*Asian J. Adv. Basic Sci.:* **2015**, *3(2)*, 45-53
*ISSN (Print): 2454 – 7492*
*ISSN (Online): 2347 – 4114*
*www.ajabs.org*

# Study on Steel Corrosion Rate in Semi Closed Seawater Area by Weight Loss Technique

**Hermine R. Z. Tadros[1*], Mona F. El Naggar[1], Fatma A. Zaghloul[2], Aida B. Tadros[1] & Gehan A. El Elaa[3]**

[1* & 1] *Marine Chemistry Lab, Marine Environment Division, NIOF, Alex, EGYPT*
[2] *Hydrobiology Lab, Marine Environment Division, NIOF, Alex, EGYPT*
[3] *Microbiology Lab., Marine Environment Division, NIOF, Alex, EGYPT*
[*] *Correspondence: E-mail: hermine_rzts@yahoo.com*

*(Received 15April, 2015; Accepted 29 April, 2015; Published 13 May, 2015)*

**ABSTRACT: The influence of various environmental parameters on the corrosion rate of the metallic structures was studied. Different physicochemical and biological parameters were measured during the period June 2011 and May 2012 at Eastern harbor (EH), front of NIOF, Alexandria. Their ranges and (annual averages) were found as follows; temperature, 16.75- 29.73°C, (22.8°C); dissolved oxygen, 2.253-7.083ml/l, (4.089ml/l), pH 8.025 - 8.415. Total alkalinity recorded relatively high values, 2.838 -3.74meq/l, (3.35meq/l). The variations of the nutrient salts, $PO_4^{-3}$, $NO_2^{-2}$ and $NO^{-3}$ differed between, 0.588-5.5378µmol/l, (1.798µmol/l); 0.369-2.938µmol/l (1.658µmol/l) and 1.606-15.633µmol/l (8.651µmol/l) respectively. Low level of $SO_4^{2-}$ was found, 1.933g/l-3.914g/l (2.954g/l). The phytoplankton annual average recorded $1.84x10^6$cells/l. The Bacillariophycea is dominating during most of the study year while the Dinophycea was frequent. The total annual average of bacterial count was 2271063 CFU/ml. The bacterial counts showed significant differences and their fluctuation in population distribution depends on the physicochemical variations.**

**The corrosion of steel panel was measured for 24hrs twice a week monthly during the study period. The monthly corrosion rates fluctuated between 3.582 and 7.5518mpy with annual average 4.78303mpy (n=24). The change of steel rate of corrosion at the marine area is directly affected with sulphate concentration, and indirectly with temperature, pH and nitrite. The data also showed the decrease in steel corrosion accompanied by increase in viable counts of bacteria. The lower average corrosion rate measured during September (3.5819mpy) and November (3.783mpy) met with lower salinity. High corrosion rate during October, 6.0926mpy was affected by high DO level and the highest phytoplankton counts.**

**Keywords:** corrosion rate; environmental parameters; seawater; steel; weight loss.

**INTRODUCTION:** Corrosion is the gradual destruction of material, usually metals, by chemical reaction with its environment. It causes cracks, holes or a buildup of residues on or within the metal. Corrosion is a permanent problem for both industry and economy in general, and in marine environment and maritime activities in particular.

The aqueous corrosion of metallic structures in marine environment is an electrochemical process that occurs on the metal surface by interaction between it and the constituents of saline water. Seawater contains about 3.4% salts and is slightly alkaline pH 8.0. It is a good electrolyte and can cause galvanic corrosion and crevice corrosion[1]. Corrosion is affected by oxygen content, velocity, temperature and biological organisms[1]. The initiation of one or several corrosion process influencing by the natural of material, surface finish, temp., humidity, wind, rain, etc.[2]

Corrosion of metal in coastal and harbor water are of important in the corrosion of fixed structure. A number of alloys including stainless steels, aluminum and nickel based alloys, are used in seawater for various applications. The localized corrosion of these materials is affected by temperature, microbial activity, chlorination and flow rate[3]. The microbial organisms in natural seawater increase the open-circuit potential, a process called ennoblement[3].

The most significant parameters that determine seawater corrosively are the content of dissolved oxygen, water temperature and its flow rate, salinity and pH, likewise the biological activity (bio-deposits), as well as the environmental zone, to which the metal is exposed[4].

Mild steel is the most versatile general purpose material due to its good mechanical strength, easy fabricability, formability and weldability, abundance and low cost[2].

The steel corrosion rate from semi-closed area; Eastern harbor, Alexandria, Egypt showed a range between 4.320mpy and 9.813mpy[5]. In the eastern coastal

zone of Alexandria, the corrosion rate of steel ranged between 3.665 - 10.462mpy[6].
While in western area, Alexandria, Egypt; the corrosion rate of steel ranged between 2.809 - 16.96mpy[7].
The corrosion rate in seawater is a function of a large number of mutually dependent factors. The lower the temperature is, the greater the oxygen solubility in water is and the greater the corrosion rate may be[8].
Ships and offshore structures require protection against the marine environment. This protection is required above and below the waterline as well as the splash zone in offshore structures, being exposed to both air and liquid assault.
In this study the corrosion of steel panel in natural seawater *in situ* was measured over the period June 2011 till May 2012. The method of weight loss was applied for measuring the corrosion of steel panel in seawater. The effect of change of some physicochemical, biological and microbiological on the rate of corrosion of steel was investigated during the study period.

## MATERIAL AND METHODS:

**1. Area of study, Eastern Harbour:** The Eastern harbour is a relatively shallow semi closed basin, sheltered from the sea by a break water leaving two openings, El-Boughaz and EL–Selsela, through which the exchange of water between the harbour and the neritic Mediterranean water takes place.
The steel panel immersion test for the study of corrosion rate of steel was done in seawater of the Eastern harbour. Only one marine area was selected in front of NIOF for the steel panel immersion (Figure 1).

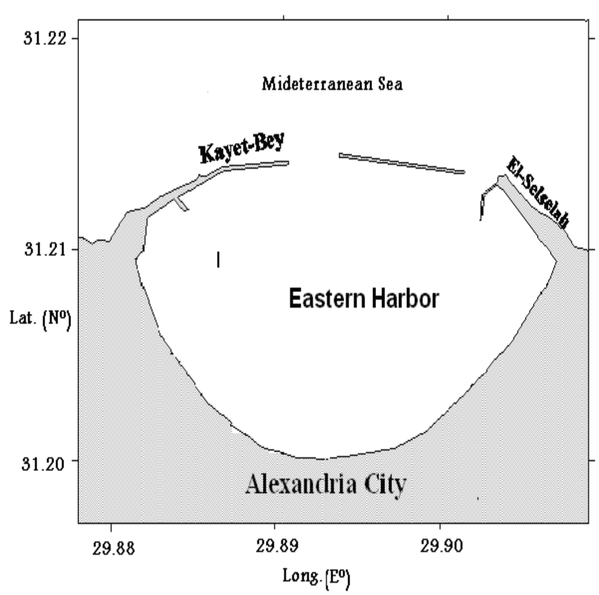


**Figure 1: Marine location of panel immersion test in front of NIOF, Eastern Harbour; Alexandria, Egypt.**

**2. Sample collection:** Surface seawater samples were collected four times monthly over the duration (June 2011-May 2012) from a fixed location at Alexandria Eastern Harbor (front of NIOF) using Neskin bottle, provided with a reversing thermometer. Samples were transferred immediately to different analysis for determination of the selected environmental parameters. Dissolved oxygen and ammonia were fixed *in situ*.

**3. Physical parameters:** Salinity and temperature of seawater were measured *in situ* using CTD SBE Sea bird electronics.

**4. Chemical parameters:**
*4.1 Dissolved oxygen (DO):* It was determined by a modified Winkler's method modified by Grasshoff[9]. Fixation of dissolved oxygen was made *in situ* using manganous sulphate and alkaline potassium iodide solutions, taking all precautions that no bubbles are formed, after complete fixation of oxygen, the precipitated manganese hydroxide is allowed to settle and then dissolved by 9N $H_2SO_4$, the liberated iodine was titrated against standard sodium thiosulphate solution using starch solution as indicator.
*4.2 Alkalinity:* Total Alkalinity was measured according to the method described by Strickland and Parsons [(10)]. Water sample was titrated against diluted HCl using methyl orange as indicator.
4.3 *Nutrient salts:* (nitrite, nitrate, ammonia and phosphate), were measured according to the standard methods[10].
*4.4 pH:* The pH was measured *in situ* using portable pH meter model (JENWAY, 3410 Electrochemistry Analyzer pH-meter).

**5. Biological parameters:**
*5.1 Phytoplankton:* One litre of surface water samples was immediately fixed with 4% neutral formaldehyde for phytoplankton samples laboratory analysis. Phytoplankton were counted and identified using 2ml settling chambers with a Nikon TS 100 inverted microscope at 400x magnification using sedimentation technique as reported in the slandered method[11] and the results were expressed in cells/l
*5.2* Bacteria: *Culture Media* - The culture medium which used for isolation was of pure grade and prepared according to the manufacturer's instructions.
*Bacterial Isolation and Enumeration:* Water samples were diluted up to $10^{-6}$ in sterile sea water. For estimation of total viable count (TVC), 1ml of each dilution was cultivated on sea water agar medium using poor plate method and incubated at 28 ºC for 24-48h[(12)]. Culture medium composition (g/l): peptone, 5; beef, 3; ferrous sulfate 0.01 and sea water, 1l. pH was adjusted at 7.

**6. Steel panel's preparation:** The steel panels with dimensions 2x7x0.3cm were prepared. Oil and grease were removed from the steel plates by suitable organic solvents, and then polished with a series of emery papers starting with coarse one and proceeding to finer grades.

**7. Steel panel's immersion test:** The prepared steel panels (triplicate) were hanged in steel frame and immersed in seawater for fixed hours (24 hrs) and then removed. The test was repeated two times each month over two successive weeks over the duration June 2011 till May 2012. Each week the immersion of the frame hanged the panel was tested over two successive days and each time the immersion was for 24 hrs. The immersion time was nearly at the same time of the day.

**8. Weight loss method:** A simple test for measuring corrosion is the weight loss method[14 & 15]. The method involves exposing a clean weighed piece of the metal or alloy to the corrosive environment for a specified time followed by cleaning to remove corrosion products and weighing the piece to determine the loss of weight. The rate of corrosion (R) is calculated as:

$$R = KW/(\rho A t)$$

Where $k$ is a constant, $W$ is the weight loss of the metal in time $t$, $A$ is the surface area of the metal exposed, and $\rho$ is the density of the metal (in g/cm³).

## RESULTS AND DISCUSSION:

**1. Chemical characteristics of the study area:**
*1.1 Temperature and salinity:* The seawater temperature of the studied area, EH, ranged between a minimum of 16.5 -16.7°C measured during January (10/1, 11/1, 16/1 & 17/1/2011 while the values recorded during February (22/2 and 23/2 /2011) were 16.6°C and 16.9°C respectively. A maximum of 32.1°C was measured during August (23/8/2011). The average of seawater temperature during the measured times of the duration (June 2011-May 2012) found to be 22.6°C.
The change of the average salinity of seawater with the corresponding average temperature is represented by the Figure (2). Salinity recorded its maximum values (39.2 and 39.5) during 14/3&22/3/ 2011 and its minimum value of (37.00) during August 2011. The annual average of salinity of the seawater at the selected location (June 2011-May 2012) is 37.47. Both annual averages of temperature and salinity are higher than that previously reported; 22.4°C & 35.85 respectively[15].

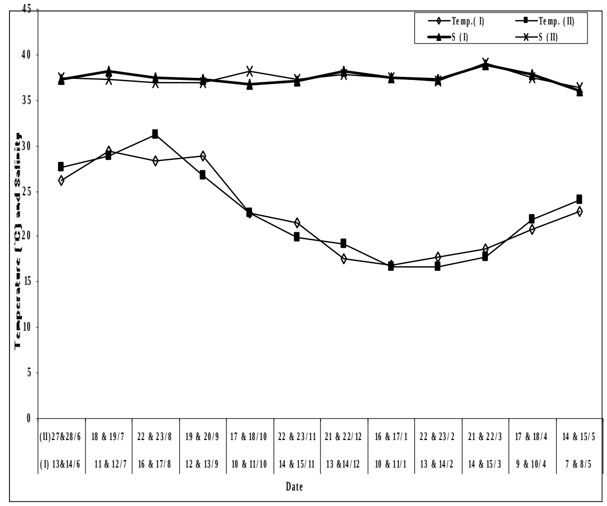


**Figure 2: Average variations of temperature and salinity of two successive days, E H, (in front of NIOF), during the study period.**

*1.2 pH:* Natural seawater is well buffered and its pH normally lies between 8.1 and 8.3.The pH values of the seawater in the selected location lies on the alkaline side and ranged between 7.97 -8.45, Figure 3, which is changed than that measured before at the same location of EH, (7.53-8.70)[16].

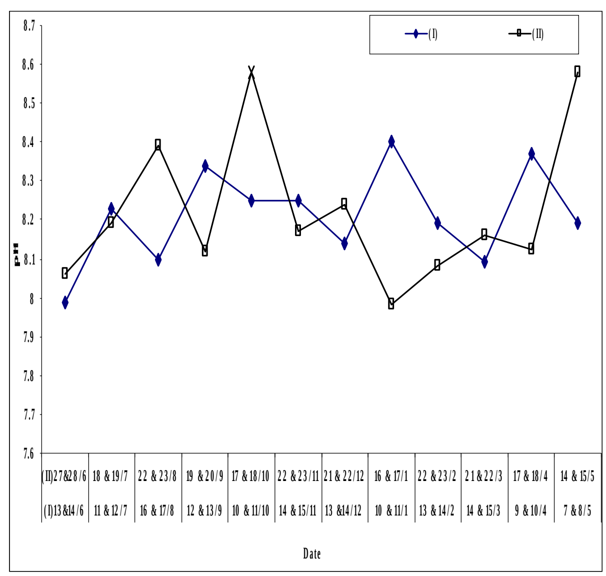


**Figure 3: Average variation of pH of two successive days, E H, (in front of NIOF), during the study period.**

*1.3 Total alkalinity:* In most of the seawater samples collected from the site in front of NIOF, alkalinity values are a bit higher than its value in the open ocean sea water (± 2 μmol kg$^{-1}$) [17] and ranged between a minimum value of 2.85meq/l (10/10/2011) to maximum value of 3.8meq/l recorded in 10/4/ 2012 except a very law value of 2.05meq/l measured at 18/10/2011 (Figure 4). The total average of alkalinity was found to be 3.35meq/l. Low total alkalinity levels was reported in EH at the area in front of (NIOF) in surface water, 2.48meq/l and the lowest one of 1.35meq/l in subsurface water with an annual average of 1.73meq/l[15].

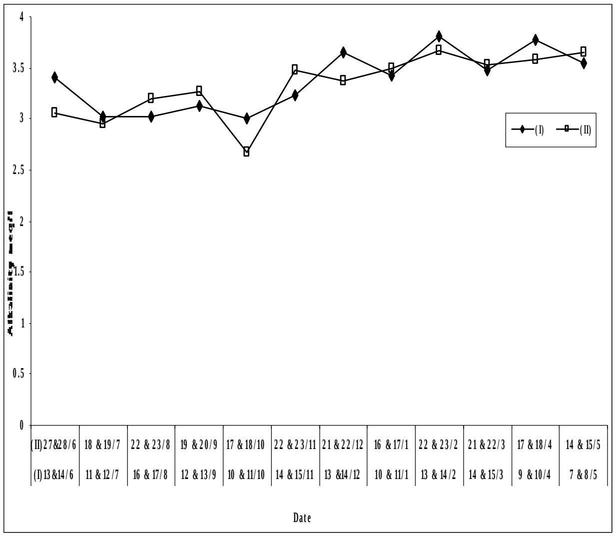


**Figure 4: Average variation of total alkalinity of two successive days, E H, (in front of NIOF), during the study period.**

*1.4 Dissolved oxygen (DO):* Dissolved oxygen in the EH during 2011-2012 showed low levels than that previously recorded[15] and ranged between a minimum concentration of 2.08ml/l measured at 19/7/2011 and a maximum concentration of 6.61ml/l on 28/6/2011 followed by 6.385ml/l on 18/10/2011. The annual DO concentration average was 3.92ml/l.

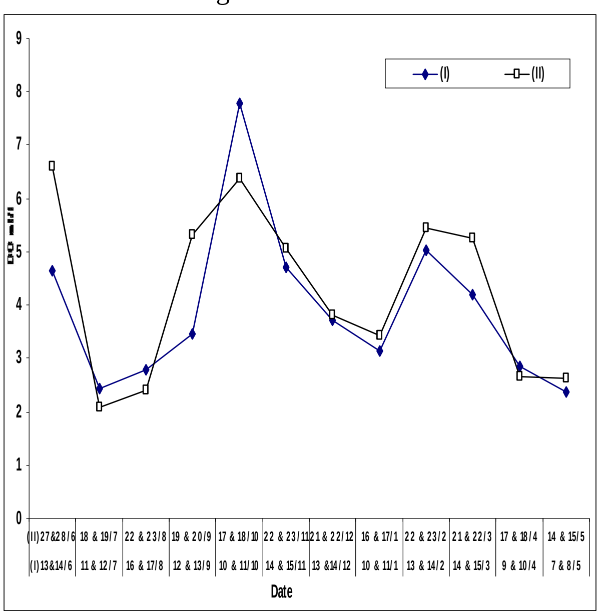


**Figure 5: Average variation of DO concentrations of two successive days, E H, (in front of NIOF), during the study period.**

*1.5 Nutrient salts:* Nitrite, nitrate and phosphate - Nutrients from anthropogenic pollution can degrade water quality and alter the balance of marine food webs. Quickly respond to nutrient changes in the water, can have repercussions throughout both pelagic and benthic food webs and thus they serve as a good bio-indicator of water quality[18].

Coastal water is generally richer than oceanic water with nutrient due to domestic effluents. The maximum concentration of nitrate was 20.94µmol/l measured on 22/3/2012 followed by 19.92µmol/l and 19.72µmol/l on 23/11/2011 and 17/1/2012 respectively. The minimum nitrate concentration recorded was 0.222µmol/l on 22/12/2011 followed by 0.612µmol/l on 19/7/2011. The annual nitrate average was 8.61µmol/l. The minimum average of nitrite concentration was measured during 15/11/2011 and found to be 0.2µmol/l and a maximum of 5.43µmol/l on 22/12/2011. The average of nitrite concentration was 1.66µmol/l. Figure 6 represents the variations of concentrations of both nitrite and nitrate over the study period.

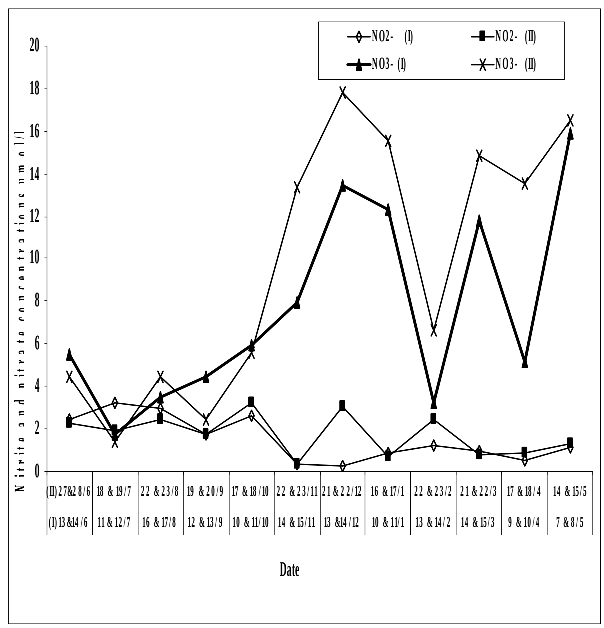


**Figure 6: Average variation of nitrite and nitrate concentrations of two successive days, E H, (in front of NIOF), during the study period.**

As shown from Figure 7; $PO_4^{3-}$ averages ranged between minimum values of 0.06µmol/l during 22/12/2011 followed by 0.1µmol/l on 11/7/2011 and 12/7/2011 respectively and maximum value of 9.55µmol/l on 22/8/2011. The annual phosphate average was 1.798µmol/l.

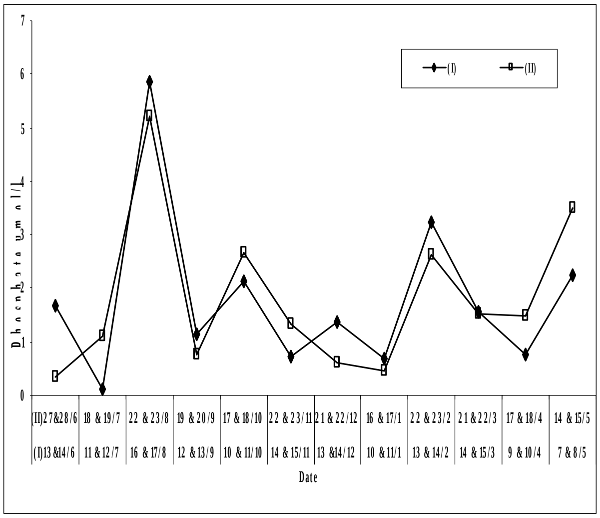


**Figure 7: Average variation of phosphate concentration of two successive days, E H, (in front of NIOF), during the study period.**

*1.6 Major ions:* sulphate: Sulphate ($SO_4^{2-}$) concentration averages fluctuated between minimum values of 1.339 g/l and 1.8255 g/l on 11/1/2012, 17/8/2011 respectively and maximum values of 4.258 g/l on 8/5/2012, Figure 8.

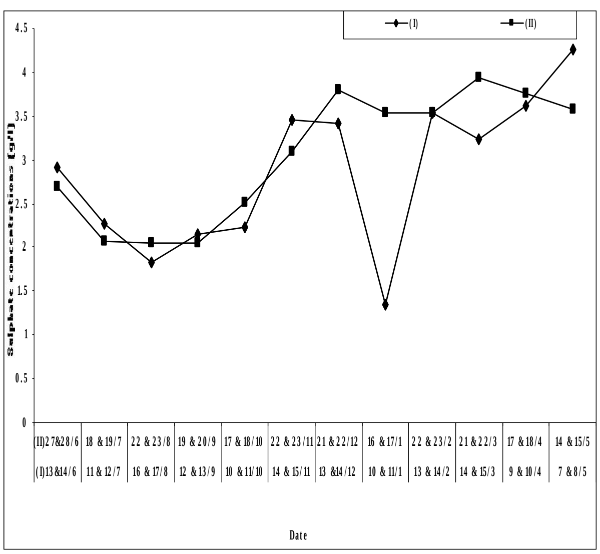


**Figure 8: Average variation of sulphate concentration of two successive days, E H, (in front of NIOF), during the study period.**

**2. Phytoplankton community structure and composition:** From the analysed data, a visible change in phytoplankton community with regard to numerical abundance and species composition was evident among the site of immersion in the first two days and the second two days of the same month and in the monthly cycle.

The phytoplankton standing crop is represented with three groups namely, Bacillariophycea, Dinophycea and Euglenophyta. The first group is dominated during most of the year (July 2011and from October 2011 till April 2012) at the selected marine site (Figure 1) while the Dinophycea was frequently recorded at the seawater most of the year. Standing crop of phytoplankton in the site of immersion of (EH) is high during all the year round except the period from January till March 2012. This may be due to low water temperature, 16.6°C, 16.75°C and 17.8°C.

Generally, phytoplankton counts increased in its average value during the second two days of immersion in each month than the first one (Figure 9), it ranged from $4.3x10^3$cellsl/l during February2012 and $3.14x10^6$cells/l during October 2011. The community composition is affected with environment conditions. Phytoplankton in the first two days fluctuated between $9.05x10^3$cells/l (February,2012) and $501.9x10^3$cells/l (November,2011) .The community composition showed high percentage frequency of Dinoflagellates; *Prorocentrum* (99%) during June (14/6/2011) it may be attributed to consumed of phosphate content (from 3.2 µmol/l to 0.15 µmol/l) as well as during 23/8/2011; *Protoperidinium* (83.4%) it is also met with consumed of phosphate (9.55 µmol/l to 0.85 µmol/l). The high counts of phytoplankton during 20/9, 17/10, 23/11, 21/03 and 22/03/2012 are accompanied with high concentration of dissolved oxygen ((5.98ml$O_2$/l, 6.84ml$O_2$/l, 5.2ml$O_2$/l, 5.309ml$O_2$/l and 5.2ml$O_2$/l respectively).

The annual average of phytoplankton standing crop attained to $1.84x10^6$cell/l during the study period (June 2011-May 2012). These counts are higher than that recorded in the same region during 2009 ($1.387x10^6$cell/l)[19]. Bacillariophycea represented 84.2% by number to the total count of phytoplankton and dominated during most of the year.

**3. The bacterial counts:** The fluctuation in population distribution of total bacterial counts may reflect complex nutritional and physicochemical variations within the ecological niches[20].

The average bacterial counts showed significant differences .The lowest average value of $6x10^3$CFU/ml achieved during (14&15May 2012) while the highest average value of $115x10^5$ found in (13&14 February 2012), Figure 10. These total bacterial counts are inversely counted with the total phytoplankton counts and total nitrate concentration, (Table 1). In aquatic systems, nutrient levels strongly influence bacterial growth, growth efficiency, and bacterial community composition[21.]

The relative importance of temperature, resource availability and bacterial community composition for the bacterial growth response is poorly understood[22].

The average of the total viable bacterial counts increases during months from June till November 2011 and ranged between (9 x$10^5$ – 81 x$10^5$) CFU/ml Table 1. During the mentioned period, the temperature varied between (19.9 – 29.35) °C, total alkalinity (2.95 – 3.475) meq/l, $NO_3^-$ (1.43 - 5.94) µg/l and $SO_4^{-2}$ (1.826 – 3.45) g/l. The lower average of total viable bacterial counts is measured during 7 & 8 May and 14 & 15 May 2012 (14x$10^3$ and 6x$10^3$CFU/ml). During the above mentioned days in May the environmental parameters showed varieties in temperature (22.8&24.0) °C, total alkalinity (3.55 & 3.65) meq/l, $NO_3^-$ (15.93 & 16.40) µg/l and $SO_4^{-2}$ (3.57 & 4.258) g/l.

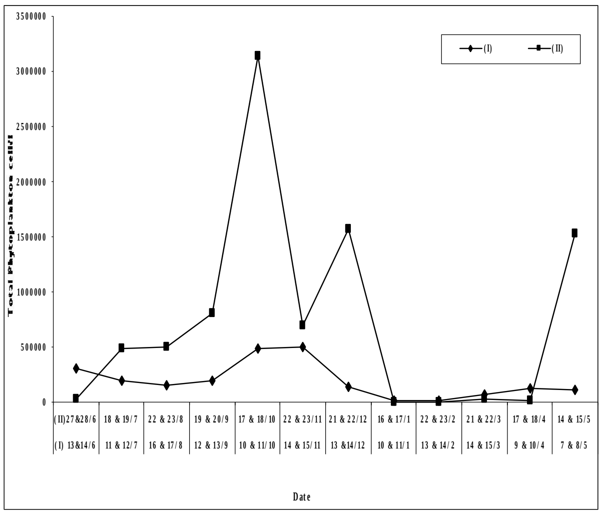


**Figure 9: Average variation of phytoplankton counts of two successive days, E H, (in front of NIOF), during the study period.**

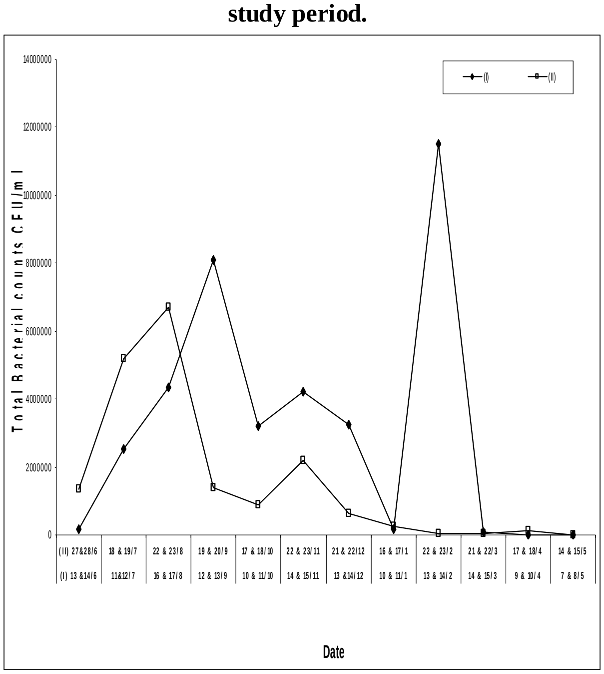


**Figure 10: Average variation of total bacterial counts of two successive days, E H, (in front of NIOF), during the study period.**

**4. Corrosion rates of steel in Eastern harbor during the study period:** The corrosion rates of metals in seawater are generally increased with larger concentration of dissolved oxygen, pH, salinity, and micro-organisms.

Weight loss technique was used to determine the corrosion rate of the used steel panel. As illustrated in the experimental part, the steel panel was immersed in seawater of the Eastern harbor twice a month over two following weeks through the duration from June 2011till May 2012. The time of steel panel immersion in seawater was about 24 hours. The annual average of the steel corrosion rate was found to be 4.783mpy (n=24). The maximum corrosion rate is found in June 2012 (7.552mpy) meets with the minimum pH value (8.025) and the minimum value is (3.582mpy) which meets with the minimum salinity (37.143) during September. The decrease of monthly averages corrosion rates of the months; June, July and August 2011 (7.5518mpy, 5.4506mpy and 4.1066mpy respectively) are accompanied by the decrease of sulphate concentrations (2.806g/l, 2.1606g/l and 1.944g/l respectively) and increase in nitrite concentrations (2.344µM, 2.581 µM and 2.738 µM) and increase in pH values (8.025, 8.21 and 8.245) and also the increase in temperature (26.9°C, 29.15°C and 29.73°C) respectively. On the other hands, the increase of the average corrosion rates of the steel panels in seawater through the months; February, March and April 2012 (4.1959mpy, 4.3314mpy and 6.0855mpy respectively) are accompanied by increase in sulphate concentrations and decrease in nitrite concentrations, decrease in pH values and temperature. The lower average corrosion rate during September (3.5819mpy) and November (3.783mpy) in comparison with the corrosion rate of steel in the rest of the months are met with lower salinity (37.143 and 37.154 respectively). The average corrosion rates during October 2011 and April 2012 are found to be 6.0926mpy and 6.0855mpy respectively and they are higher than their values during the rest of the months except June 2011. During October high dissolved oxygen was measured (7.083ml/l) while during April the increase on sulphate concentration (3.688 g/l) and alkalinity (3.68meq/l) may have the high effect on the increase of steel corrosion. During December, January and February, the averages of the rate of steel corrosion lie in the range 3.9515mpy–4.2511mpy. These values are lower than the measured values during the months June 2011-May 2012 except the rates of the steel corrosion during the months September and November due to the values of seawater salinity as mentioned above.

The bacterial counts has a direct effect on the rate of steel corrosion in which the decrease of the averages corrosion rates of the months; June, July and August

2011 ((7.5518mpy, 5.4506mpy and 4.1066mpy respectively) are accompanied by increase of the averages of viable bacterial counts ($760x10^3$CFU/ml, 3875 x $10^3$ CFU/ml and 5237 x $10^3$ CFU/ml) respectively. On the other hands, the increase of the average corrosion rates of the steel panels in seawater through the months; February, March and April 2012 are accompanied by decrease in the total viable bacterial counts.

The lower corrosion rates in seawater have been attributed to the formation of a stable biofilm, which acts as a barrier against corrosion.

The relation between the corrosion rate of steel panels and the different studied environmental parameters can be represented by the mathematical model that was deduced for prediction of the rate of steel corrosion in semi-closed area (EH) over the period June 2011- May 2012, by the following equation:

Corrosion rate= 18.08296 + 0.016378 S + 0.082479 Temp. - 2.02455; pH - 0.97986 Alk.; + 0.119465; DO - 0.3185; $PO_4^{-3}$ + 0.706022; $NO_2^-$ - 0.03045; $NO_3^-$ +1.11821; $SO_4^{-2}$ $R^2$=0.5185, n=24, ρ=0.05.

## CONCLUSION:

The corrosion rates of the steel panels which measured *in situ* for 24hrs over a period 2011-2012 at EH (front of NIOF) ranged between 3.582-7.552mpy.

A mathematical model was deduced which investigate the relation between the steel corrosion rates and physicochemical parameters which was measured at the studied area.

Total viable bacterial counts at the study area have inverse effect on steel corrosion rate in most cases.

**Table 1: Average of the studied environmental parameters 2011-2012, EH, in front of NIOF, Alexandria-Egypt during 2011-2012.**

| Average of two successive days | Temp. | pH | Alk. | DO | $PO_4^{3-}$ | $NO_2^-$ | $NO_3^-$ | $SO_4^{2-}$ | S | Total Phytoplankton | Bacteria |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | °C | | meq/l | m/l | µg/l | | | g/l | | Cell/l | CFU/ml |
| **Date/2011** | | | | | | | | | | | |
| 13/6&14/6 | 26.15 | 7.99 | 3.4 | 4.66 | 1.68 | 2.45 | 5.5 | 2.919 | 37.25 | 307560 | $155x10^3$ |
| 27/6&28/6 | 27.65 | 8.06 | 3.05 | 6.61 | 0.33 | 2.24 | 4.49 | 2.693 | 37.386 | 28360 | $1365x10^3$ |
| 11/7&12/7 | 29.35 | 8.23 | 3.03 | 2.43 | 0.1 | 3.23 | 1.79 | 2.267 | 38.112 | 200363 | $255x10^4$ |
| 18/7&19/7 | 28.95 | 8.19 | 2.95 | 2.08 | 1.1 | 1.94 | 1.43 | 2.068 | 37.265 | 479705 | $52x10^5$ |
| 16/8&17/8 | 28.3 | 8.1 | 3.03 | 2.78 | 5.88 | 2.99 | 3.47 | 1.826 | 37.463 | 147445 | $435x10^4$ |
| 22/8&23/8 | 31.15 | 8.39 | 3.2 | 2.4 | 5.2 | 2.49 | 4.44 | 2.041 | 37.008 | 504220 | $6725x10^3$ |
| 12/9&13/9 | 28.8 | 8.34 | 3.13 | 3.46 | 1.15 | 1.79 | 4.49 | 2.15 | 37.3 | 194360 | $81x10^5$ |
| 19/9&20/9 | 26.65 | 8.12 | 3.28 | 5.32 | 0.78 | 1.71 | 2.48 | 2.06 | 36.985 | 808335 | $139x10^4$ |
| 10/10&11/10 | 22.65 | 8.25 | 3 | 7.78 | 2.13 | 2.66 | 5.94 | 2.235 | 36.7 | 480605 | $32x10^5$ |
| 17/10&18/10 | 25.35 | 8.58 | 2.98 | 6.39 | 2.65 | 3.21 | 5.59 | 2.52 | 38.152 | 3137470 | $9X10^5$ |
| 14/11&15/11 | 21.55 | 8.25 | 3.23 | 4.7 | 0.73 | 0.35 | 8 | 3.45 | 37.1 | 501885 | $12x10^5$ |
| 22/11&23/11 | 19.9 | 8.17 | 3.48 | 5.05 | 1.35 | 0.39 | 13.4 | 3.09 | 37.208 | 687950 | $22x10^5$ |
| 13/12&14/12 | 17.5 | 8.14 | 3.65 | 3.7 | 1.38 | 0.3 | 13.41 | 3.422 | 38.15 | 132670 | $765x10^3$ |
| 21/12&22/12 | 19.15 | 8.24 | 3.38 | 3.82 | 0.6 | 3.1 | 17.86 | 3.799 | 37.85 | 1573328 | $625x10^3$ |
| **Date/2012** | | | | | | | | | | | |
| 10/01&11/01 | 16.9 | 8.4 | 3.43 | 3.13 | 0.7 | 0.85 | 12.27 | 1.339 | 37.55 | 13538 | $15x10^4$ |
| 16/01&17/01 | 16.6 | 7.98 | 3.5 | 3.43 | 0.48 | 0.74 | 15.55 | 3.541 | 37.4 | 4760 | $24x10^4$ |
| 13/02&14/02 | 17.75 | 8.19 | 3.8 | 5.03 | 3.23 | 1.2 | 3.24 | 3.015 | 37.3 | 9045 | $115x10^5$ |
| 22/02&23/02 | 16.75 | 8.08 | 3.68 | 5.43 | 2.63 | 2.44 | 6.66 | 3.531 | 37.15 | 4298 | $3x10^4$ |
| 14/03&15/03 | 18.65 | 8.09 | 3.48 | 4.19 | 1.58 | 0.96 | 11.75 | 3.243 | 38.85 | 67095 | $9x10^4$ |
| 21/03&22/03 | 17.8 | 8.16 | 3.53 | 5.26 | 1.53 | 0.83 | 14.82 | 3.938 | 39 | 22280 | $4x10^4$ |
| 9/04&10/04 | 20.8 | 8.37 | 3.78 | 2.85 | 0.75 | 0.55 | 5.17 | 3.609 | 37.8 | 125843 | $85x10^2$ |
| 17/04&18/04 | 21.95 | 8.13 | 3.58 | 2.65 | 1.48 | 0.91 | 13.5 | 3.767 | 37.4 | 11730 | $106x10^3$ |
| 7/05&8/05 | 22.8 | 8.19 | 3.55 | 2.39 | 2.26 | 1.13 | 15.93 | 4.258 | 36.05 | 109188 | $14x10^3$ |
| 14/05&15/05 | 24 | 8.58 | 3.65 | 2.62 | 3.5 | 1.35 | 16.49 | 3.57 | 36.45 | 1531115 | $6x10^3$ |

**Table 2: Monthly average of the environmental parameters and corrosion rate in, EH front of NIOF, Alexandria-Egypt during June 2011- May 2012.**

| Date | Temp. | pH | Alk. | DO | $PO_4^{3-}$ | $NO_2^-$ | $NO_3^-$ | $SO_4^{2-}$ | S | Total Phytoplankton | Bacteria | Corr. Rate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | °C | | meq/l | m/l | µg/l | | | g/l | | Cell/l | CFU/ml | mpy |
| June | 26.9 | 8.03 | 3.225 | 5.635 | 1 | 2.344 | 4.996 | 2.806 | 37.318 | 671840 | 760000 | 7.5518 |
| July | 29.15 | 8.21 | 2.988 | 2.253 | 0.6 | 2.581 | 1.6065 | 2.167 | 37.689 | 1360135 | 3875000 | 5.4506 |
| August | 29.73 | 8.25 | 3.113 | 2.588 | 5.538 | 2.738 | 3.955 | 1.933 | 37.235 | 1303330 | 55375000 | 4.1066 |
| September | 27.725 | 8.23 | 3.2 | 4.388 | 0.963 | 1.75 | 3.485 | 2.101 | 37.143 | 20053905 | 4745000 | 3.5819 |
| October | 24 | 8.42 | 2.838 | 7.083 | 2.389 | 2.938 | 5.768 | 2.378 | 37.426 | 7236150 | 2050000 | 6.0926 |
| November | 20.725 | 8.21 | 3.35 | 4.875 | 1.038 | 0.369 | 10.676 | 3.272 | 37.154 | 2369670 | 2300000 | 3.783 |
| December | 18.325 | 8.19 | 3.513 | 3.76 | 0.989 | 1.7 | 15.633 | 3.611 | 37.999 | 3361875 | 1892500 | 4.2511 |
| January | 16.75 | 8.19 | 3.46 | 3.278 | 0.588 | 0.794 | 13.913 | 2.44 | 37.475 | 36595 | 195000 | 3.9515 |
| February | 17.25 | 8.14 | 3.74 | 5.23 | 2.925 | 1.819 | 4.948 | 3.541 | 37.225 | 26685 | 5765000 | 4.1959 |
| March | 18.23 | 8.13 | 3.5 | 4.721 | 1.55 | 0.894 | 13.282 | 3.591 | 38.925 | 178750 | 65000 | 4.3314 |
| April | 21.38 | 8.25 | 3.68 | 2.75 | 1.113 | 0.732 | 9.333 | 3.688 | 37.6 | 275145 | 57750 | 6.0855 |
| May | 23.4 | 8.39 | 3.6 | 2.504 | 2.878 | 1.238 | 16.21 | 3.914 | 36.25 | 3280605 | 10000 | 4.0145 |
| Average | 22.8 | 8.22 | 3.35 | 4.089 | 1.798 | 1.658 | 8.651 | 2.954 | 37.453 | 1843015 | 2271063 | 4.78303 |

## REFERENCES:


1. Herbert H. U. (1948) Corrosion Handbook, (John Wiley & Sons, INC, New York), 1253. www.books.google.com-HH Uhlig, RW Revie - 2011.
2. Anees U. M., Shahreer A., Ismaeel A. and Saleh Al-F. (1999) Corrosion Behaviour of Steels in Gulf Seawater environment, *Desalination*, 123, 205-213.
3. Sridhar, N., Brossia, C. S., Dunn, D. S. and Andreko, A. (2004) Predicting Localized Corrosion in Seawater, *Corrosion*, 60 (10), 915-936.
4. Farro N. W., Veleva L. and Aguilar P. (2009) Copper Marine Corrosion: I. Corrosion Rates in Atmospheric and Seawater Environments of Peruvian Port, *The Open Corrosion Journal*, 2, 130-138.
5. Tadros, A. B. and Goma, R. H. (2006) Effect of physicochemical and biological parameters of seawater on steel corrosion on laboratory scale. *4th Conference* Scientific Outlook & Technology Development in the Arab World, Syria Arab Republic, Extended Abstract, 1054-1056.
6. Aida B. T. and Hermine R. Z. T. (2009) Environmental Parameters and Steel corrosion studies of Eastern Coastal Area, Alexandria, Egypt, *Pakistan Journal of Oceanography*, 5(1&2), 29-44.
7. Aida B. T., Rokaya H. G., Hermine R. Z. T., Manal G. M., Ebtessam El-S.M. and Ahmad R. (2012) Change of the Corrosion Rate of Steel with the Sulphate Ions in Seawater, *Journal of the Arab Institute of Navigation,* 28, 7-18.
8. Zakowski K., Narozny M., Szocinski M. and Darowicki K. (2014) Influence of water salinity on corrosion risk-the case of the southern Baltic Sea coast, *Environ Monit Assess.*, 186(8), 4871–4879. http://www.ncbi.nlm.nih.gov/pubmed/?term=Narozny%20M%5Bauth%5D
9. Grasshoff K., Kremling and Ehrhardt M. (1999) Methods of seawater analysis. 3rd completely revised and extended edition, Willey-VCH. Verlag Gmbh, Germany, 634.
10. Strickland J. D. and Parsons T. R. (1972) A Practical Handbook of Sea Water Analysis.Canada Ottawa, 311.
11. American Publication Health Associations, (A.P.H.A.) (1989) Standard Methods for the Examination of Water and Wastewater, 17th ed., APHA Washington, D.C.
12. Zobell (1946) Marine Microbiology, Waltham, MA, Chronica Botanica, 240.
13. Standard Practice, for Preparing, Cleaning and Evaluating Corrosion Test Specimens (1990).
14. Robert, B. (2005) Corrosion Tests and Standards Manual: Environmental effects on corrosion, Chapter 48- steels, 559, Chapter 53- steels, 604. Copyright©2005 by ASTM International.www.astm.org.
15. Ramzy B. N., Aida B. T., Manal A. M., Mekkawy M.A. A. and Amaal E.A. A. T. (2014) Water Chemistry of Alexandria Eastern Harbour, *Global Journal of Environmental Sciences and Toxicology*, 1(2), 49-67.
16. Faragallah H. M., Tadros H. R. Z. and Okbah M.A. (2009) Nutrient salts and chlorophyll-a during short term scale in the Eastern Harbor, Alexandria (Egypt), *Egyptian Journal of Aquatic Research,* 35(3), 243-250.
17. Mareva Ch. and Frank J. M. (2007) Effect of filtration on the total alkalinity of open-ocean seawater, *Limnol. Oceanogr. Methods,* 5, 293-295.

**18.** Monica M., Anna S., Charlotte L., Bryan F. (2010) Associations among Plankton Abundance, Water Quality and Sediment Quality in the San Francisco Bay: Nitrogen and Phosphorus, *Berkeley Scientific Journal Infectious Disease*, 14 (1), 45-54.

**19.** Khairy, H. M., Hussein, N. R., Faragallah, H. M. and Dorgham, M.M. (2014) The phytoplankton communities in two eutrophic areas on the Alexandria coast, Egypt, *Revista de Biologia Marina y Oceanografia*, 49(2), 267-277.

**20.** Anderson P. and Srensen H.M. (1986) Population dynamic and trophic coapling in pelagic micro-organisms in eutrophic coastal waters, *Mar. Ecol. Prog. Ser*., 33, 90.

**21.** Thanaporn Ch-Im, Phanthitra Ph., Kamolchanok P. (2010) Effects of Environmental Parameters on Bacterial Levels in Seawater from Juvenile Green Turtle (*Chelonia mydas*) kept in Captivity, *Fisheries and Aquaculture Journal*, FAJ-9, 1-8.

**22.** Rickard D. J. D., Lasse R., Sara S. de L., Agneta A. (2013) Effect of resource availability on bacterial community responses to increased temperature, *Aquatic Microbial Ecology*, 68, 131-142.