Research Article

# Impact of Alexandria Corniche Road Widening on Mediterranean Sea Water Quality, Egypt

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## ABSTRACT

**Background**: The Corniche is the main road that runs along Alexandria's coastline. Since 1998, certain developmental activities have been undertaken along this road, aiming at widening it in order to overcome the traffic congestion and to compensate for the erosion of some beaches.

**Objectives**: to assess the impact of such developmental activities on the Mediterranean Sea water quality.

**Methods**: During the period from July 2011 to March 2012, a single water sample was collected monthly during summer and winter seasons from four chosen beaches. Sea water samples were subjected to physical, chemical and microbiological examination. Wilcoxon signed-rank test was used to determine the variation in sea water quality following Corniche Road Widening Project. Besides, an assessment of the quality of sea water in the selected beaches was carried out by comparing different measured characteristics with national and/or international standards.

**Results**: Results of the study revealed that Corniche Road Widening Project did not cause any statistically significant difference in any physicochemical characteristic of sea water in both Sidi-Bishr and Cleopatra beaches. As for Stanly beach, dissolved oxygen (DO) and nitrate increased significantly (to 7.7 ml $O_2$/L and 3.9µmole/L respectively) and, in Shatby, DO increased while turbidity and alkalinity decreased significantly. They were found to be 7.7 ml $O_2$/L, 0.045 NTU, and 1.6mEq/L respectively. Concerning the biological characteristics of sea water, there was a statistically significant difference in four parameters measured in Shatby beach. With respect to sea water quality, beaches under study were all complying with Egyptian guidelines, WHO and USEPA as regards physicochemical properties. Concerning microbiological quality, all samples were complying with WHO and EPA levels for enterococci except in August.

**Conclusion**: The study recommends the use of best management practices for all construction projects with possible impacts on water bodies, and emphasizes the importance of environmental impact assessment studies and continuous monitoring of sea water quality for public health protection.

***Key words:*** *Alexandria, biological characteristics, Corniche Road Widening Project, physicochemical characteristics, sea water quality*

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## INTRODUCTION

In Alexandria, the second largest city in Egypt and the main port, beaches extend for 50 km along the coast of the Mediterranean sea from Abu Qir in the east to El-Agami in the west (Figure 1). The coastal zone is presently experiencing two main problems resulting from natural and human activities namely beach erosion and pollution.[(1)]

The Corniche is the main road that runs along Alexandria's coastline. Since 1998, certain

developmental activities have been undertaken along this road, aiming at widening the road in order to overcome the traffic congestion and also to compensate for the erosion of some beaches. These developments have begun in March 1998 and were finished in June 2003. The width of the road was increased from 12m to a width ranging from 19.5 to 60.0 m for a total distance of 23.1 km long. The amount of thrown gravel was 1,233,000 tons and about 93,210 concrete jetties were placed. The majority of the developments occurred from SidiBishr to El-Shatby area while El-Maamoura and El-Anfoushy beaches were not involved (Figure1).[2]

Construction is a temporary activity in any given location, but its impacts can range from temporary to long-term. Impacts include both physical and chemical impacts on water bodies, and biological impacts on aquatic organisms and communities. Besides, impacts to human aquatic resource uses can include impaired drinking water supplies, recreation, navigation, fishing, water storage, aesthetics, property value, irrigation, industrial water supplies, and storm water management. Though some surface waters can eventually recover from construction discharge impacts, they may continue to be degraded by excess storm water and pollutants from buildings, roads, and other structures put in place by construction activity.[3]

Water quality monitoring is recommended for road works to provide compliance with regulatory requirements and to ensure that environmental degradation does not occur as a result of the works.[4] It also aims at protecting the public health. Its purpose is not to prohibit recreational water use but, instead to ensure that recreational areas are operated safely so that the largest population gets the maximum possible benefit.[5]

One recent study has shown that construction activities incorporating best management practices can be conducted without lasting detrimental effects on water quality.[6] Another one that is improperly designed and non-environmentally friendly sea shore facilities have created harmful impacts on the coastal ecosystem.[7] A further study detected seven construction-impacted water quality parameters. In particular, impacts on turbidity, total suspended solids, and total iron during construction, impacts on chloride and sulfate during and after construction, and impacts on acidity and nitrate after construction were observed.[8] The first study of marine sciences was in the Ancient Alexandria Library, founded in the third century at the behest of Alexander the Great. The library and the adjacent museum could be considered as the first university of the world.[9]

The aim of this study was to assess the impact of Corniche Road Widening Project on Mediterranean sea water quality.

## METHODS

**Study setting:**

The study was carried out in Alexandria beaches.

Beach inclusion criteria were as follows:

- Being within the area extending from Sidi Bishr to El-Shatby where Corniche Road widening occurred, and
- Presence of data concerning sea water quality of the beach between 1987 and 1998 (after the construction of Alexandria wastewater treatment plants and before the project of Corniche Road widening in Alexandria). This is to omit the impact of stopping the discharge of wastewater to the sea on the variation of any of the sea water characteristics.

Accordingly, four beaches, namely from east to west: Sidi Bishr, Stanly, Cleopatra and Shatby, were included in the study (Figure 1). The lengths of these beaches were 2300, 150, 20 and 140 meters respectively. The dominant prevailing current in all beaches is from west to east.

**Sampling design:**

During the period from July 2011 to March 2012, one sea water sample was collected monthly during summer and winter seasons from the bathing area of the beaches selected for the study.

**Data collection method and statistical analysis:**

Assessment of the impact of Corniche Road Widening Project has been based upon comparison of published results of previous researches[10- 13] tackling sea water quality in Alexandria between 1987 and 1998, i.e. pre-widening data, and results of the same analyses carried out during the present study i.e. post-widening data. Sea water samples were analyzed for pH, turbidity, dissolved oxygen (DO), salinity, alkalinity, ammonia, nitrate, algal

count and classification, as well as total bacterial count and *Streptococcus faecalis*. Wilcoxon signed-rank test was used to determine whether variation in sea water quality occurred following Corniche Road Widening Project or not by comparing pre-widening and post-widening data for each characteristic within each beach. Besides, an assessment of the quality of sea water in the beaches under study was carried out by comparing different measured characteristics with national and/or international standards. All analyses were carried out according to APHA, Standard Methods for the Examination of Water and Wastewater.[14]

## RESULTS AND DISCUSSION

### I- Impact of Corniche Road widening:

#### 1. Impacts on physicochemical characteristics of sea water:

As shown in table 1, Wilcoxon signed-rank test showed that the Corniche Road Widening Project did not cause any statistically significant change in any physicochemical characteristic of sea water in both Sidi Bishr and Cleopatra beaches. After the project, Cleopatra beach had a higher DO level than Sidi-Bishr beach, although they were equal before the project (figure 2). However, such variation was not found to be significant. Regarding nutrients, nitrate concentration increased in these 2 beaches over its concentration detected before the project (figure 3), but such increase also remained not significant.

This was in accordance with a seven years study (1998-2004), carried out on the coastal water of El Aqaba Gulf, that reported that the area was not impacted by the rapid recreational and human developments which took place in the last 10 years.[15]

Similarly, one research carried out in Ohio proved that some construction activities can have negligible impacts on water quality. Such results helped to strengthen the theory that construction projects utilizing appropriate Best Management Practices (BMPs) can yield minimal impact on overall water quality of surrounding water bodies.[6] BMPs include – but are not limited to - protection of stockpiles and materials from wind and rain by storing them under secured plastic sheeting or temporary roofs, checking thoroughly and frequently for leaks, cleaning up spills immediately, disposing of all waste properly, and recycling construction materials, including solvents, water-based paints, vehicle fluids, broken asphalt and concrete, wood, and cleared vegetation.[16] In addition to the application of BMPs, the absence of significant impact of the project under study on sea water quality in Alexandria could be attributed to wave action: a study on Elba Island in Italy found out that sediments used for beach nourishment were initially incompatible with the parent beach because they were droved from natural deposits from offshore, inland deposits or dredged material from navigation process. Fortunately, wave action could overcome this problem with time.[17]

As for the other two beaches under study, a significant difference was observed in some water parameters after implementation of the project (Table 1, figures 2 - 4): In Stanly beach, DO and nitrate increased significantly ($p < .05$). In Shatby, DO increased while turbidity and alkalinity decreased significantly ($p < .05$). The increase in DO in Shatby beach could be attributed to the decrease in turbidity thus allowing more sunlight to penetrate into the sea water and enhancing algal photosynthetic activity. As regards Stanly beach, no pre-widening data concerning turbidity were available so as to make the same correlation between DO increase and turbidity decrease.

An environmental impact assessment study for a construction project nearby the Mississippi River considered the main impact to be that on water quality due to generation of construction runoff.

This runoff might contain high concentrations of suspended solids and contaminants. Potential sources include erosion from site surface, earth working area, wash-water from dust suppression, fuel, oil and lubricants from maintenance of construction vehicles and equipment.[18] As concerns the present research, it was clear that discharge of suspended solids to the sea was controlled and neither increase in turbidity nor decrease in DO level was observed in the beaches under study.

#### I. 2. Impacts on biological characteristics of sea water:

As shown in table 2, only one beach, namely Shatby, was included in the study according to the inclusion criteria adopted. Wilcoxon signed-rank test showed that there is a statistically

significant difference in four biological characteristics (Heterotrophic Plate Count (HPC), enterococci most probable number/100ml, total algal count and Diatoms count) of sea water in Shatby beach. The first two parameters showed a decrease in pattern while total algal count and diatoms showed an increase in pattern. Reduction of Heterotrophic Plate Count and of enterococci most probable number/100ml could not be considered attributed to the project, but to a better wastewater management system in Alexandria City. This better management would lead to the significant decrease in turbidity detected in this beach (Table 1), allowing more sunlight to penetrate and creating favorable condition for algae to increase significantly (Table 2) and to carry out photosynthesis producing more DO which also showed a significant increase in this beach (Table 1).

This was in contrast to a study on the Red Sea beaches that reported that improperly designed and non-environmentally-friendly sea shore recreation facilities have created harmful impacts on the coastal ecosystem, such as deteriorating water quality, changing the marine biota, altering the depositional-hydrodynamic regime as a result of blocking littoral currents by protruding structures, and creating down-drift erosion to the neighboring beaches.[7]

**II- Assessment of sea water quality after Corniche Road widening according to national and international standards:**

In addition to the determination of the impact of Corniche Road Widening Project on the quality of sea water in Alexandria, assessment of this quality was determined according to national (Egyptian Environmental Law 4/94 and its amendment law 9/2009[19]) and international (World Health Organization[20] and US Environmental Protection Agency [21]) guidelines as shown in table 3.

First, pH was within the guideline values in the four beaches under study and during all study period. It was ranging between 7.5 and 8.4.

Second, as regards turbidity, it was stated in the EPA guidelines from the ecosystem approach: it should not exceed 25 NTU for salt water aquatic life so as not to hinder photosynthesis of aquatic plants, the main producer of dissolved oxygen in water. Alexandria beaches under study were all complying with this level and turbidity was varying between 0.01 and 0.4 NTU for the whole study period.

Dissolved oxygen levels are strongly influenced by point source discharges and for that reason the US EPA uses DO in preliminary evaluation of in-stream water quality. Pollutants from rain water runoff and point-source wastewater discharges contain organic materials and nutrients that contribute to consumption of dissolved oxygen. Dissolved oxygen concentrations below 5 milligrams per liter are considered to be unhealthy for many aquatic biota. When the level of dissolved oxygen falls to 2 mg/l, severe physiological stress to marine organisms occurs and death may result. For these reasons, the amount of dissolved oxygen in water is a good indicator of its quality. [22] In the present study, DO level was found to drop below the 5 mg/L level only once, and it was in Cleopatra beach. Reasons for such drop were not clear but recovery occurred in the following month and DO was measured to be 7.5 mg/L.

While an appropriate concentration of salts is vital for aquatic plants and animals, salinity that is beyond the normal range for any species of organism will cause stress or even death to that organism. Results of this study showed salinity values in the range of 32–46‰, which is normal for coastal water.

Ammonia occurs naturally in water bodies as a result of the breakdown of organic and inorganic matter in soil and water, excretion from living organisms, and reduction of atmospheric nitrogen by microorganisms. Total ammonia concentrations in surface waters are typically less than 0.2 mg/l but may reach 2-3 mg/l. Higher concentrations could be an indicator of pollution such as domestic sewage, industrial waste, or fertilizer runoff.[23] Ammonium ion is less toxic than $NH_3$, both of them exist in equilibrium in aqueous solutions and the concentration of each form depends upon pH level of the solution. Therefore, criteria for total ammonia have been established by the EPA, to reflect the varying toxicity of $NH_3$ with pH. Criteria have been set for the protection of aquatic life, and tabulated for a pH range from 6.5 to 9.0 and a water temperature range from 0 to 30 °C.[24] According to water temperature and pH recorded during the study period, ammonia concentrations were complying with these criteria in all analyzed samples. Regarding nitrates, their natural levels in

surface waters seldom exceed 0.1 mg/l as N, but waters influenced by human activity normally contain up to 5 mg/l as N. When such value exceeds 5 mg/l, it may be and indicator for pollution by animal or human waste or from fertilizer runoff.[25] In Egypt, EEAA has set a maximum level of nitrate in recreational water as 40 mg/L and all beaches under study were far below such limit.

Finally, with respect to microbiological quality of sea water, all samples were complying with WHO and EPA levels for enterococci (40/100 ml and 35/100 ml respectively) except in August where Sidi Bishr and Cleopatra samples showed enterococci most probable number of 2400/100 ml. In Stanly beach, it was 210/100 ml. This could be due to bathers' contamination i.e. high number of swimmers using these beaches in the summer season. Results of samples collected in the following month for the same beaches revealed a decline in enterococci MPN/100ml to an acceptable level: 20/100ml for Sidi Bishr, 6.8/100ml for Cleopatra and 14/100ml for Stanly.

The most frequent adverse health outcome associated with exposure to fecally contaminated recreational water is enteric illness. A cause–effect relationship between bather-derived pollution and acute febrile respiratory illness (AFRI), which is a more severe health outcome than gastroenteritis, has been shown. For marine waters, only intestinal enterococci (fecal streptococci) showed a dose–response relationship for both gastrointestinal illness and AFRI. This was the reason why WHO has incorporated it as one of the guidelines for safe recreational water.[20]

Algal count was not stated in any guideline for surface water quality. However, the WHO reported that marine cyanobacterial dermatitis ("swimmers' itch" or "seaweed dermatitis") is a severe contact dermatitis that may occur after swimming in seas containing blooms of certain species of marine cyanobacteria (blue green algae). The symptoms are itching and burning within a few minutes to a few hours after swimming in the sea where the cyanobacteria are suspended. Within areas subject to the occurrence of marine toxic algae or cyanobacteria, it is important to carry out adequate monitoring activities and surveillance programmes. In affected areas, it is appropriate to provide health information to general practitioners and the general public, in particular recreational water users. Precautionary measures include avoiding areas with visible algal concentrations and/or algal scums in the sea as well as on the shore, avoiding sitting downwind of any algal material drying on the shore and showering to remove any algal material. [20] All these measures should be applied all over Alexandria beaches since blue green algae were found in many water samples all over the study period and in all studied beaches, but with no significant difference from their number before implementation of the project.

## CONCLUSION AND RECOMMENDATION

Corniche Road Widening Project did not cause any statistically significant change in any physicochemical characteristic of sea water in both Sidi Bishr and Cleopatra beaches. As for Stanly beach, DO and nitrate increased significantly and in Shatby, DO increased while turbidity and alkalinity decreased significantly from the pre-widening data collected.

Concerning the biological characteristics of sea water, there was a statistically significant change in four parameters measured in Shatby beach. They are the Heterotrophic Plate Count, enterococci most probable number/100ml, total algal count and diatoms count. The first two parameters showed a decrease in pattern while total algal count and diatoms showed an increase pattern. Reduction of Heterotrophic Plate Count and of enterococci most probable number/100ml could not be considered attributed to the project, but to a better wastewater management system in Alexandria city.

With respect to sea water quality, beaches under study were all complying with Egyptian guidelines, WHO and USEPA as regards physicochemical properties. As regards microbiological quality, all samples were complying with WHO and EPA levels for enterococci except in August for Sidi Bishr, Cleopatra and Stanly beaches. In addition, blue green algae were detected in all studied beaches, but with no significant difference from their number before implementation of the project.

The study recommends the use of Best Management Practices for all construction projects with possible impacts on water bodies, and emphasizes the importance of environmental impact assessment studies and continuous monitoring of sea water quality for public health protection.


**Figure 1**: Alexandria map showing main beaches and the location of sampling sites

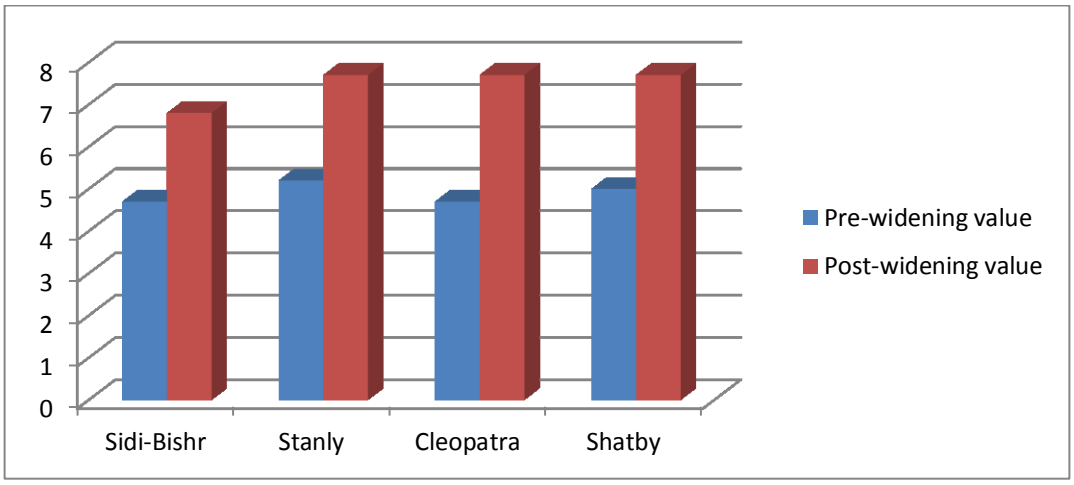


**Figure 2**: Variation in dissolved oxygen (ml $O_2$/L) in four beaches in Alexandria, Egypt, after Corniche Road widening

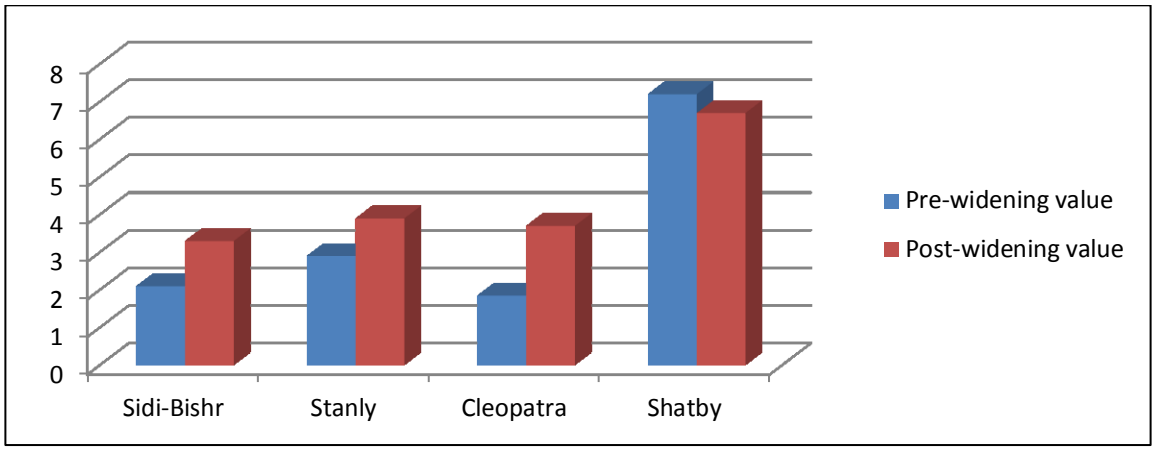


**Figure 3**: Variation in nitrate (µmole/L) in four beaches in Alexandria, Egypt, after Corniche Road widening

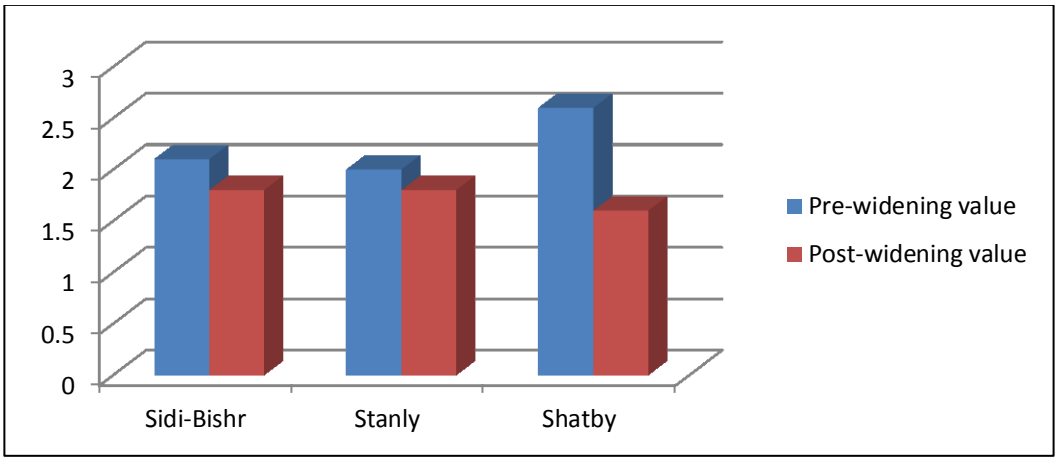


**Figure 4:** Variation in alkalinity (ml.Eq/L) in three beaches in Alexandria, Egypt, after Corniche Road widening

**Table 1:** Variation in sea water quality after Corniche Road Widening according to physicochemical characteristics and place, Alexandria, Egypt

| Characteristics | Descriptive statistics | Beaches | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sidi Bishr | | Stanly | | Cleopatra | | Shatby | |
| | | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| pH | Minimum | 7.9 | 8 | 7.9 | 7.8 | 7.8 | 7.5 | 7.2 | 7.8 |
| | Maximum | 8.3 | 8.4 | 8.3 | 8.3 | 8.2 | 8.4 | 8.9 | 8.4 |
| Turbidity, NTU | Minimum | - | 0.01 | - | 0.01 | - | 0.01 | 1.5 | 0.01 |
| | Maximum | - | 2.3 | - | 0.11 | - | 0.4 | 5 | 0.1 |
| | Median | - | 0.4 | - | 0.1 | - | 0.1 | 3 | 0.045* |
| Dissolved Oxygen, ml $O_2$/L | Minimum | 4.1 | 3.2 | 4.3 | 5.4 | 4 | 0 | 4 | 4.3 |
| | Maximum | 5.9 | 11.4 | 7.2 | 9.7 | 7.6 | 8.3 | 10.3 | 9.2 |
| | Median | 4.7 | 6.8 | 5.2 | 7.7** | 4.7 | 7.7 | 5 | 7.7* |
| Salinity, ‰ | Minimum | 37.5 | 35.7 | 37 | 33 | 35 | 36 | 35.5 | 32 |
| | Maximum | 39 | 46 | 40 | 45 | 39 | 45.5 | 41.8 | 45 |
| | Median | 38.9 | 41.8 | 38.8 | 39.5 | 38 | 42.7 | 38.5 | 40.75 |
| Alkalinity, ml.eq/L | Minimum | 1.7 | 0.7 | 0.7 | 0.7 | - | 0.2 | 2.2 | 0.5 |
| | Maximum | 2.5 | 5.5 | 2.7 | 2.8 | - | 2.75 | 3.3 | 2.9 |
| | Median | 2.1 | 1.8 | 2 | 1.8 | - | 2.3 | 2.6 | 1.6* |
| Ammonia, µmole/L | Minimum | 2.5 | 0.5 | 2.7 | 0.6 | - | 0.3 | 1.7 | 0.7 |
| | Maximum | 8 | 11 | 10.3 | 6.1 | - | 4.5 | 23.2 | 6.8 |
| | Median | 5 | 2.4 | 3.6 | 2.8 | - | 2.3 | 6.35 | 3.15 |
| Nitrate, µmole/L | Minimum | 0.8 | 4.9 | 1 | 1.1 | 0.3 | 0.8 | 3.3 | 1.2 |
| | Maximum | 0.8 | 5.1 | 14.6 | 9.4 | 11.9 | 11 | 18 | 13.9 |
| | Median | 2.1 | 3.3 | 2.9 | 3.9* | 1.85 | 3.7 | 7.2 | 6.7 |

* Significant difference at the P<0.05

** Significant difference at the P<0.01

**Table 2:** Variation in sea water quality after Corniche Road widening according to biological characteristics in Shatby Beach, Alexandria, Egypt

| Biological Characteristics | Descriptive statistics | Shatby Beach | | |
|---|---|---|---|---|
| | | Pre | Post | p-value |
| Heterotrophic Plate Count, CFU/ ml | Minimum | 1.5E+3 | 7 | .043* |
| | Maximum | 1.1E+5 | 2.3E+2 | |
| Enterococcci, MPN/100 ml | Minimum | 1.2E+2 | 8 | .028* |
| | Maximum | 8.3E+2 | 24 | |
| Green Algae | Minimum | 0 | 0 | .465 |
| | Maximum | 2.6E+4 | 3.9E+4 | |
| Blue Green Algae | Minimum | 0 | 0 | .273 |
| | Maximum | 1.3E+4 | 2.7E+4 | |
| Diatoms | Minimum | 1.8E+3 | 9.0E+3 | .046* |
| | Maximum | 1.5E+6 | 2.1E+5 | |

* Significant difference at the P<.05

**Table 3:** Assessment of the quality of Mediterranean Sea water, Alexandria, Egypt

| Characteristics | Alexandria Beaches | Law 9/2009 [19] | WHO Guidelines [20] | EPA Guidelines [21] |
|---|---|---|---|---|
| pH | 7.5 - 8.4 | 6-9 | 6.5-8.5 | 6 – 8.5 |
| Turbidity, NTU | 0.01 – 0.4 | NM* | NM* | 25 NTU |
| Dissolved Oxygen, ml $O_2$/L | 0 – 11.4 | NM* | NM* | Not less than 5 mg/L (3.5 ml $O_2$/L) |
| Salinity, ‰ | 32 - 46 | NM* | NM* | NM* |
| Alkalinity, ml.eq/L | 0.2 – 5.5 | NM* | NM* | NM* |
| Ammonia, µmole/L | 0.3 - 11 | NM* | Different values according to pH | NM* |
| Nitrate, µmole/L | 1.1 – 13.9 | Not more than 40 mg/l (2.5E+6 µmole/L) | NM* | NM* |
| Heterotrophic Plate Count, CFU/ ml | 7 – 1.5E+3 | NM* | NM* | NM* |
| Enterococcci, MPN/100 ml | 2 – 2.4E+3 | NM* | 40 | 35 |
| Green Algae | 0 – 1.2E+5 | NM* | NM* | NM* |
| Blue Green Algae | 0 – 2.7E+4 | NM* | NM* | NM* |

* NM = Not mentioned

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