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Determination of Some Micro-Nutrient Salt Concentrations of Al-Nawras Lagoon Surface Waters at Jeddah Coast on the Red Sea

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Abstract. Al-Nawras lagoon is a semi-enclosed shallow basin; it is located in the middle part of the northern Cornish of Jeddah coastal area, Saudi Red Sea coast. In this study, the micro-nutrient salts of the surface waters of the lagoon were seasonally investigated between autumn 2006 and summer 2007. Five stations were appointed, and the level contents of nitrate, nitrite, ammonia, phosphate and silicate were determined. The study revealed that the highest levels of temperature and salinity were found between stations 2 and 4 due to the low water exchange between the lagoon and the open sea as those stations are located in the middle of the lagoon; meanwhile lower levels of temperature and salinity were found at stations 1 and 5; as station 1 is the nearest to ground water influx outlet point at the north of the lagoon, whereas station 5 locates at the south of the lagoon and the nearest to the open sea water. High nitrate concentrations were recorded at station 1 over the four seasons 37.08-53.12 µg/l, while other stations recorded lower values 0.24-7.27 µg/l. High levels of nitrite were recorded ranged from 0.35-15.24 µg/l during the period of the study. Ammonia levels were significantly higher at the northern inlet of the lagoon than at the southern outlet 0.37-12.73 µg/l. Station 1 sustained high phosphate and silicate concentrations over the four seasons, while other stations recorded lower values. In general, the northern part of the lagoon is influenced by the effluent discharge point receiving groundwater mixed with sewage.

Introduction

Over two decades, the urban development and population growth are the most obvious features of the Saudi cities along the eastern shores of the Red Sea, included the development of the sea fronts for coastal cities. Jeddah District is one of those cities, which attracts tourists and visitors from various parts of the Kingdom and neighboring countries to enjoy the sea and benefit from other services provided, and it is believed in past years, keenness of broad segments of the community, to spend their holidays in tourist villages, resorts, and escort services, which were established along the coasts for recreation, leisure activities. These strong interaction adverse effects on the marine environments were accompanied by solid and nonsolid wastes, which reach the sea. The most important of those, ground waters mixed with treated and untreated sewage which find its way to the sea. The area of Jeddah coastal waters on the Red Sea has received a fair amount of attention in determining levels of micro nutrients, for instance (El-Rayis *et al*., 1982; Behairy and Saad, 1984; Dowaidar and Shaikh, 1984; El-Rayis, 1998; El-Rayis and Moammar, 1998; El-Sayed and Niaz, 1999; Khomayis, 2002; Hashim *et al*., 2002; and Samkari, 2004). This paper investigates some micro-nutrient salts in the surface waters of Al-Nawras lagoon at the northern Cornish of Jeddah coast, Saudi Arabia.

The exchange of water between the lagoon and the open sea is very complex, which might be due to the waves break near the entrance. The lagoon was chosen because it is one of most vital sites and important tourist places in the city of Jeddah, surrounded by many human recreational activities, and it also receives groundwater mixed with an incomplete treated sewage from the effluent discharge point on coastal waters of Jeddah.

Materials and Methods

Al-Nawras Lagoon is situated in the middle part of the northern Cornish of Jeddah coast. It is bounded on the east by the main Cornish Road and surrounded by many café shops and on the west by Al-Nawras Resort Chalets. It lies between latitudes 21°35, 261 & 21°34, 661 N, and longitudes 39°6, 750 & 39°6, 500 E. The lagoon is described as a semi-confined area; it is approximately 1250 meters long and an average depth of 3.5 meters, with an average width of 80 meters (Fig. 1).

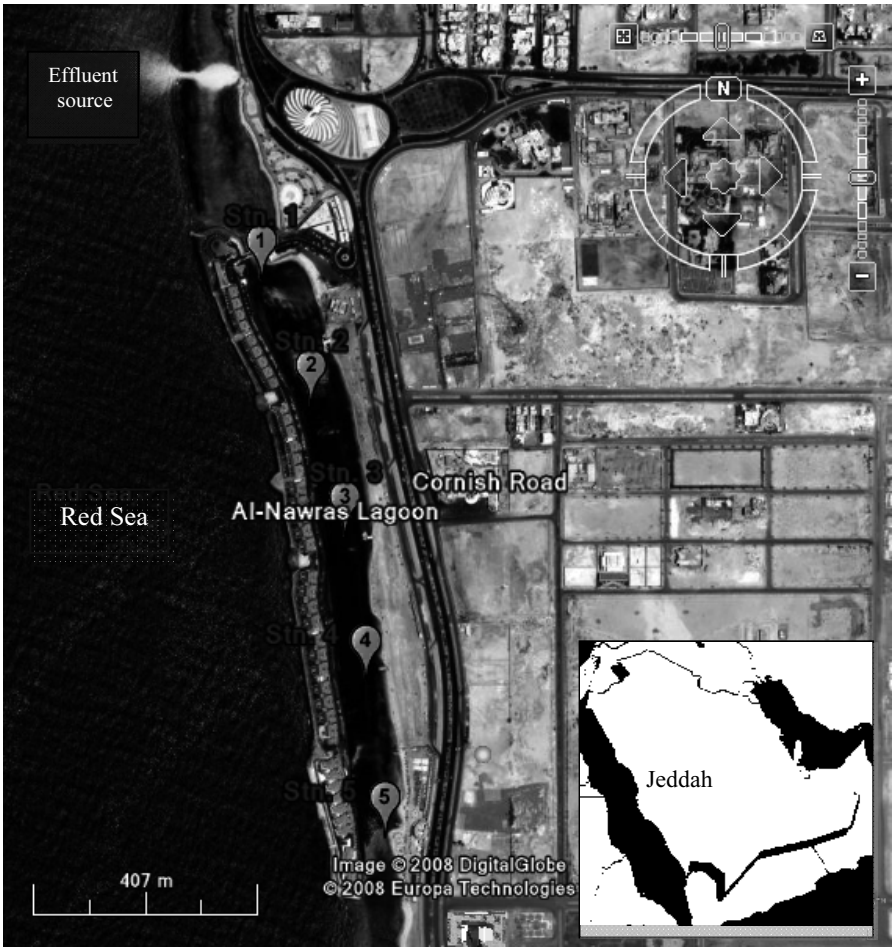

Fig. 1. An aerial photo shows Al-Nawras lagoon on the coast of Jeddah city, Red Sea.

Sea water samples were collected seasonally from autumn 2006 to summer 2007. Five stations were appointed along the lagoon, station 1 was located 300 m away from the effluent discharge point, and then stations 2, 3, 4 and 5 were located at every 250 m intervals (Fig. 1). At each station, replicate surface seawater samples were collected in the early morning using a precleaned plastic bucket, the first (a) from the eastern bank of the lagoon, the second (b) in the middle, and the third (c) was at western bank which is bounded by the lagoon resort chalets. Salinity, temperature and pH values were measured in situ, whereas samples for dissolved oxygen were fixed in the field. Other micro-

nutrients (NO_2; NO_3; NH_4; PO_4 and SiO_4) in water samples were determined on returning back to the laboratory. Salinity values were determined using a portable refractometer. Temperature was determined using a mercury thermometer ranging from 0°C to 50°C in 0.1°C divisions. Dissolved oxygen was determined according to Winkler's procedure and back titration of liberated iodine respectively according to (Strickland and Parsons, 1972). Nutrients analysis (NO_2; NO_3; NH_4; PO_4 and SiO_4) were carried out according to recommended methods by (Strickland and Parsons, 1972). Absorbance readings for nutrients were obtained from a SHIMADZU spectrophotometer (Model UV-160A). All data were analyzed using the Statistics program version 5.5. Analysis of Variance (ANOVA) was applied to the data and Cochran's test was used to test for homogeneity of variance.

Results

The results of the present study showed normal seasonal variations of temperature profiles for Al-Nawras lagoon surface waters (Fig. 2) as follows: High ranges of temperatures were recorded in summer season 2007, but the highest temperature of 34.5°C was found at station 4, meanwhile station 1 recorded lower range of temperatures nearly all over the year. Lower values of temperatures were recorded during winter season of 2007 fluctuated between 22.8-23.97°C showing that the lowest temperature of 22.8°C was found at station 5. The general pattern of temperature shows that during summer time it ranges between 30.9-34.5°C, then temperatures gradually decreasing reaching its minimum during winter time passing through autumn, and then tends to increase gradually again in spring reaching its maximum in the following summer. There were also no significant differences in water temperature between stations; meanwhile there were significant differences in water temperature between seasons ($P < 0.03$).

Salinity values of Al-Nawras lagoon surface water are shown in (Fig. 3) from 28.2 to 40.9%. Stations 1 and 5 have reported lower salinity values in autumn and winter seasons respectively than in spring and summer, whereas stations 3 and 4 in the middle of the lagoon recorded higher salinity values. No significant differences among sampling stations were reported, but there were significant differences in water salinity values between seasons ($P > 0.01$).

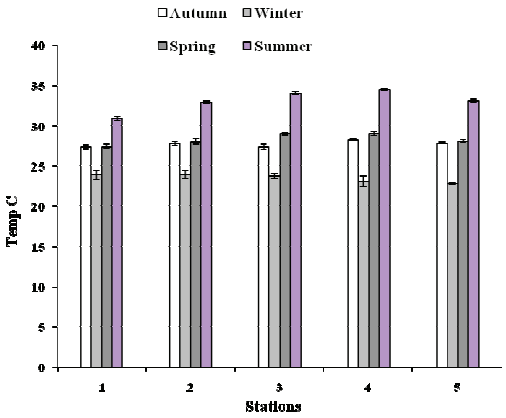

Fig. 2. Temperature levels at Al-Nawras lagoon surface waters.

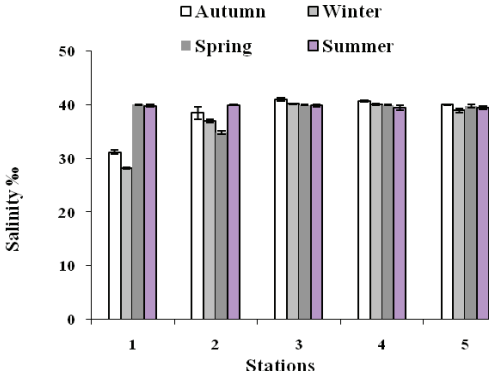

Fig. 3. Salinity levels at Al-Nawras lagoon surface waters.

The pH values of Al-Nawras lagoon surface water are represented in (Fig. 4). pH values showed some homogeneity were they ranged from 6.81-8.12. The pH values along the lagoon did not show significant difference among sampling stations and seasons. There was no interaction between stations and seasons.

Dissolved oxygen level at each station in the surface waters of Al-Nawras lagoon during the period from November 2006 and August 2007 are presented in (Fig. 5). The DO_2 levels were widely varied between 1.71 and 7.91 mg/l. Lower DO_2 values were recorded in autumn season,

and station 1 was the lowest 1.71 mg/l, while higher values were recorded in spring and summer seasons respectively. DO_2 values along the lagoon did not show significant difference among sampling stations and seasons.

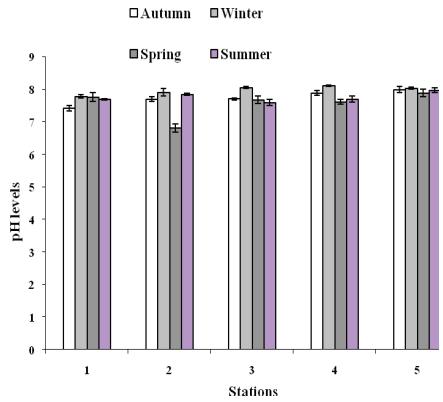

Fig. 4 . pH levels at Al-Nawras lagoon surface waters.

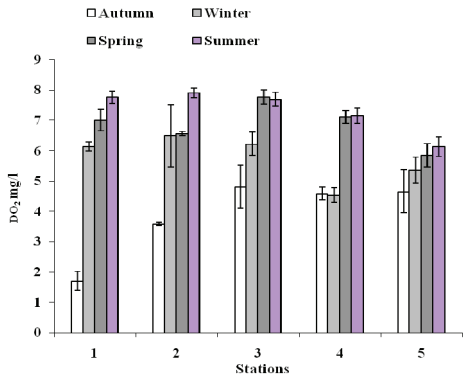

Fig. 5. Dissolved oxygen concentration (DO_2 mg/l) at Al-Nawras lagoon surface waters.

Nitrite concentrations of Al-Nawras lagoon surface waters showed wide range of variations between stations ranged from 0.35-15.24 µg/l during the four seasons. Station 1 sustained high levels as compared to stations 2, 3, 4 and 5 throughout the 4 seasons of study, which recorded lower levels (Fig. 6). There were significant differences in nitrite concentrations between stations and seasons ($P<0.02$ and $P<0.05$) respectively.

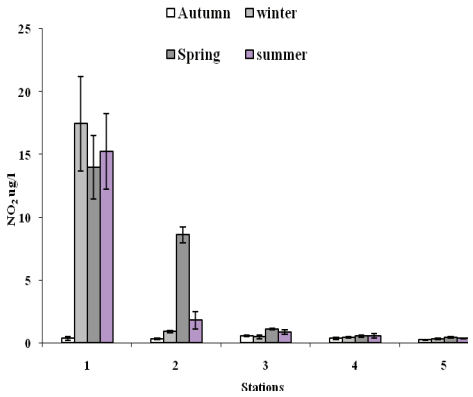

Fig. 6. Nitrite levels (NO_2 µg/l) at Al-Nawras lagoon surface waters.

Nitrate levels of Al-Nawras lagoon surface waters are presented in (Fig. 7). It showed wide range of variations (0.24-53.12 µg/l). Station 1 sustained high nitrate concentrations over the four seasons, while other stations recorded lower values except during autumn season where it was still high. There was a marked decrease in nitrate concentrations from sampling stations 3-5 during winter, spring and summer seasons. The data analysis revealed significant differences for nitrate concentrations between stations and seasons ($P < 0.001$).

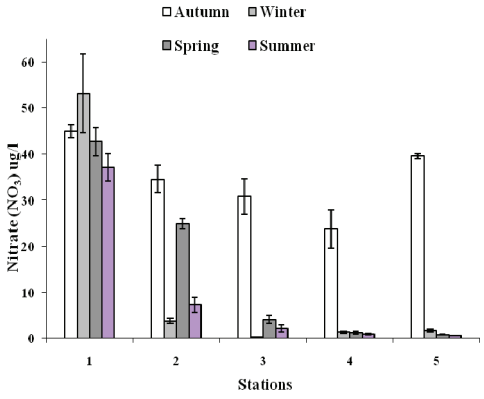

Fig. 7. Nitrate levels (NO_3 µg/l) at Al-Nawras lagoon surface waters.

Ammonia variations are shown in (Fig. 8). It showed irregular fluctuations from 0.37-12.37 µg/l. Stations 1 & 2 sustained higher concentrations, whereas stations 3, 4, and 5 showed lower values.

Significant differences in the ammonia values were found among stations.

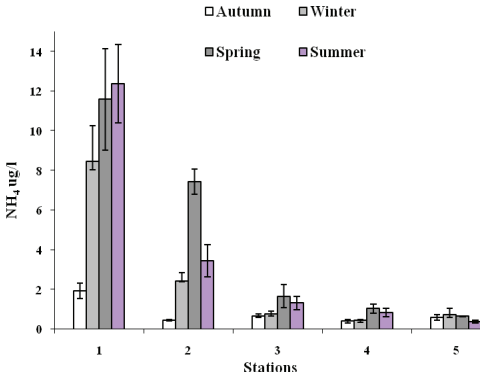

Fig. 8. Ammonia levels (NH_4 µg/l) at Al-Nawras lagoon surface waters.

Phosphate content of Al-Nawras lagoon surface waters are presented in (Fig. 9). Phosphate content varied from a low of 0.28 µg/l at station 5 to a maximum of 49.46 µg/l at station 1, high concentrations were only found during autumn season at all 5 stations, while other stations recorded lower values except during autumn season. There was a marked decrease in PO_4 values between sampling stations 2 and 5 during winter, spring and summer seasons. The data analysis revealed no significant differences for phosphate concentrations between stations, meanwhile significant differences between seasons ($P < 0.001$).

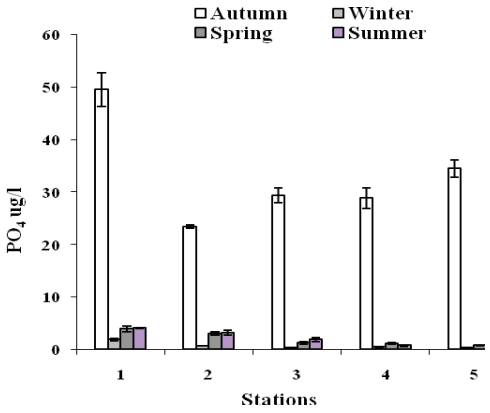

Fig. 9. Phosphate levels (PO_4µg/l) at Al-Nawras lagoon surface waters.

Silicate content of Al-Nawras lagoon surface waters are presented in (Fig. 10). Silicate content varied from a low of 0.6 µg/l at station 5 in the summer to a maximum of 78.09 µg/l at station, which sustained high SiO_4 concentrations over the four seasons, while other stations recorded lower values. There was a marked decrease in SiO_4 values from sampling stations 3-5 during winter, spring and summer seasons. The data analysis revealed significant differences for silicate concentrations between stations and seasons ($P < 0.001$).

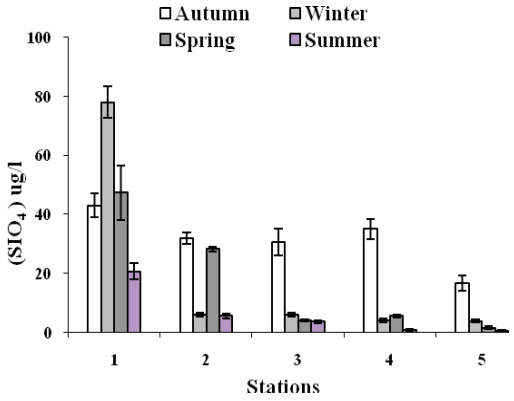

Fig. 10. Silicate levels (SiO_4 µg/l) at Al-Nawras lagoon surface waters.

Discussion

Al-Nawras lagoon is a semi enclosed area (Fig. 1). The seawater quality of Al-Nawras lagoon was evaluated seasonally by analyzing the parameters mentioned above in the sampling stations selected along the lagoon. The results obtained were discussed as follows:

Surface water temperature values were decreased from autumn to winter, and tended to rise up in spring and reached its maximum value in summer 22.8-34.5°C. This range of surface temperature was in the same trend reported by Hashim *et al*., (2002) on Al-Nawras lagoon surface water temperature 24.-29.8°C. Similar observation was recorded by Samkari, (2004) who reported that the surface seawater for some lagoons and lakes on Jeddah coasts ranged from 25.5-33.5°C. In a report for MEPA, (1987), mentioned that at the north of Red sea surface temperature lies between 21-26°C, while in the south 28-32°C. Surface

Table 1. A two-way ANOVA testing.

Temp	DF	MS	F	p-level	SALINITY	DF	MS	F	p-level
Stations (St)	4	67.94391632	0.639425	0.637459	**Stations (St)**	4	151.697	1.425	0.243
Seasons (Se)	3	346.7626953	3.263411	**0.031156**	**Seasons (Se)**	3	409.842	3.851	**0.016**
St*Se	12	77.33680725	0.727823	0.716082	**St X Se**	12	165.827	1.558	0.144
Residual	40	106.2577667			**Residual**	40	106.425		
Total	59				**Total**	59			
pH	**DF**	**MS**	**F**	**p-level**	**DO_2**	**DF**	**MS**	**F**	**p-level**
Stations (St)	4	94.13790894	0.887659	0.480132	**Stations (St)**	4	120.3972	1.132719	0.35491547
Seasons (Se)	3	75.31101227	0.710134	0.551676	**Seasons (Se)**	3	114.9437	1.081411	0.36794192
St*Se	12	93.40833282	0.88078	0.572393	**St*Se**	12	106.6337	1.003229	0.46376264
Residual	40	106.0518875			**Residual**	40	106.2904		
Total	59				**Total**	59			
NO_2	**DF**	**MS**	**F**	**p-level**	**NO_3**	**DF**	**MS**	**F**	**p-level**
Stations (St)	4	346.0615	3.129572	**0.02488595**	**Stations (St)**	4	2804.007	22.01865	**0.001**
Seasons (Se)	3	305.5919	2.76359	**0.0544036**	**Seasons (Se)**	3	1970.824	15.47603	**0.001**
St*Se	12	146.4343	1.324264	0.24343151	**St*Se**	12	218.9634	1.719424	9.88565E-02
Residual	40	110.5779			**Residual**	40	127.3469		
Total	59				**Total**	59			
NH_4	**DF**	**MS**	**F**	**p-level**	**PO_4**	**DF**	**MS**	**F**	**p-level**
Stations (St)	4	234.43	2.16	0.09	**Stations (St)**	4	149.9266205	1.375046	0.259815
Seasons (Se)	3	200.18	1.85	0.15	**Seasons (Se)**	3	3292.56665	30.19763	**2.28E-10**
St*Se	12	137.91	1.27	0.27	**St*Se**	12	238.8838196	2.190913	**0.031692**
Residual	40	108.44			**Residual**	40	109.0339279		
Total	59				**Total**	59			
SiO_4	**DF**	**MS**	**F**	**p-level**					
Stations (St)	4	3768.268555	24.08503	**3.38E-10**					
Seasons (Se)	3	2106.974365	13.46681	**3.22E-06**					
St*Se	12	613.6602173	3.922233	**0.000532**					
Residual	40	156.4568634							
Total	59								

temperature for different coastal areas in Jeddah ranges between 23-31.5°C (Khomayis, 2002). These differences reflect the continental influence on surface temperature of coastal water which undergoes larger daily and seasonal variations than those of the open sea.

Salinity values resulted in this study revealed that water salinity recorded lower values (stations 1 & 5) due to their locations at the vicinity of the north and south ends of the lagoon. The salinity then increased in the middle at stations 2, 3 & 4 which can be attributed to the lower exchange of water between the open sea and the lagoon as those stations are located in the middle of the lagoon. This finding is supported by Hashim *et al.*, (2002) report, who revealed that the salinity at Al-Nawras lagoon between April 2000 and January 2001 ranged from 39.3-40.4%. The distribution of salinity in the surface waters of two shallow coastal lagoons in the western side of the middle part of Jeddah on the Red Sea (Al-Arbaeen and Reayat Al-Shabab lagoons) ranged between 5.0-35.2% and 5.0-38% respectively. The low value found in the vicinity of the discharge site of the sewage treatment plant effluent, which agreed with the recent study, while the higher values were observed at the lagoons opening on the sea (El-Rayis & Moammar, 1998). In a study on some Jeddah coastal water areas conducted by Samkari, (2004) found that lower salinity values as 25.5-31% of surface water, he attributed that for the presence of sewage discharge in the area. He also reported higher salinity values as high as 39.5% in other area on the coastal water of Jeddah.

Dissolved oxygen values were widely varied between 1.71-7.91 mg/l. Lower DO_2 values were recorded in autumn season, and station 1 was the lowest 1.71 mg/l where the most important effluent ground water is located nearby, while higher values were recorded in spring and summer seasons respectively. DO_2 values reported by Khomayis, (2002) revealed wide range of 1.8-10.04 mg O_2/l in several coastal areas of Jeddah. He returned the great variations in DO_2 values to the effect of temperature. The DO_2 values recorded at Al-Nawras lagoon were ranged from 1.1-4.2 mg/l (Hashim *et al*., 2002). These values were in agreement with the recent study, which showed that during autumn and winter seasons DO_2 values were quite close to oxygen saturation values, but in warmer seasons values become so high, affected by high temperatures.

Recent study showed that nitrite concentrations of Al-Nawras lagoon surface waters showed wide range of variations between stations, ranged from 0.35-15.24 µg/l during the four seasons, and station 1 sustained high levels, as compared to stations 2, 3, 4 and 5 throughout the 4 seasons of study which recorded lower levels. This is compatible with Samkari, (2004) who reported similar figures in his study on other lagoons in Jeddah areas. Another study reported by El-Sayed and Niaz, (1999) demonstrated that the concentration of nitrite in the Cornish area on the southern coast city of Jeddah ranged between 0.02-1.61 µmol/l. In a study on some of Jeddah coastal areas, Khomayis, (2002) reported the same trend of NO_2 values between 0.30-1.02 µmol/l. In this study results of the nitrite concentration are compatible with what is known to exist, nitrite smaller quantities than nitrate in seawater, which mostly result from an oxidation process by phytoplankton turning nitrite to nitrate, (Harris, 1986), with the exception of station 1 which showed high NO_2 content. The high nitrite concentration at station 1 could be attributed to its occurrence near the effluent discharge point. Meanwhile stations (2, 3, 4, and 5) recorded low concentration of nitrite because of the low exchange of water between the lagoon and the open sea, which is still good in station 2 compared to stations 3, 4 and 5 where the average concentration of nitrite 0.22-1.79 µmol/l. Al-Nawras lagoon waters contain concentration of NO_2 from 0.02-0.25 µmol/l reported by Hashim *et al*., (2002). Behairy and Saad, (1984) also found nitrite levels in coastal waters of Jeddah varied from 0.06 to 1.46 µg/l based on data for the years 1982-83 in the coastal waters of Jeddah.

Nitrate levels in this study varied from a low of 0.24 µg/l at station 5 in winter 2007 to a maximum of 53.12 µg/l at station 1 in winter 2006. In a study conducted on the Red Sea focused on nutrients reported by UNEP, (1997) indicated that concentration of nitrates ranging from 0.0-3.0 µmol/l. A large variation in nitrate concentration in coastal waters of Jeddah have been reported by Behairy and Saad, (1984) averaged from 0.02 to 56.37 µg/l. However their study area was in front of a sewage discharged from a waste treatment plant, and the sewage effluent usually increases the levels of nutrient salts. Nitrate levels in the study of Khomayis, (2002) focused on nutrients in the coastal waters of Jeddah has revealed a range from 0.1 to a maximum of 8.87 µg/l. High nitrate concentrations were reported by Samkari, (2004) on some lagoons in Jeddah area 0.08-62.31 µmol/l, he referred the high values to sewage

effluent pollution in the lagoons. The results of the current study seem reasonable, as stations 1 and 2 which sustained high concentrations of nitrate is affected by groundwater mixed with sewage effluent.

Ammonia is presented in all natural waters, even if only at very low concentrations. The major sources of ammonium input in the marine environment are believed to be land runoff, zooplankton excretion, remineralization of organic matter, sewage discharges, and decomposition of animal and plant matters (Ketchum, 1962; Verlencar, 1987 and Seager *et al*., 1988). In the present study the concentration of ammonia varied from a low of 0.37 µg/l at stations 4 & 5 in autumn and summer respectively to a high of 11. 58 & 12.37 µg/l at station 1 in spring and summer seasons, the high NH_4 values at station 1 could be referred to its location in the vicinity of the effluent point for groundwater mixed with sewage. Normally lower ammonia values should occur with lower nitrite content and vice versa Khomayis, (2002). In his study Khomayis, (2002) recorded ammonia concentration ranged from 0.20-36.0 µg/l, he referred that to the decomposition of organic material. Ammonia concentration was also recorded by Hashim *et al*., (2002) at Al-Nawras lagoon surface water in June 2000 and January 2001 of 0.19 and 2.49 µg/l. (Samkari, 2004) reported high values of ammonia in the surface waters at lagoons on the coastal area of Jeddah of 0.38-103.98 µg/l, he referred that high values are due to the effect of sewage wastes discharge. Extremely high NH4 concentrations were reported by El-Rayis *et al*., (1982), ranged from 132-1929 µmol/l at two coastal lagoons of Jeddah Al-Arbaeen lagoons, and 4-307 µmol/l at Reayat Al-Shabab lagoon as those two lagoons receive untreated sewage.

The recent study revealed that the concentration of PO_4 varied from a low of 0.28 µg/l at station 5 to a maximum of 49.46 µg/l at station 1, and the high concentrations were only found during autumn season at all 5 stations, because of the prevailing north/northwesterly winds which contribute in pushing ground water mixed with sewage to discharge into the lagoon (Hashim, 2002). In spite of phosphorus concentration in the Red Sea waters being generally low (MEPA Series, 1987), high values of reactive phosphate of 0.5-68.4 µmol/l were reported at Jeddah coastal waters by El-Rayies *et al.,* (1982) who attributed the variation in the average concentrations of nutrients to the variations of discharge rate of

sewage effluent into the coastal waters in the different periods. Low phosphate concentrations were reported of 0.16-0.74 µmol/l by (El-Sayed & Niaz, 1999), they found PO_4 concentrations of 3.42 µmol/l, while in sewage water it is determined as 170 µmol/l. Phosphate concentration was also recorded by Hashim *et al*., (2002) at Al-Nawras lagoon surface water in June 2000 and January 2001 to be of 0.05-0.93 µmol/l.

The present study revealed that silicate content of Al-Nawras lagoon range from a low of 0.6 µg/l at station 5 in the summer, to a maximum of 78.09 µg/l at station, which sustained high SiO_4 concentrations over the four seasons, while other stations recorded lower values. MEPA Series, (1987) reported that concentration of the reactive Silicates in the Red Sea waters are generally in the range of 2.0 µmol/l. Meanwhile El-Rayies *et al*., (1982) have reported wide range of variation in Jeddah coastal surface water of 1.0-56.1 µmol/l. In another study for Khomayis, (2002), he reported silicate concentration ranged from undetectable levels to 5.39 µg/l. High silicate concentrations were reported by Samkari, (2004) on some lagoons in Jeddah area to be 0.5-68.84 µmol/l, he referred that to sewage effluent pollution in the lagoons. These figures are compatible with the recent study, as the silicate concentration varied between 0.6-78.09 µg/l.

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تقدير تراكيز بعض الأملاح المغذية للمياه السطحية لبحيرة النورس بساحل جدة على البحر الأحمر

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المستخلص. تقع بحيرة النورس في الجزء الأوسط من الكورنيش الشمالي لساحل جدة على الجانب السعودي للبحر الأحمر. في هذه الدراسة تم قياس الأملاح المغذية في المياه السطحية للبحيرة مثل: النترات، والنتريت، والأمونيا، والفوسفات، والسيليكات، فصلياً بين خريف ٢٠٠٦ وصيف ٢٠٠٧ ميلادية في خمس محطات. كشفت الدراسة أن أعلى مستويات درجة الحرارة والملوحة وجدت ما بين محطات ٢ و٤، نظراً لانخفاض تبادل المياه بين البحيرة والبحر المفتوح ، حيث أن تلك المحطات تقع في وسط البحيرة؛ بينما لوحظ انخفاض مستويات درجات الحرارة والملوحة في المحطتين ١ و ٥؛ وذلك بسبب قرب المحطة ١ إلى منفذ نقطة دفق المياه الجوفية في شمال البحيرة، في حين أن محطة ٥ تقع في أقصى جنوب البحيرة وهي الأقرب إلى مياه البحر المفتوح. كما سجلت المحطة ١ تركيزات مرتفعة من النترات على مدى أربعة فصول ٣٧,٠٨ – ٥٣,١٢ ميكروجرام/ لتر، في حين سجلت المحطات الأخرى قيمًا أقل، تراوحت ما بين ٠,٢٤– ٧,٢٧ ميكروجرام/ لتر. سجلت مستويات عالية من النتريت تراوحت ما بين ٠,٣٥–١٥,٢٤ ميكروجرام/ لتر. تركيزات الأمونيا كانت أعلى بكثير في مدخل

البحيرة الشمالي مما كانت عليه في منفذها الجنوبي ٠,٣٧–١٢,٧٣ ميكروجرام/ لتر. على مدى أربعة مواسم سجلت المحطة ١ ارتفاعًا مطردًا في تركيزات الفوسفات والسيليكا، في حين أن المحطات الأخرى سجلت قيمًا أقل. وبصفة عامة فإن الجزء الشمالي من البحيرة متأثر بنقطة الدفق، التي تستقبل المياه الجوفية المختلطة بمياه الصرف الصحي.