple-mentation of a coastal zone management program.

MATERIALS AND METHODS

Study area

El- Mex Bay is relatively large coastal embayment west of Alexandria, at longitude 29° 45′ and 29° 54′ E and latitude 31° 07′ and 31° 15′ N, from Agami headland (west) to the Western Harbor (east), with an average depth of about 10 m and surface area of about 19.4 km^2 (El- Sherif, 2006). The bay is an important fishery ground as well as recreation area. It includes both the Western and Dekhaila harbors. The bay is one of the heavily polluted areas on the Egyptian Mediterranean coast, receiving huge amount of agricultural, industrial, and sewage wastes from the adjacent Lake Mariut through El- Umoum drain. Accordingly to different estima-tions in literatures the volume of the wastewaters varied between 7×10^6 and 8×10^6 m^3 day^{-1} (Dorgham, 2011), which is supposed to increase with the growing population density of Alexandria city. In addition to El- Umoum Drain discharge, industrial wastes from several industries in the surrounding area, like chemical, chloro-alkali, tanneries, cement, and petroleum, are also discharged to the bay. These conditions cause pronounced eutrophication and drastic environmental changes.

Sampling design

Samples were collected seasonally during a year (from autumn 2011 to autumn 2012) at the selected stations. The stations were selected to cover all possible climatic and environmental charac-teristics of the different parts of the study area. Eight stations were chosen in the El- Mex Bay for the present study, the locations of the sampling stations are shown in Figure 1.

The samples for hydrographic measurements and nutrient analysis were collected. The water temperature was measured with an ordinary thermometer graduated to 0.1ºC, the limit of visibility of water was measured by using a white enameled Secchi disc, the salinity measured by using Salinometer and the measurements were done by electrode (range 0-199.9 µm, 2-19.99 ms) model (Oyster, inspected 82738, Extech instruments, Germany). The pH values by using a pocket digital pH meter, and nutrients (phosphate, nitrate, nitrite, ammonia and silicate) were determined according to the methods mentioned in Grasshoff (1976). Chlorophyll *a* and dissolved oxygen content in the water was carried out according to Strickland and Parsons (1972).

The remotely sensed satellite imagery (LAND SAT 3) was found to be the most appropriate one for this study, as with its regional

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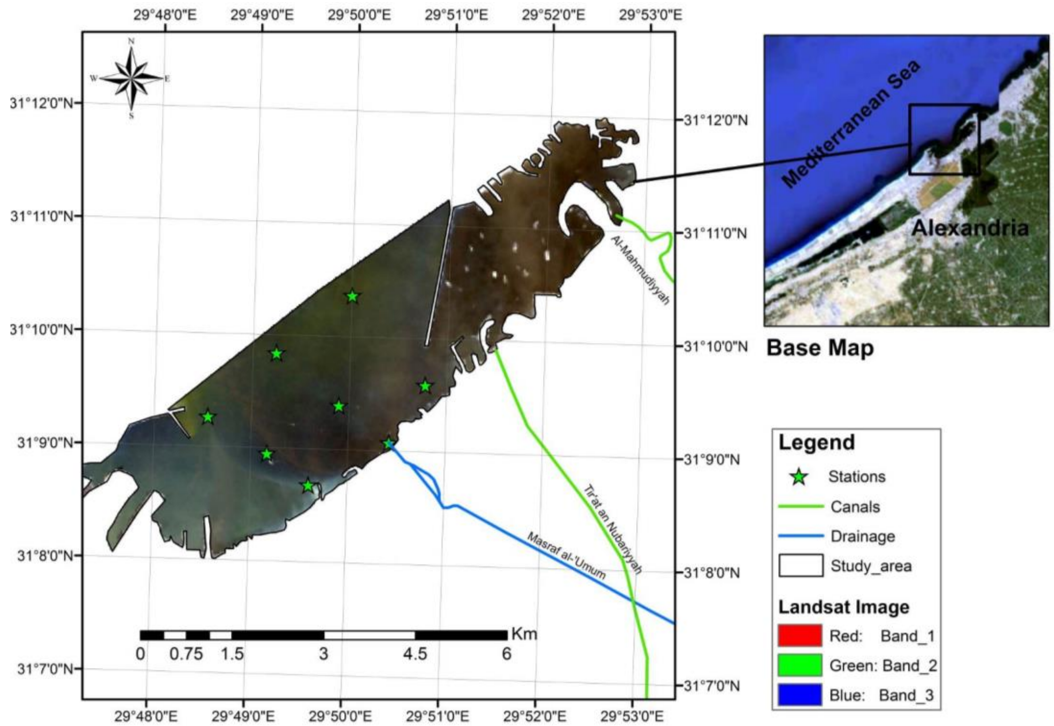

Figure 1. Base map showing the study sites.

coverage, all necessary map features were obviously clear and interpreted. A raster depending software was used for the purpose of digitizing the map features. ARC-GIS 10 and Envi software was used for this purpose for its high digitization capabilities, also in finalizing and visualizing data. The analysis and interpretation of physico-chemical parameters were done by ARC-GIS 10.

RESULTS

The hydrographic conditions and the eutrophication parameters varied widely during the study period. However, the water temperature did not deviate from the seasonal fluctuations normal on Egypt's Mediterranean coast (15-34°C) (El- Sherif, 2006). Although the bay is a shallow basin subject to vigorous mixing during much of the year, the largest value was reported in summer 2012 (32 °C) and the smallest one in winter 2012 (14.2°C) as shown in Figure 2.

Salinity is considered as a sensitive parameter for measuring the rate of dilution of seawater caused by land-based sources discharge and subsequently it reflects the degree of contamination in aquatic environment. Water salinity at El- Mex Bay showed wide variations from a minimum of 6.20 ‰ in front of El- Umoum Drain during winter 2012 to a maximum of 33.50 ‰ during autumn 2012 inside the sea (Figure 3), which directly reflects the changes in the volume and dispersion of the discharged wastewater through El-Umoum drain. This observation agrees with those found by several authors at the same area (Mahmoud et al., 2009). The seasonal values of salinity at El- Mex Bay water reflects the mixing of the bay water with fresh water. The salinity of the drain water, on the other hand, did not exceed 7‰. Generally the water salinity in the recent period decreased which insure the effects of land drainage.

The transparency of the bay water was relatively low for almost the whole year, with Secchi disc readings varying from 0.4 to 0.6 m. The water was more turbid (0.3- 0.4 m) in summer and autumn 2012, but relatively clear (1- 3 m) during winter and spring 2012 (Figure 4).

The pH values of water samples varied over rather a wider range (4.51- 8.01) with negligible differences between stations so, it was considered to range between slight alkaline and acidic (Figure 5).

Dissolved oxygen is considered as one of the most important and useful parameters in identification of different water masses and in assessing the degree of pollution especially with organic pollutants which affects fish and other marine life through oxygen reduction or depletion. The distribution pattern of DO at El- Mex Bay showed a wide variation and fluctuated between 2.52 to9.11 mg/L (Figure 6). The maximum value of DO recorded at station I during autumn 2012 can be attributed to lower water temperature (16.0°C) as well as agitation of water by strong winds (Nessim, 1994; Hendy, 2013). Drain water is characterized by relative lower

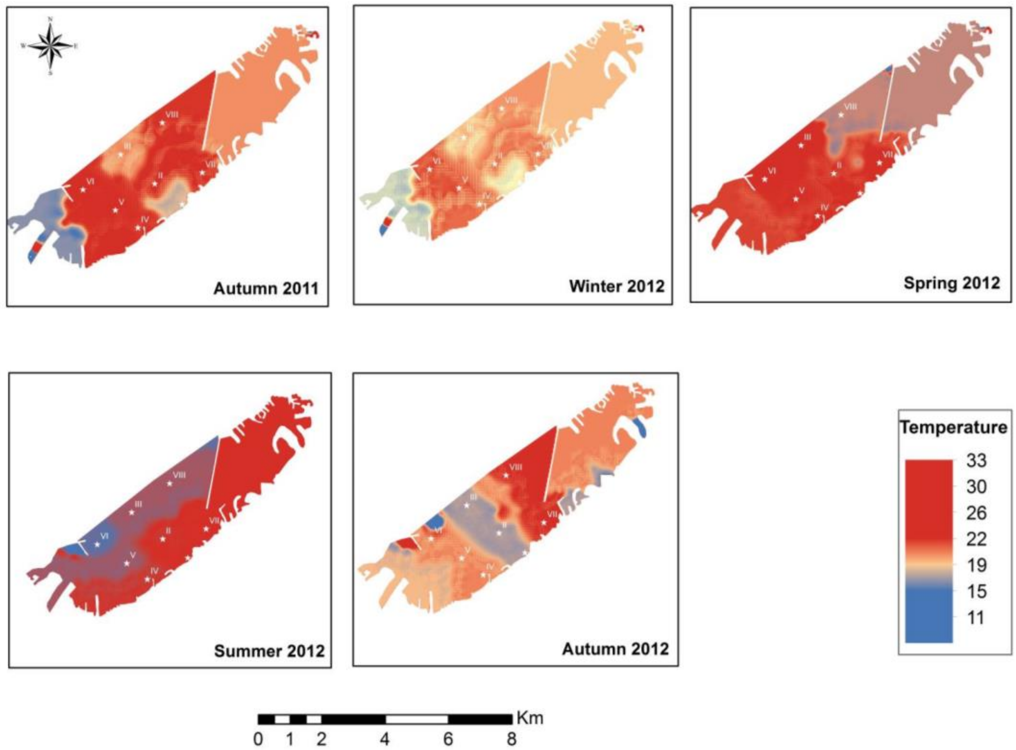

Figure 2. Variations of water temperature (˚C) at different stations during study period.

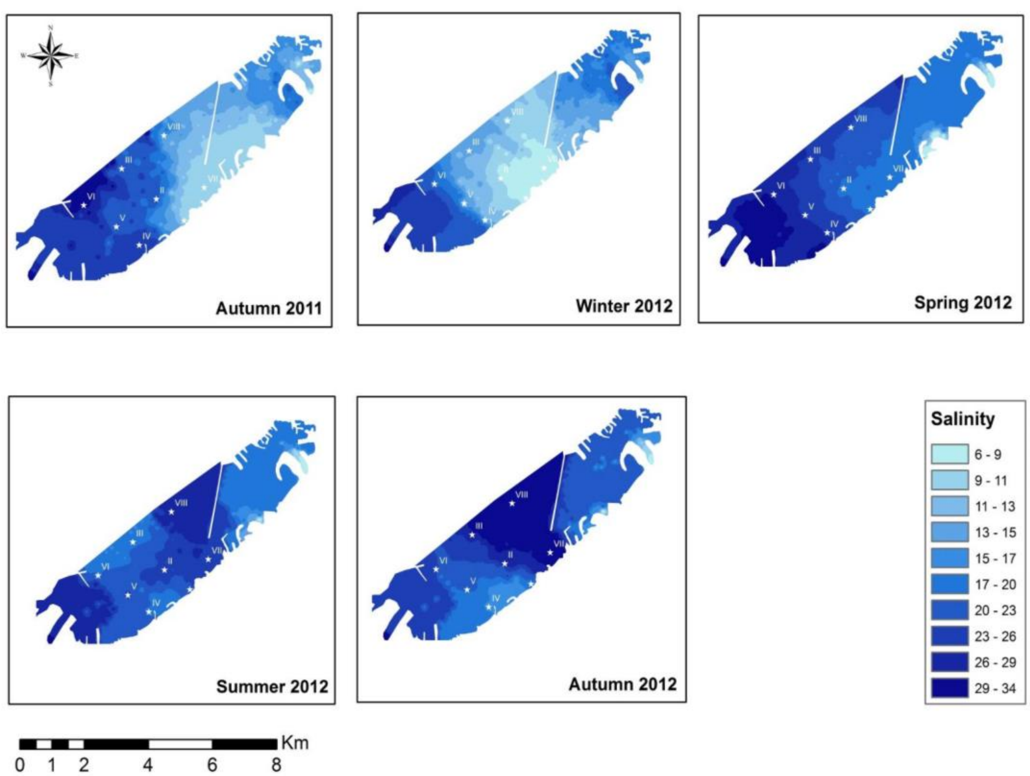

Figure 3. The seasonal distribution of salinity (‰) during study period at El- Mex Bay.

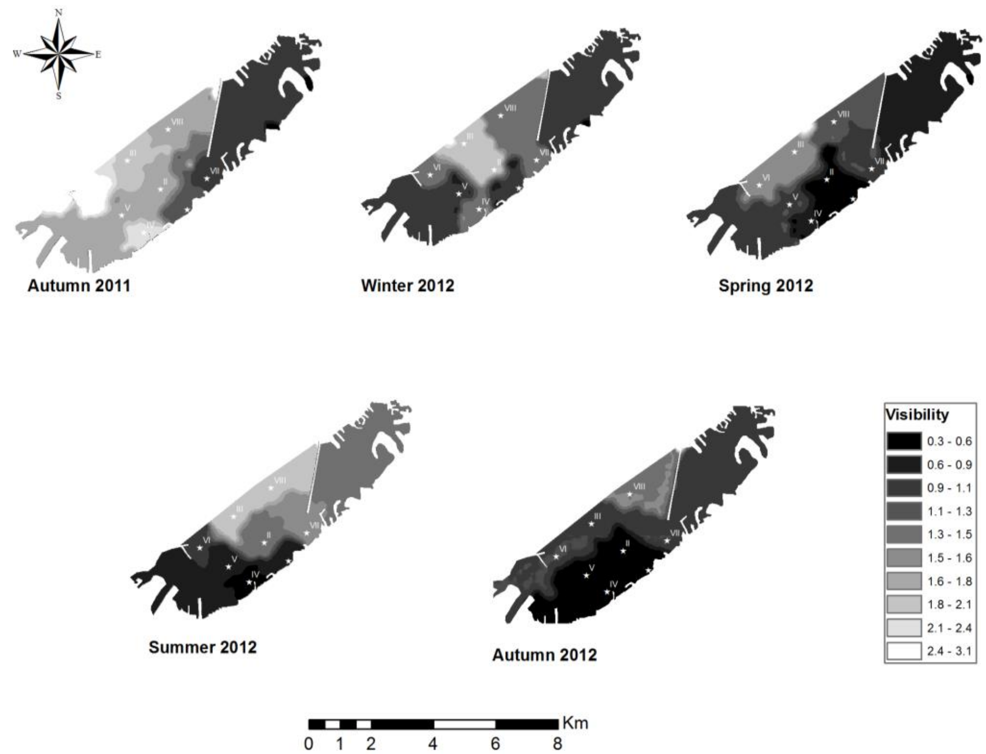

Figure 4. The seasonal distribution of transparency (m) during study period at El- Mex Bay.

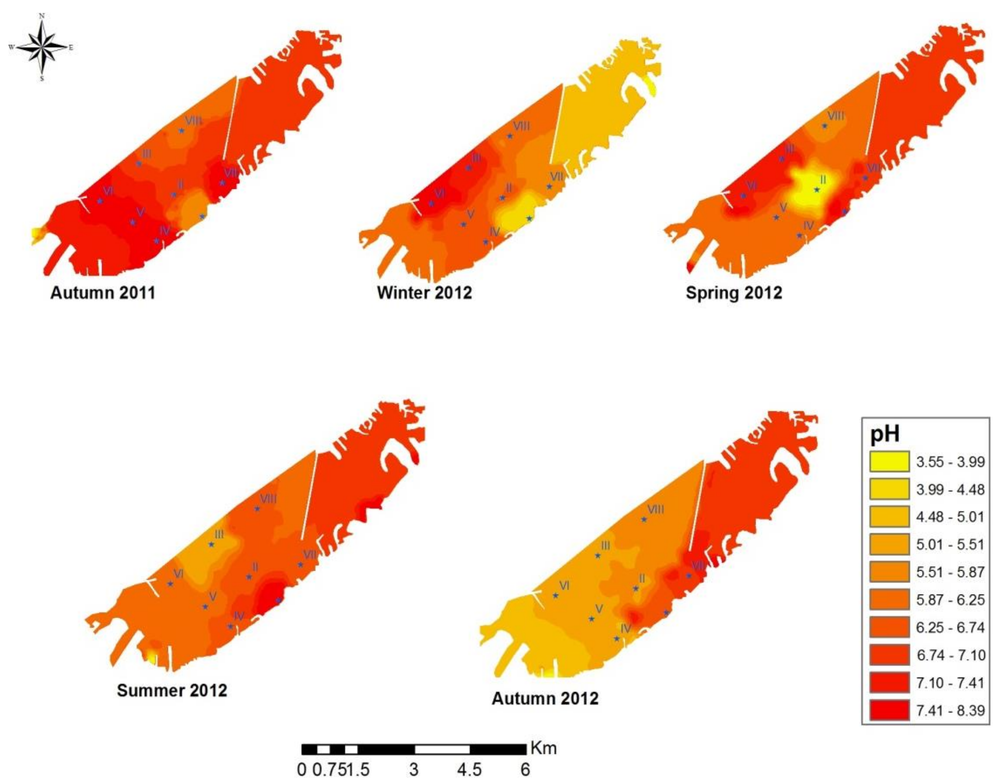

Figure 5. The seasonal distribution of pH during study period at El- Mex Bay.

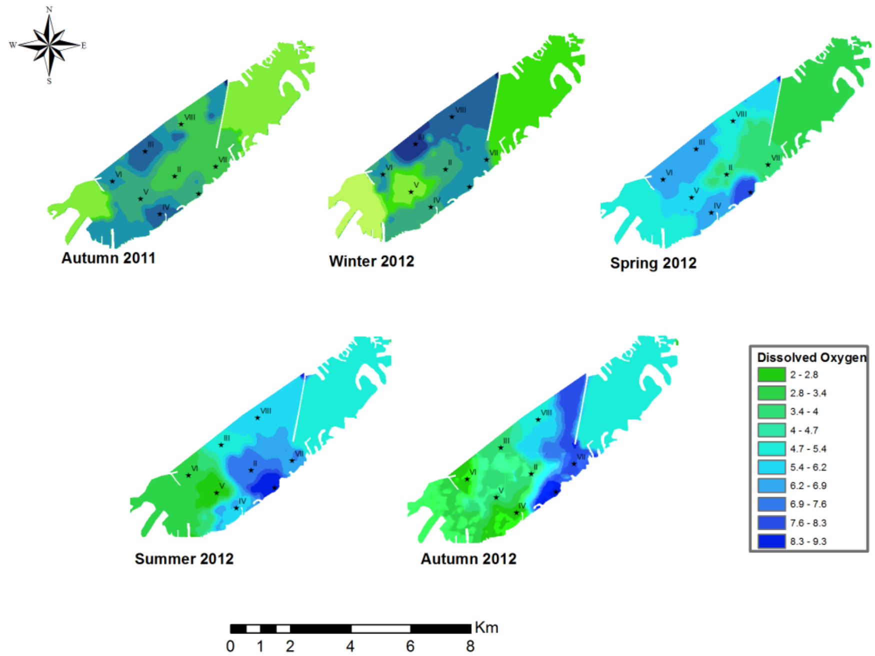

Figure 6. The seasonal distribution of DO (mg/l) during study period at El- Mex Bay.

oxygen content (5.8 mg/L), and complete depletion of oxygen was not observed among all samples but the values were found in under saturated conditions. The data showed sharp decrease in oxygen content of El-Mex Bay water during the study period that revealed the undesirable conditions.

The continuous nutrient enrichment resulting from the discharged wastes and other human activities raised the fertility in El- Mex Bay to a high level. However, the concentrations of nutrient salts displayed different ranges of variations relative to those occurring in the supplying sources.

Nitrite that appears in water results mainly from bio-chemical oxidation of ammonia (nitrification) or the reduction of nitrate (denitrification). During the period of study, station I during spring 2012 and autumn 2012 recoded higher contents of nitrite than those recorded in sea water (14.57 and 15.17 µg/l respectively), consequently, the discharged of El- Umoum drain water affected directly the in front area. The seasonal distribution of nitrite content was represented graphically in Figure 7. Due to the mixing of drainage water with seawater at El- Mex Bay, the values of NO_2 dropped to less than 0.23 µg/l during winter and spring 2012.

Nitrate is the most stable form of inorganic nitrogen in oxygenated water. It is the end product of nitrification process in natural water. Figure 8 illustrates that El-Umoum drain (station I) attained higher value of nitrate than most of the studied stations during survey with value of 20.09 µg/l, which means that El- Umoum drain possesses twice as much nitrate content as that of surrounding area. Several factors may affect the distribution of nitrate content in the investigated area, such as, the drainage water (the main factor), decom-position of organic matter, regeneration from suspended matter and bottom sediment as well as phytoplankton assimilation. The minimum values of NO_3 were observed during winter and spring 2012 (0.21 µg/l to 0.11 µg/l, respectively).

The environmental significance of phosphorus arises out of its role as a major nutrient for both plants and micro-organisms (Vanloon and Duffy, 2000). The mean concentration had a higher range and fluctuated between 0.84 (Okbah et al., 1999) and 3.34 µM (Said et al., 1991). Stations I and II (El-Umoum drain) attained higher values of reactive phosphate than all stations during the period of study with values 9.09 and 10.14 µg/l respectively (Figure 9).

The continuous discharging of polluted water into El-Mex Bay caused massive development of algal blooms and a gradual deterioration of water quality was created (Hussein and Gharib, 2012).

The land-runoff discharges from human settlements, certain industries and agricultural activities are largely the cause of man-made eutrophication in the Egyptian Mediterranean coastal waters of Alexandria. Controlled fertilization, mainly by nitrogen and phosphorous of infertile marine systems increases primary production, which can have consequence for fishery yield. Conversely, uncontrolled eutrophication of productive systems can lead to undesirable consequences (Hussein and

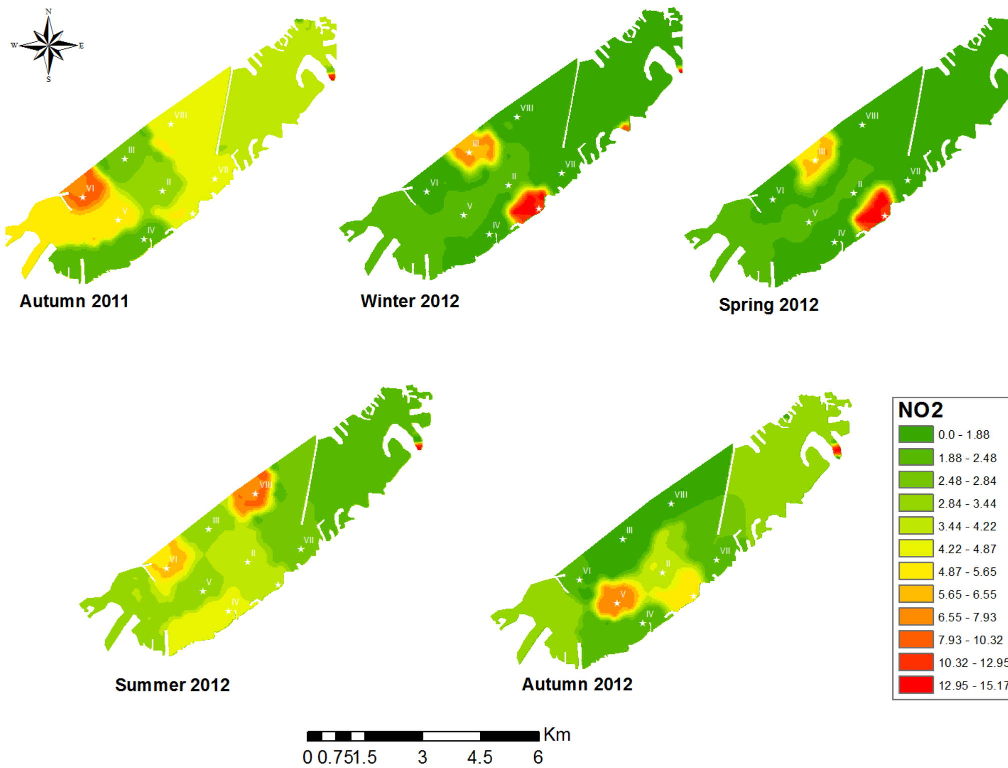

Figure 7. The seasonal distribution of NO_2 (µg/l) during study period at El- Mex Bay.

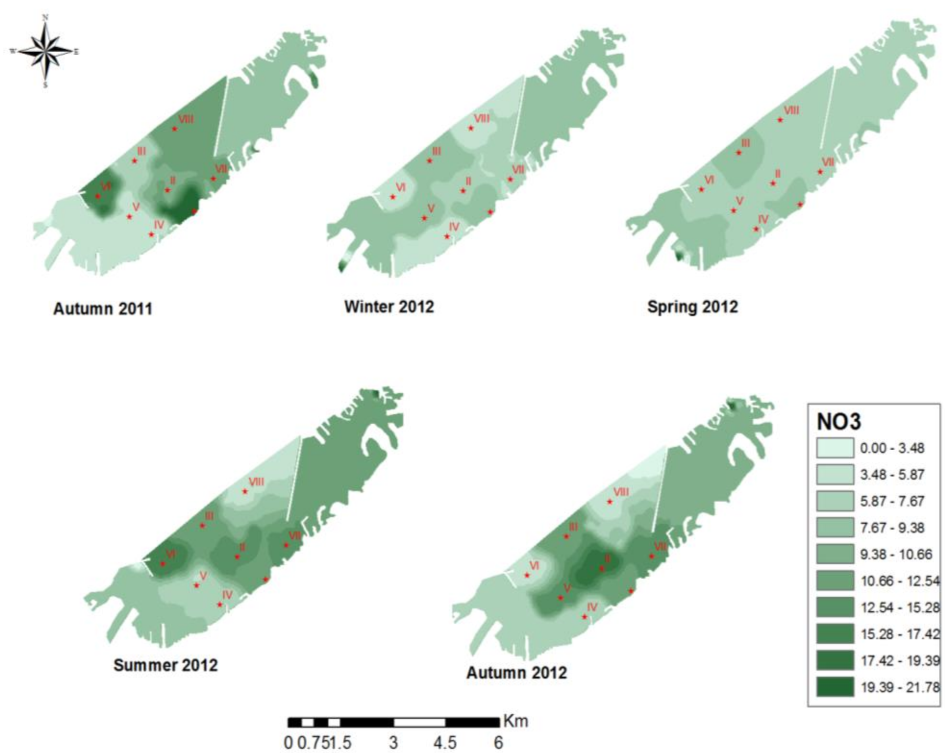

Figure 8. The seasonal distribution of NO_3 (µg/l) during study period at El- Mex Bay.

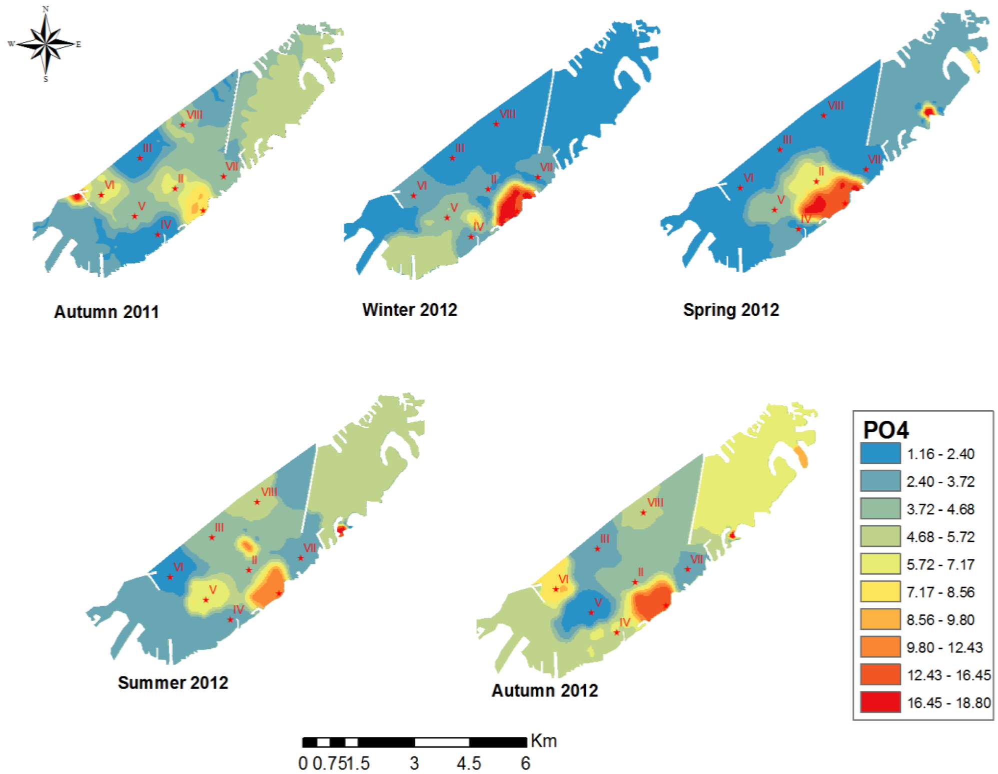

Figure 9. The seasonal distribution of PO_4 (µg/l) during study period at El- Mex Bay.

Gharib, 2012).

The maximum value of chlorophyll-a has recorded during 2 seasons summer and autumn 2012 with an annual average (34.38 and 29.92 µg/l, respectively). The high concentration of Chl-a content recorded in the water coincided with low salinity and high values of nutrient salts, which reflects such eutrophication condition caused by drainage effluents (Figure 10).

DISCUSSION

El-Mex Bay area has been and still being subjected to continuous major and drastic changes as a result of human activities; consequences of growing heavy industries (chloro-alkali plant, petrochemicals, pulp, metal plating, industrial dyes, and textiles) and uncontrolled disposal of resulting wastes, in addition coastal water of El- Mex Bay received huge amounts of untreated industrial wastes. The different human activities that bring large amounts of nutrient salts and harmful substances to the bay appear to have a pronounced impact on the physico-chemical characteristics.

The current regime there effectively controls the temporal and spatial variations of the ecological parameters. The predominant current directions were directed north-eastward under the influence of the north-westerly wind and sometimes directed south-eastward when the wind has southwesterly component in December 2012 and January 2012. The current and wind directions interpret that directions in 2012 and 2013 were not different from that in 1996 and 1997 whereas, the wind speed in winter 2012 was 27.36 knots and in January 2013 was 29.8 knots that exceed that which occurred in December 1996 which was 26 knots. Also, the current speed increased in winter 2013 and became 86.21 cm/s whereas winter in 1996 was 49.94 cm/s. El- Mex Bay and the two surrounding harbors (Western and El- Dekhela) are subjected to two main problems. Storm surges in association with spring tides which cause considerable trouble to coastal roads. Storm surges raise the sea level by 40 cm, causing overtopping of adjacent of beaches and structures. Storm waves in winter attack El- Mex Bay from the NW direction (Hendy, 2013). Moreover, the water exchange between the harbor and the sea exerts a considerable influence on the environmental and biological characteristics of the harbor, since one such cycle takes about 30 days to complete (El-Gindy, 1986; Hassan and Saad, 1996).

The spatial distribution of salinity was in fact a better reflection of the effect of El- Umoum Drain discharge into El- Mex Bay. In the long term, salinity decreased gradually from 39.6 ‰ in 1997 (Dorgham, 1997) to 33.50‰ during

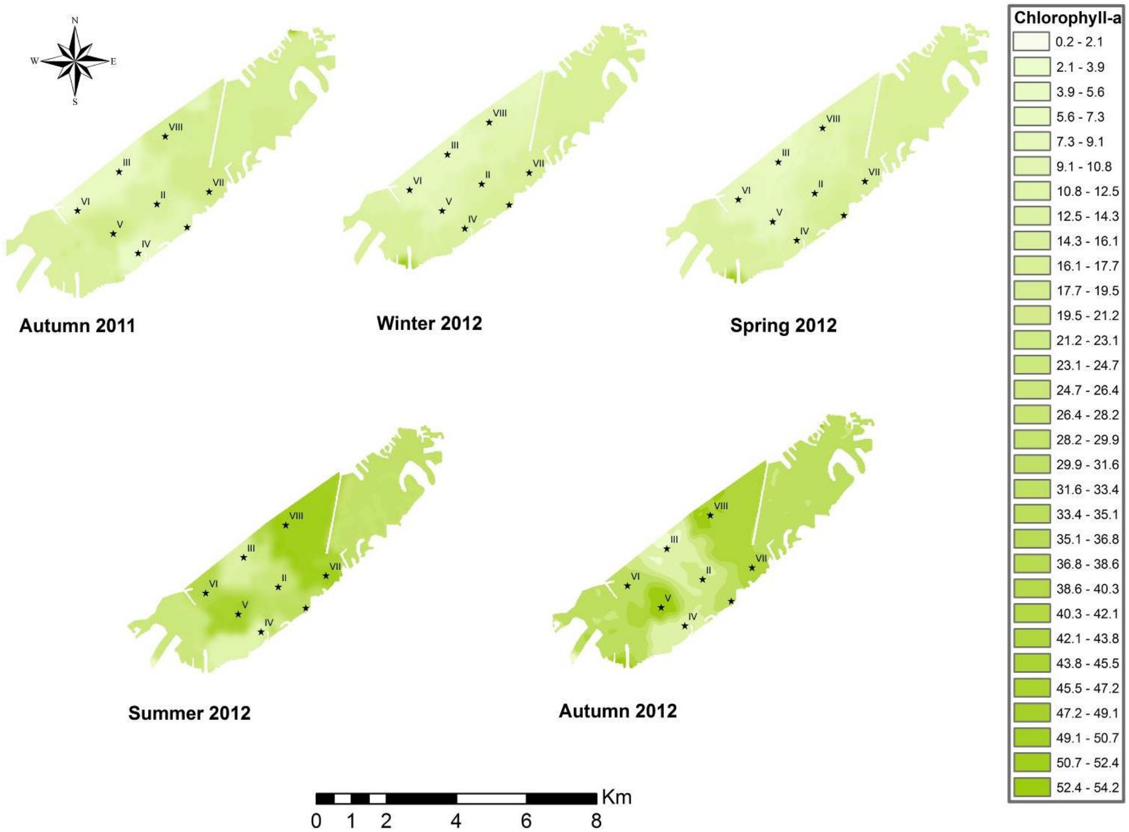

Figure 10. The seasonal distribution of chlorophyll- *a* (µg/l) during study period at El- Mex Bay.

the present study, indicating the chronic impact of the land-based effluents.

Although mixing processes caused by ship traffic and land-based runoff are the major cause of water turbidity in the bay, abnormally intensive phytoplankton blooms also substantially reduced water transparency; the two variables showed an inverse relationship all the year round.

The physico-chemical variables revealed that water temperature did not deviate from the normal seasonal fluctuations on the southeastern coast of the Mediterranean sea (15- 30°C). The pH values were always on the slight alkaline side and lower than that of the open sea. The decrease in the pH value coincided with the drop in oxygen content due to the effect of accumulating organic pollutants as well as the discharge of brackish water. El- Mex Bay demonstrated wide range of variations in its salinity on the spatial scale relative to the dispersal pattern of the discharged waste waters. The salinity of the near-shore waters sustained usually low values, increasing seaward to exceed 26.1 ‰ in the open part of the sea which reflects the effect of land drainage.

The water column of El- Mex Bay suffers from pronounced turbidity, particularly in front of the land runoff, whereas the Secchi disc readings were mostly < 1 m. Such turbidity is attributed to the strong mixing caused by discharged wastes, heavy traffic of fishing boats, and high count of plankton organisms. However, the open area of the bay shows comparatively high transparency (up to 5 m). These observations agreed with those of other studies (Mahmoud et al., 2009; Dorgham, 2011; Hendy, 2013).

In spite of the extremely high primary production in El- Mex Bay, dissolved oxygen was generally low along the water with a relatively small vertical gradient. The decrease in dissolved oxygen with depth is attributed to its consumption in oxidation of organic matter and the stagnation conditions prevailing in summer (Nessim and Tadros, 1986). The inter-annual records of dissolved oxygen testify to the continuing deterioration of water quality during the past two decades: its concentration fell from 1.6- 10.9 mg l^{-1} in 1997 (Labib, 1997) to <9.11 mg l^{-1} during the present study. It is therefore important to notice that the oxygen concentrations in the water of the study area was comparable to the threshold level of well oxygenation (<9.11 mg l^{-1}) proposed by Huet (1973) and near the bottom it resembled the hypoxia condition stated by Stachowitsch and Avcin (1988). Accordingly, El- Mex

Bay is categorized as an area with critical limits of dissolved oxygen (3.5-4.2 mg l^{-1}) necessary for healthy growth of biota in both cold and warm waters (Grundy, 1971; Arin 1974).

The seasonal distribution of nitrate in the water dropped in spring and summer owing to its intensive uptake by the abnormal phytoplankton blooms. Although the difference in nitrate between stations may be related to the effect of discharged wastes at the surface, it is probable that nitrification and mineralization of nitrate take place at different rates in the two layers. This concurs with the seasonally distribution of nitrate at all the stations, which reflects the ecological conditions prevailing at each one in different seasons. At stations I and II, nitrate attained its maximum concentration during summer and autumn 2012, when salinity dropped to its lowest value during the year; meanwhile, station I sustained the highest value for several seasons, possibly as a result of the dissolution of stored chemical fertilizers.

Nitrite levels in sea water can be regarded as a measure of the rate of nitrification and denitrification processes, which are also related to salinity variation. In the study area, the difference in nitrite between stations indicates that in the low salinity area, these processes occurred at the surface and the bottom at two different rates, while in the higher salinity area they took place at approximately similar rates. This suggests that nitrification occurred more rapidly in the former area, while denitrification was the faster process in the latter.

The value of the phosphate decreased gradually along the remaining stations due to detergents and decomposition of organic matter which is a general component of urban sewage may be the important source of reactive phosphate. The relative decrease of phosphate content in stations (III, V, VI, VII and VIII) may be attributed to several factors that lead to removal of phosphorus from the water, the consumption of phosphate by algae and aquatic plant phosphate adsorption on the clay mineral and suspended matter or precipitation by iron, calcium and aluminum.

The long-term observations of the nutritional conditions demonstrated wide variability in the spatial distribution in the bay, but the levels of all nutrient salts reflect high eutrophication. The markedly high nutrients reported during 1995 and 1996 (Soliman and Gharib, 1998; Gharib, 1998; Dorgham, 1997) reflect the large amount of nutrients reaching the bay through the discharged wastewaters, since the maximum values were reported in front of the land runoff. In contrast, the comparatively low concentrations during 2003- 2005 represented the amount of nutrients in area especially the locations far from entrance of El- Umoum Drain. It is clear that El- Mex Bay is characterized by great load of organic matter on the long-term scale. The phytoplankton demonstrated pronouncedly intensive growth in El- Mex Bay, maximizing the level of eutrophication condition, since the inter-annual records over the past three decades indicate pronouncedly high chlorophyll- a concentration in the bay (Dorgham, 2011).

Chlorophyll- a is considered as essential component responsible for photosynthesis process. It was primary photosynthesis pigment in all oxygen evolving photosynthetic plants. In the present study, we used chlorophyll-a concentration as an indicator of phytoplankton abundance and biomass in coastal waters. In the present study, the maximum chlorophyll- a concentrations was recorded at station (I) as 52.65 µg/l. The high concentration of Chl-a content recorded in the water coincided with low salinity, high temperature and high values of nutrient salts, which reflects such eutrophication condition caused by drainage effluents. These data agreed with that obtained by El-Sherif (2006) and Hendy (2013) where Chl-a ranged from 9.4 to 21.3 µg/l. Gharib (1998) observed that the phytoplankton abundance and the number of species increased consistently towards the outer region of El-Mex Bay, where the salinity was high.

Conclusion and recommendations

El-Mex Bay is located under stress condition due to the discharge of untreated domestic, industrial and agricultural effluents, beside the effect of ships movements from and to the harbors. Therefore, the condition at this bay is eutrophic and completely different from the open sea water. These are expected to continue and add to climatic influence of increasing temperature and rising sea level in the future.

As a consequence of rapid population growth, industrial development, untreated or poorly treated industrial waste, domestic sewage, industrial waste and agricultural runoff have moved to and through Mariut Lake south of the city and then released into The sea. This lake has also received a large loading of agricultural runoff through canals and drains. El- Mex Bay is subjected to severe environmental conditions.

Some recommendations includes:

1. the control of the discharge of drainage and sewage water into El- Umoum Drain, Mariut Lake and El- Mex Bay.
2. Water quality will continue deteriorating due to salt water intrusion; soil transport is still in progress. Water treatment plants and sewage systems are necessary for soil conservation, archeological sites protection and upgrading of health conditions.
3. Unplanned urbanization without consideration for the needed infrastructure is still progressing. This may lead to increased risk of extreme events and water pollution. A strong institutional capability in monitoring and assessment is necessary for law enforcement.
4. Low income, shortage of awareness and high unemployment rates are the main driving forces leading to low water quality due to careless behavior of coastal

area inhabitants. Planned industrial and tourism development, building a Marina and revival of fishing industries may be possible relief for upgrading conditions.

5. Pollution recovery and restoration by offshore extension of sewage pipelines.

6. Coastal management for future projects at Alexandria requires an environmental impact assessment study (EIA). This has to be enforced by monitoring and law enforcement and upgrading of awareness.

7. Establishment of management information system that stores all previous information and data which will help in future development, management and restoration of the Alexandria coastal zone.

Conflict of interest

The authors did not declare any conflict of interest.

REFERENCES

Abuldahab O, Halim Y, El-Rayis OA (1986). Mercury species in coastal marine organisms from different trophic levels west of Alexandria. FAO Fishery Report, 325 Suppl.:1-7.

Abuldahab O, Khalil AN, Halim Y (1990). Chromium fluxes through Mex Bay inshore waters. Marine Pollution Bulletin, 21:68-73.
http://dx.doi.org/10.1016/0025-326X(90)90190-J

De Jonge VN, Elliott M, Orive E (2002). Causes, historical development, effects and future challenges of a common environmental problem: eutrophication, Hydrobiologia, 475/476, 1- 19. http://dx.doi.org/10.1023/A:1020366418295

Dorgham MM (1997). Phytoplankton dynamics and ecology in a polluted area on the Alexandria Mediterranean coast. Proceedings of the 3rd international conference on Mediterranean coastal environment, Qawra, Malta, 1:151-160.

Dorgham MM, Abdel-Aziz NE, El-Deeb KZ, Okbah MA (2004). Eutrophication problems in the Western Harbor of Alexandria, Egypt. OCEANOLOGIA, 46:25-44.

Dorgham MM (2011). Eutrophication problem in Egypt. Book: Eutrophication: causes, consequences and control, Ch. 8:171-194.

El- Rayis OA, Saad MAH (1984). Concentration of Cu, Cd, Zn, Fe and Mn in the River Nile water and its contribution to the Mediterranean Sea. VIIes Jurnees Etud. Pollutions, Lucerne, CIESM, pp.45-52.

El- Sherif Z (2006). Effects of Industrial, Touristic and Marine Transport on Physical, Chemical and Biological Characteristics of Water and Fish Populations, West of Alexandria.

El-Gindy AAH (1986). Estimation of water exchange and residence time of the water in the Western Harbor of Alexandria (Egypt), Rapp. Comm. Int. MerM´edit. (CIESM) No. 30(2).

Gharib SM (1998). Phytoplankton community structure in Mex bay, Alexandria, Egypt. Egypt. J. Aquat. Biol. Fish., 2, 81-104.

Grasshoff G (1976). Method of seawater analysis. Verlag Chemie Weinheim, New York, 317p.

Grundy RD (1971). Strategies for control of man-made eutrophication, Environ. Sci. Technol. 5 (12):1184-1190. http://dx.doi.org/10.1021/es60059a011

Halim Y, Abuldahab O, El-Rayis OA (1986). Chemical forms of mercury in flesh, gills and liver from fish species of different habitats from two localities, west of Alexandria. FAO Fishery Report, 325 Suppl.: 99-103.

Hassan MH, Saad NN (1996). Some studies on the effect of Alexandria Western Harbor on the coastal waters, pp. 464–472, Proc. 6th Int. Conf. 'Environmental protection is a must', NIOF/USPD, Alexandria.

Hendy DM (2013). Assessing the coastal vulnerability to climate change in El- Max Bay, Egypt. M.Sc. IGSR, 122 pp.

Huet M, (1973). Text book of fish culture. Breeding and cultivation of fish, Fish. News Books Ltd, Surrey, 436 pp.

Hussein NR, Gharib SM (2012). Studies on spatio-temporal dynamics of phytoplankton in El-Umum drain in west of Alexandria, Egypt. J. Environ. Biol. 33, 101-105.

Labib W (1997). Eutrophication in Mex Bay, Alexandria (Egypt). Environmental studies and statistical approach. Bull. Nat. Inst. of Oceanogr. And Fish., A.R.E., 23:49-68.

Mahmoud TH, Masoud MS, Shaltout NA, Hussein NR (2009). The biological pump of carbon dioxide in El-Mex Bay, Alexandria, Egypt. Egyp. J. Aqua. Res. 36(1):11-20.

Nessim RB, Tadros A B (1986). Distribution of nutrient salts in the water and pore water of the Western Harbor of Alexandria, Egypt, Bull. Natl. Inst. Oceanogr. Fish. (Egypt), 12:165-174.

Nessim RB (1994). Environmental Characteristics of Mex Bay, First Arab Conference on Marine Environment Protection, 5-7 Feb., Sheraton, Alexandria, 221-243.

Okbah MA, Tayel FTR (1999). Water Quality in The Coastal Area of Alexandria, Bulletin of National Institute of Oceanography and Fisheries, A.R.E., 25:89-102.

Said MA, El-Deek MS, Mahmoud TH, Shridah MMA (1991). Physico-chemical characteristics of different water types of El- Mex Bay, Alexandria, Egypt. Bull. Nat. Inst. Oceangr. and Fish., ARE, 17(1): 103-116.

Soliman AM, Gharib SM (1998). Water characteristics, phytoplankton and zooplankton population of El-Mex bay region. Bull. Fac. Sci. Alex. Univ., 38:45-66.

Stachowitsch M., Avcin A., 1988, Eutrophication induced modifications of benthic communities, UNESCO Rep. Mar. Sci., 49:67–80.

Strickland JDH, Parsons TR (1972). A practical handbook of sea water analysis, second edition. Fish. Res. Bd. Can. Bull., (176):310.

Tayel F, Shiradah M (1996). Fe, Cu, Mn, Pb and Cd in some fish species from western harbor of Alexandria, Egypt. Bulletin of the National Institute of Oceanography and fisheries, 22:85-96.

Vanloon R, Duffy A (2000). Zinc biochemistry and physiology and their arrangements. In: New trends in bioinorganic chemistry (ed R.J.P. Williams and J.R.R.F.D. Silva) Acad. Press, London: 11-57.

Youssef DH (2001). Total alkalinity, carbonate and speciation of bicarbonate in front of Alexandria, Egypt. Bulletin of the National Institute of Oceanography and Fisheries, 27:45-63.

Zakaria HY, Radwan A A, and Said MA (2007). Influence of salinity variations on zooplankton community in El- Mex Bay, Alexandria, Egypt, Egyptian Journal Of Aquatic Research, VOL. 33(3):52-67.