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Bacteria and Nutrients as Pollution Indicators in the Al-Nawrus Recreational Lagoon, Jeddah

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Abststract. Environmental pollution that renders shore waters unsatisfactory for public use has become a global health problem. This study was carried out to examine certain pollution-indicating water quality parameters in sampling stations located at Al-Nawrus lagoon (North of Jeddah) during June 2005 - January 2006. These parameters included: aerobic heterotrophic bacteria, total coliform (TC), fecal coliform (FC), dissolved oxygen (DO), and nutrients (NO_2-N, NO_3-N, NH_4-N and PO_4-P). DO and nutrient concentrations varied greatly in the water at different sampling stations compared with their respected values in the open sea. A comparison of the mean values of nutrients in Al-Nawrus lagoon with those of other locations in the Red Sea suggests that the mean levels of NO_3 were similar to those of polluted areas, whereas mean concentrations of NO_2, NH_4 and PO_4 were generally similar to those of unpolluted or slightly polluted areas. Counts of aerobic heterotrophic bacteria, TC and FC did not show any seasonal pattern. Highest counts of aerobic heterotrophic bacteria were obtained at stations towards the north and the lowest were recorded at stations toward the south. Similarly, TC and FC counts were higher at the north sampling stations than the south ones, and with little variations between their numbers. FC was not recovered at stations to the south. The study shows that aerobic heterotrophic bacteria, except at certain sampling stations similar to the levels reported for normal unpolluted sea water.

Keywords: Pollution, Nutrients, Coliforms, Aerobic heterotrophic bacteria Al-Nawrus Lagoon, Red Sea.

Introduction

Coastline alteration from dredging, filling and construction is one of the environmental problems causing massive destruction of marine life and key habitats in several locations along the Saudi coastal line of the Red Sea and the Arabian Gulf. Extensive coastline modifications have been carried out on an increasing scale in Jeddah. Currently, the original coastline has been completely altered by dredging and filling operations.

Jeddah is a huge metropolitan area with an estimated population of 3 millions. Several recreational cities and centres have been developed along the Jeddah coastline without adequate evaluation of potential environmental impacts (UNEP, 1997). One of the main sources of coastal pollution in Jeddah is the discharge of poorly treated or untreated sewage effluents into coastal waters. Pollution due to sewage discharge in Jeddah, and the consequent damage to marine life, is well documented at the Southern Corniche area (El Sayed and Niaz, 1999, and El Sayed, 2002 a&b), at the Al-Arbaeen Lagoon (El Rayis, *et al*., 1984, Basaham, 1998; and El Sayed, 2002c) and at the Al-Shabab Lagoon (Turki *et al*., 2002; El Sayed, 2002c; and Turki, 2006).

Recreational waters generally contain assorted microbes whether indigenous or derived from external discharges such as sewage, industry, farming, and others. This microbial mixture can present a hazard to bathers when an effective dose of pathogen colonize a suitable growth site in the body and lead to a disease (WHO, 1998; and Elmanama, *et al.,* 2005).

The extent of seawater pollution varies according to the quality and quantity of pollutants. However, the problem of seawater pollution is acknowledged worldwide. As a result of recreational activities, many individuals may contract diseases that may range from self-limiting gastrointestinal disturbance to severe and life-threatening infections. The disease incidence is dependent on several factors, such as the extent and type of water pollution, the time and type of exposure, the immune status of users, and other factors (Bartram and Rees, 2000; and Elmanama *et al.,* 2005).

Seawater and beach quality monitoring and assessment are considered vital parts of any integrated coastal management program (Afifi *et al.,* 2000). Extensive research with the aim of establishing guidelines and standards for recreational water quality has been conducted all over the world (Elmanama *et al.*, 2005).

The public has become increasingly aware of the potential health hazard of fecal contamination of water. This heightened awareness is resulting in an increased frequency of water quality monitoring for pollution-indicating FC (Devane *et al.,* 2007).

Lagoons are semi-enclosed systems displaying a wide range of physical and chemical characteristics. Like many natural resources, many lagoons have deteriorated due to waste disposal and recreation (Yilmaz *et al.,* 2004).

In several estuaries, especially in the ones with low water turnover, phytoplankton production may considerably increase leading to endemic anoxic episodes. Capuzzo and Kester (1987) discuss that the ocean dumping of sludge raises environmental concern such as bioaccumulation and biomagnifications of pathogenic organisms and chemical contaminants, elevation of suspended matter with the associated turbidity, and nutrient enrichment with the resulting eutrophication, and oxygen depletion (Braga *et al.,* 2000).

Monitoring nutrient concentration in seawater is very important in verifying the pollution impact on the coastal system, because they reflect on terrestrial input and recycling of these nutrients in the coastal waters (Braga *et al.,* 2000).

Al-Nawrus lagoon is a shallow semi-enclosed coastal lagoon on the Red Sea coast of Jeddah (Fig. 1). The lagoon is approximately 1250 m long, and ~80 m width, with an average depth of 3.5 m. The lagoon is open to the sea at the southern end, and is closed at the northern side. However, at present, there is limited exchange of water at the northern dead end through pipes. This lagoon is an important recreational area and offers some water sports like fishing, boating and skiing. Despite its importance, there is a lack of sound water quality monitoring. This could lead to serious environmental and health concerns.

The present work, therefore, is carried out to analyse pollution-indicating water quality parameters in order to assess any deviation from normal, that indicates any environmental problems and to suggest any remedial action needed.

Materials and Methods

Sampling and Analytical Methods

Water samples were collected on three sampling dates during June and October 2005 and January 2006 (Fig. 1). Fourteen sampling stations were established and were regularly spaced from each other. One of the sampling stations was the open sea and served as control. The parameters analysed included: aerobic heterotrophic bacteria, total coliform (TC), fecal coliform (FC), dissolved oxygen (DO), and nutrients (NO_2-N, NO_3-N, NH_4-N and PO_4-P).

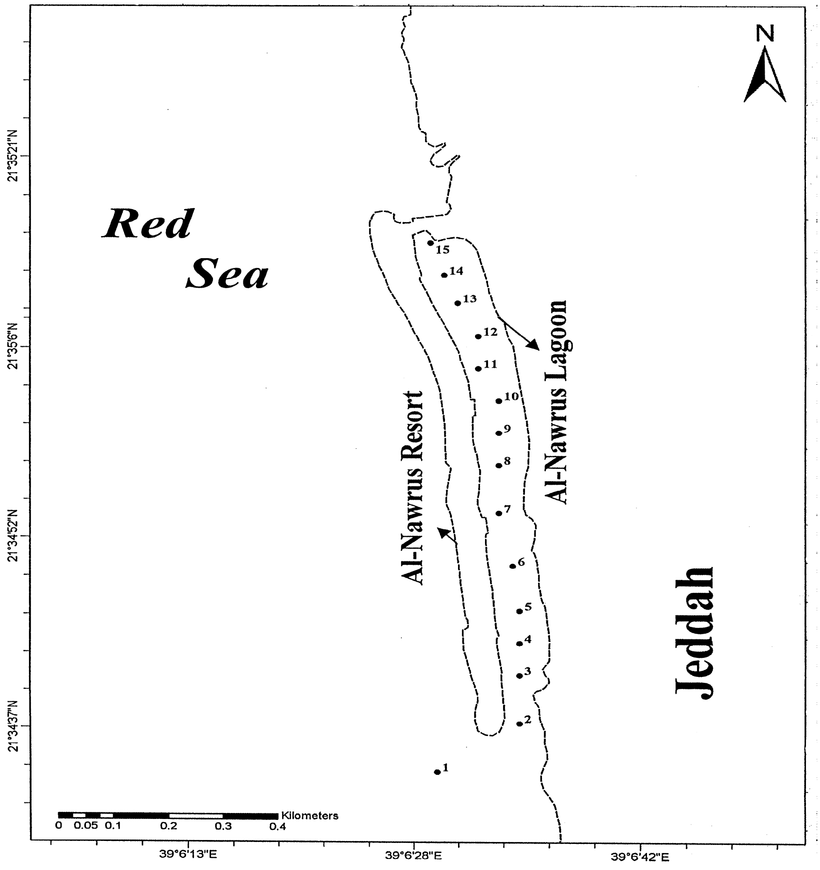

Fig. 1. Map of the study area, showing sampling stations.

Populations of aerobic heterotrophic bacteria were estimated using a spread plate technique on marine agar (Difco 2216E), nutrient agar and medium A_3 (Mudarris, 1997). Three replicates were used for each dilution and the bacteria enumerated following incubation at 20°C in a thermostatically-controlled incubator. Plates were observed for 2 weeks. The membrane filtration technique was used for quantification of TC and FC (APHA, 1998; and Niemi *et al.,* 2001).

Water samples from the lagoon were collected and preserved in the appropriate containers for chemical analysis (Aminot and Chaussepied, 1983), whereas samples for bacteriological analysis were collected by hand in sterile 200 ml bottles which are closed just below the water surface. The samples were transported in ice box back to the laboratory.

Dissolved oxygen (DO) content in the water samples was determined with the conventional Winkler's method and back titration of liberated iodine respectively, according to Anderson and Foyen (1969). The water samples for NO_2, NO_3, NH_4 and PO_4 determinations were analyzed according to the recommended methods complied by Parsons *et al*., (1984) using a Pye-Unicam Spectrophotometer (Model PU-8600).

Data Analysis

Correlation between chemical parameters and bacterial density was carried out using the Pearson coefficient, by performing pair-wise tests.

Results and Discussion

Bacterial Distribution

Total bacterial counts from the 15 sampling stations at the Al-Nawrus lagoon, Jeddah (Fig. 1) are shown in Table 1. It may be seen that the number of bacteria recovered from the fifteen stations sampled in Al-Nawrus lagoon showed high variation through out the study period. The highest counts of heterotrophic bacteria were obtained at the northern sampling stations (14-15), at $\times 10^5$-10^6 colony-forming units (CFU) / ml. Conversely, the lowest numbers were recorded at the southernmost sampling stations (stations 1 to 5). The TC and FC counts showed little variation during the study period (Table 1); with the highest counts of TC at approximately $\times 10^2$ CFU/100 ml at the northern stations 15 and 14. The lowest counts were obtained at the southernmost stations 1 and 4. In addition, FC were not recovered from stations 1, 2, 3, 4 and 5 throughout the study period. However, the highest FC counts were obtained at the last two northern stations (stations 15 and 14), at approximately $\times 10$ CFU / 100 ml of seawater.

Table 1. Total number of aerobic heterotrophic, TC and FC enumerated during the survey at various stations located in Al-Nawrus lagoon during the period of the study.

Sample no.	June 2005			October 2005			January 2006		
	Number of aerobic heterotrophic bacteria ($\times 10^3$/ml)	Number of TC (× 10/100ml)	Number of FC (× 10/100ml)	Number of aerobic heterotrophic bacteria ($\times 10^3$/ml)	Number of TC (× 10/100ml)	Number of FC (× 10/100ml)	Number of aerobic heterotrophic bacteria ($\times 10^3$/ml)	Number of TC (× 10/100ml)	Number of FC (× 10/100ml)
1	2.0	1.0	0.0	1.2	1.0	0.0	0.8	0.0	0.0
2	3.5	1.0	0.0	2.0	2.0	0.0	3.0	1.0	0.0
3	6.5	2.0	0.0	5.0	1.0	0.0	4.0	2.0	0.0
4	7.0	1.0	0.0	8.0	1.0	0.0	7.2	1.0	0.0
5	8.0	2.0	0.0	7.0	1.0	0.0	6.5	1.0	0.0
6	2.0	1.0	0.5	17	2.0	0.0	18	1.0	0.0
7	30	3.0	0.5	50	3.0	0.0	60	4.0	1.0
8	90	2.0	0.0	80	3.0	0.0	90	3.0	0.5
9	100	2.0	0.0	150	2.0	0.5	82	2.0	1.0
10	250	4.0	1.0	200	4.0	0.5	130	2.0	0.5
11	310	7.0	2.0	350	4.0	1.0	280	5.0	2.0
12	400	6.0	1.0	600	5.0	1.0	390	7.0	1.0
13	510	14	2.0	500	7.0	1.0	400	7.0	1.0
14	700	15	4.0	730	10	3.0	750	15	5.0
15	1500	18	6.0	800	17	4.0	1000	20	4.0

Total number of aerobic heterotrophic bacteria TC and FC did not show any seasonal distribution. Bacterial counts remain to the same order of magnitude during the three sampling months of June, October and January.

From the results of the present study, it was apparent that the largest water-borne bacterial populations at some stations were higher than the maximum levels reported for normal unpolluted sea water of the Red Sea (Mudarris, 1997). A similar number was obtained from polluted sea water along the Indian coast (Ramaiah *et al.,* 2002). On the other hand, bacterial density reported in this study is not different from densities reported in normal sea water in other areas (Simidu *et al.*, 1977; Patrick, 1978; Kogure *et al.*, 1980; and Mudarris and Austin, 1988).

Lack of seasonal distribution is to be expected because temperature in the Jeddah coastal waters is normally high, varying between 26°C and 30°C (Al-Barakati *et al.,* 2002). Mesophilic bacteria grow equally well between temperatures of 15 and 36°C. This was also reported in a study carried out in the Jeddah coastal waters (Mandura *et al.*, 1994). The TC and FC contamination found in the present study did not exceed the specified recommended limits of coliform bacteria for bathing beaches guidelines established by the EEC (TC < 500/100 ml and FC < 100/100 ml for 80% of samples) and the Presidency of Meteorology and Environment (PME) of Saudi Arabia guidelines for plants effluents (PME, 2003). The WHO (1977a, b) put a guideline for classification and action in which water samples containing 2000 FC /100 ml should be deemed heavily polluted. In addition, FC counts of 1000-2000 / 100 ml are considered to represent distinct pollution. Counts between 201-999 FC / 100 ml would indicate moderate pollution, and counts of 50-200 / 100 ml would indicate slight pollution.

It is seen that the most of the stations to the south are not polluted but only two stations towards the north are slightly polluted (14 and 15). However, even with this level of pollution, it is not suitable to swim around.

Distribution of Dissolved Oxygen and Nutrients

Results of dissolved oxygen (DO), dissolved inorganic nitrogen (NO_2, NO_3, NH_4) and reactive phosphate (PO_4) contents, at each station, in the surface waters of Al-Nawrus lagoon, during June, October 2005 and January 2006, are presented in Table 2. In general, DO and nutrient concentrations varied greatly in water samples in Al-Nawrus lagoon compared with values in the open sea (station 1). The lagoon shows an increase in the concentration of nutrients and at times decrease in the oxygen content of the samples. This is probably due to accelerated organic decomposition in the lagoon leading to oxygen consumption and release of inorganic nutrients. DO concentration in the lagoon was in general close to that of the open sea except for 3 sampling dates in June, probably a result of some stagnation and elevated summer temperature. The mean, minimum, maximum and standard deviation values of DO, NO_2, NO_3, NH_4 and PO_4, in the water sample (stations 2-15) from Al-Nawrus lagoon are listed in Table 2. The oxygen and nutrients concentrations were: DO, 1.1-4.2 mg/l; NO_2-N, 0.01-0.07 µmol/l; NO_3-N, 0.17-3.70 µmol/l; NH_4-N, 0.13-2.49 µmo/l; PO_4-P, 0.05-0.93 µmol/l. Station 1 in the open sea can be considered to reflect background levels of dissolved oxygen and nutrients.

Average nutrient concentrations from this study are compared to results reported from a number of locations in the Red Sea at Jeddah (Table 3).

NO_2: Al-Nawrus lagoon waters contain concentrations of NO_2 (0.13 µmol/l) which is about an order of magnitude greater than those of waters from unpolluted coastal areas at Jeddah (*e.g.* Sharm Obhur, 0.02 µmol/l). Waters from the Al-Arbaeen lagoon, which is highly regarded as polluted however, contain higher concentrations (0.3 µmol/l). The content of NO_2 in Al-Nawrus waters are comparable to those found at other coastal areas of Jeddah such as those close to the entrance of Al-Shabab lagoon (0.2 µmol/l).

NO_3: The mean NO_3 concentrations in Al-Nawrus water (2.09 µmol/l) is slightly lower than the 2.7 umol/l reported for the polluted waters from Al-Arbaeen lagoon, but higher than those of the Red Sea coastal waters (near the entrance of Al-Arbaeen and Al-Shabab lagoons, 1.1 and 0.3 µmol/l, respectively) or the unpolluted coast of Jeddah (1.3 µmol/l). Waters from Al-Shabab lagoon, which are mainly influenced by domestic wastewater, contain comparable NO_3 concentrations (1.8 µmol/l) to those measured in Al-Nawrus lagoon.

Table 2. Concentration of dissolved oxygen and nutrients (nitrogen and phosphorus species) during the survey at various stations located in El-Nawrus lagoon.

Sample no.	June 2005					October 2005					January 2006				
	DO mg/l	NO_2-N µmol/l	NO_3-N µmol/l	NH_4-N µmol/l	PO_4-P µmol/l	DO mg/l	NO_2-N µmol/l	NO_3-N µmol/l	NH_4-N µmol/l	PO_4-P µmol/l	DO mg/l	NO_2-N µmol/l	NO_3-N µmol/l	NH_4-N µmol/l	PO_4-P µmol/l
1	4.1	0.02	0.60	0.15	0.10	4.2	0.01	0.56	0.13	0.08	4.2	0.02	0.70	0.19	0.13
2	3.8	0.04	1.00	0.27	0.08	4.1	0.02	1.30	0.74	0.17	4.1	0.09	1.53	0.67	0.16
3	3.6	0.07	0.87	0.85	0.06	4.2	0.05	1.60	0.91	0.29	4.0	0.20	1.82	0.83	0.30
4	3.5	0.05	0.69	0.20	0.15	3.8	0.06	1.43	1.20	0.31	3.9	0.18	1.65	1.47	0.25
5	3.7	0.05	0.70	0.22	0.15	3.9	0.08	1.20	1.39	0.37	3.8	0.18	1.82	1.85	0.40
6	4.2	0.06	2.30	0.20	0.05	4.1	0.04	2.25	1.51	0.13	4.0	0.13	2.14	1.96	0.14
7	3.6	0.04	1.05	0.50	0.10	3.9	0.02	2.10	2.11	0.92	3.7	0.10	1.82	1.38	0.83
8	3.4	0.03	0.84	0.20	0.08	3.8	0.04	2.21	1.22	0.93	3.6	0.12	2.05	1.05	0.57
9	2.5	0.02	0.21	1.73	0.20	3.9	0.06	2.30	2.49	0.46	3.5	0.14	2.24	2.33	0.35
10	2.4	0.02	0.17	1.68	0.18	3.8	0.03	2.32	2.35	0.39	3.2	0.08	2.41	1.29	0.27
11	1.1	0.03	0.18	1.73	0.17	4.0	0.06	2.40	2.28	0.50	3.6	0.14	3.64	1.63	0.40
12	3.1	0.04	0.75	0.23	0.15	3.8	0.05	2.62	1.35	0.47	3.5	0.12	2.75	1.23	0.32
13	3.8	0.04	0.65	0.47	0.10	4.0	0.04	3.70	2.20	0.54	3.3	0.16	2.20	1.53	0.55
14	3.4	0.05	0.88	0.39	0.10	4.2	0.10	1.10	1.52	0.71	4.1	0.14	2.20	1.32	0.61
15	3.7	0.08	0.90	0.40	0.15	4.1	0.09	2.05	1.87	0.62	4.0	0.13	2.42	1.40	0.49
Mean	3.3	0.04	0.79	0.61	0.12	3.99	0.05	1.94	1.55	0.46	3.77	0.13	2.09	1.34	0.38
Min	1.1	0.02	0.17	0.15	0.05	3.80	0.01	0.56	0.13	0.08	3.20	0.02	0.70	0.19	0.13
Max	4.2	0.07	2.30	1.73	0.20	4.2	0.10	3.70	2.49	0.93	4.20	0.20	3.64	2.33	0.83

Table 3. Average concentrations (µmol/l) of nutrients in Al-Nawrus lagoon compared with those found in some Jeddah lagoons, Jeddah coast, Sharm Obhour and oceanic Red Sea.

Location	NO_2-N (µmol/l)	NO_3-N (µmol/l)	NH_4-N (µmol/l)	PO_4-P (µmol/l)	Ref.	Comment
Al-Arbaeen Lagoon	3.0	2.7	466	44.1	1	highly polluted
Al-Shbab Lagoon	0.4	1.8	62	20.2	1	highly polluted
Red Sea Coastal water (near the entrance of Al-Arbaeen Lagoon)	0.6	1.1	10	0.6	1	slightly polluted
Red Sea Coastal water (near the entrance of Al-Shabab Lagoon)	0.2	0.3	3	0.4	1	slightly polluted
Jeddah Coast (offshore waters)	0.2	1.3	1.0	0.9	1	polluted
Sharm Obhour	0.02	0.7	2.0	0.2	1	unpolluted (NO_2, NO_3, PO_4)
Oceanic Central Red Sea	–	0.2	–	0.1	2	unpolluted
El-Nawrus Lagoon	0.13	2.09	1.55	0.46	3	

1. El Rayis, 1998. 2. Edwards & Head, 1987. 3. Present study

NH_4: The NH_4 contents found in Al-Nawrus lagoon waters (1.55 µmol/l) are higher than those found in the polluted waters of Jeddah coast (1.0 µmol/l) but lower than those of highly polluted waters of Al-Arbaeen and Al-Shabab lagoons (466 and 62 µmol/l, respectively). Concentration of NH_4 found in the present study is comparable to those found in Sharm Obhur (2.0 µmol/l) or the entrance of Al-Shabab lagoon (3.0 µmol/l). Both locations are regarded as slightly polluted.

PO_4: The mean PO_4 concentration of 0.46 µmol/l reported for the waters of Al-Nawrus lagoon is lower than those reported for polluted waters from Al-Arbaeen and Al-Shabab lagoons (44.1 and 20.2 µmol/l, respectively). The content of PO_4 in Al-Nawrus waters are higher than those found in unpolluted waters of Sharm Obhur (0.2 µmol/l) and the oceanic central Red Sea (0.1 µmol/l), but are comparable to those found in the slightly polluted areas, such as those of the Red Sea coastal water near Al-Arbaeen (0.6 µmol/l) and Al-Shabab (0.4 µmol/l) lagoons.

In summary, comparison of the nutrient concentrations in Al-Nawrus lagoon with data from similar environments at Jeddah Red Sea coast suggests that mean levels of NO_3 is similar in magnitude to those of polluted areas, while NO_2, NH_4 and PO_4 concentrations are generally similar to those of slightly polluted areas.

Relationships between Chemical and Bacteriological Parameters

In the present study a correlation matrix was produced to investigate the relationship between the concentrations of DO, nutrients and the bacterial densities, in the water samples from Al-Nawrus lagoon (Table 4). It can be seen from the data in Table 4 that relationship, between bacterial density and chemical parameters studied may be a consequence of the complexity of the Al-Nawrus ecosystem. During July 2005**,** DO and NO_3 concentrations are positively correlated to one another ($P < 0.01$); this is understandable because DO is needed in the conversion of NO_2 to NO_3. Nitrate is inversely correlated to NH_4 ($P < 0.05$). An increase in NH_4 should give rise to increased NO_3 through nitrification; however, NH_4 is only slightly above normal in the present study while NO_3 is appreciably above normal concentration. This means additional nitrate is reaching the lagoon, probably from wastewater discharged in the recreational area and / or fertilizers used in the green sections of the recreational area. NO_2 is positively correlated to NO_3 and is also inversely correlated to NH_4 and PO_4 but these correlations are only significant for NO_3 ($P < 0.01$). In October 2005, NO_3 is positively correlated with NH_4 and PO_4, only with NH_4 this correlation is significant ($P < 0.01$) but showed insignificantly an inverse relationship to DO. Essentially the same relationships are observed in the edited data set, during January 2006, (Table 4) with NO_3 being negatively correlated with DO content of the water ($P < 0.05$) and positively correlated with NH_4 and PO_4, although these correlations are only significant for NH_4 ($P < 0.05$). The increasing amount of domestic discharges enhanced oxygen consumption that resulted in low oxygen concentrations but high concentrations of NO_3 and NH_4. NO_2 is positively correlated to NO_3, NH_4 and PO_4 but these correlations are only significant for NH_4 ($P < 0.05$). This relation is meaningful since the system is mainly under the effect of wastewater discharges rich in nutrient.

Table 4. Results of correlation analyses on data generated during the surveys.

	DO	NO_2	NO_3	NH_4	PO_4	AHB	CB	FCB
June 2005: 10 significant correlations								
DO	1							
NO_2	0.44	1						
NO_3	0.66^{**}	0.55^{**}	1					
NH_4	-0.84^{**}	-0.41	-0.61^{*}	1				
PO_4	-0.76^{**}	-0.36	-0.74^{*}	0.61^{*}	1			
AHB	-0.05	0.45	0.08	-0.01	0.24	1		
CB	-0.05	0.37	-0.10	-0.01	0.13	0.92^{**}	1	
FCH	-0.08	0.46	-0.15	0.01	0.16	0.97^{**}	0.94^{**}	1
October 2005: 7 significant correlations								
DO	1							
NO_2	0.09	1						
NO_3	-0.41	-0.07	1					
NH_4	-0.41	0.27	0.70^{**}	1				
PO_4	-0.35	0.26	0.35	0.47	1			
AHB	0.12	0.60^{*}	0.34	0.36	0.39	1		
CB	0.23	0.56^{*}	0.23	0.32	0.41	0.89^{**}	1	
FCH	0.30	0.70^{**}	0.09	0.28	0.34	0.91^{**}	0.96^{**}	1
January 2006: 6 significant correlations								
DO	1							
NO_2	-0.09	1						
NO_3	-0.53^{*}	0.32	1					
NH_4	-0.42	0.52^{*}	0.53^{*}	1				
PO_4	-0.27	0.19	0.25	0.21	1			
AHB	0.03	0.08	0.43	0.09	0.40	1		
CB	0.10	0.13	0.38	0.83	0.48	0.97^{**}	1	
FCH	0.13	0.06	0.42	0.14	0.51	0.91^{**}	0.92^{**}	1

* = Significant at $P < 0.05$.

** = Significant at $P < 0.0I$.

AHB = Aerobic Heterotrophic Bacteria.

Strong positive correlations between the densities of the three bacterial indicators were apparent in all data sets. The bacterial population also correlated positively with NO_2 during October only. Nevertheless in common with this study, Daby *et al.*, (2002) found weak correlations between the bacterial density and nutrients levels in the long-term survey. Other authors obtained similar relationships between TC and FC (Nunes, 1984; Cachola and Sampayo, 1984; Baptista, 1993; and Dionisio *et al.,* 2000). The high correlation between TC and FC for all sampling periods is due to the fact that FC is a sub-group of TC. The result is consistent with the findings in the southern California coastal water (Noble *et al.,* 2001) and the Tijuan-Ensenada, Baja California, Mexico shoreline water (Oronzo-Borbón *et al.,* 2006).

Conclusions

The present work represented the first study of the water quality in waters of Al-Nawrus lagoon, a shallow coastal lagoon on the western side of the northern part of Jeddah, on the Red Sea which has been of a great importance as recreational area.

The results in this study indicated that only two stations towards the north are slightly polluted, however, even with this level of pollution, it is not suitable to swim around. In addition, comparison of the nutrient concentrations in Al-Nawrus lagoon with data from similar environments at Jeddah Red Sea coast suggests that mean levels of NO_3 is similar in magnitude to those of polluted areas, influenced by domestic wastewater, while NO_2, NH_4 and PO_4 concentrations are generally similar to those of slightly polluted areas.

However, considering that the lagoon is a site of important recreational activities and of future increased loading of waste, this study suggests that the inlet at the northern end of the lagoon should be deep enough and subjected to periodical dredging and for a continuous monitoring program in the area.

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البكتيريا والأملاح المغذية كمؤشر لتلوث مياه بحيرة النورس، جدة

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المملكة العربية السعودية

المستخلص. أدى التلوث البيئي للشواطئ، إلى عدم مناسبتها لممارسة الأنشطة المختلفة من قبل الناس، كظاهرة عالمية غير مقتصرة على منطقة بحد ذاتها. بناءً على الخلفية السابقة أجربت هذه الدراسة لاختبار جودة المياه البحرية من خلال اختبار عدد من المحطات في بحيرة النورس الترفيهية (شمال جدة)، خلال الفترة من يونيو ٢٠٠٥ إلى يناير ٢٠٠٦م لتحديد العدد الكلي للبكتيريا الهوائية عضوية التغذية، وبكتيريا القولون، والقولون البرازية، بالإضافة إلى عدد من القياسات الكيميائية المتضمنة الأكسجين الذائب، والأملاح المغذية. وقد اتضح من نتائج القياسات وجود اختلافات كبيرة في تراكيز الأكسجين الذائب، والأملاح المغذية في مياه محطات الدراسة المختلفة، وذلك من خلال مقارنتها بنتائج مياه البحر المفتوح. كما أشارت عملية مقارنة متوسطات قيم الأملاح المغذية في بحيرة النورس وبعض المناطق الساحلية بمدينة جدة إلى تشابه قيم النترات، مع قيم المناطق الملوثة، بينما كان متوسط تراكيز النيتريت والأمونيا والفوسفور مشابه لتلك المسجلة في المناطق قليلة التلوث.

إن أعداد البكتيريا الهوائية عضوية التغذية، وبكتيريا القولون، والقولون البرازية لم تُشر إلى وجود أي تأثير يذكر للفصول

المختلفة. كما سجلت أعلى الأعداد للبكتيريا الهوائية عضوية التغذية في المحطات الشمالية، وأقلها في المحطات الجنوبية باتجاه البحر المفتوح. فيما يخص أعداد بكتيريا القولون، والقولون البرازية يتضح وجود اختلافات بسيطة فيما بين المحطات، سجلت أعلى الأعداد لبكتيريا القولون في اتجاه محطات الشمال، كما هو الحال بالنسبة للبكتيريا الهوائية عضوية التغذية. علماً بأن بكتيريا القولون البرازية لم تعزل من أي من محطات الجنوب. وعلى وجه العموم، وفيما عدا بعض المحطات، لم تكن هنالك اختلافات ذات دلالة في أعداد البكتريا عضوية التغذية بين بحيرة النورس، وبين نتائج من مناطق غير ملوثة.