EGYPTIAN JOURNAL OF AQUATIC RESEARCH 1687-4285
VOL. 32 NO. 1, 2006: 220-234.

SANITARY AND AESTHETIC QUALITY OF EGYPTIAN COASTAL WATERS OF AQABA GULF, SUEZ GULF AND RED SEA

MOHAMED EL-SHENAWY*, AIDA FARAG , MOHAMED ZAKY

National Institute of Oceanography and Fisheries, El-Anfoushy, Alexandria, Egypt.

**E.mail: Dr_El-Shenawy@hotmail.com*

Keywords: water quality, recreational waters, bacterial indicators, Aqaba Gulf, Suez Gulf, Red Sea.

ABSTRACT

During the course of 7 years (1998-2004), five field trips were performed annually in January, march, May, July and September. 1400 water samples (200 samples/year) were collected from 40 coastal sites covering the recreational areas as well as different hot spots and some protectorate areas. Hydrochemical parameters including temperature, salinity, pH and dissolved oxygen as well as bacteriological parameters including total coliforms, *E. coli* and fecal streptococci were investigated. Inverse relationships were observed between salinity and each of total coliforms (TC) ($r = -0.149$, $P \leq 0.05$) and *E. coli* (EC) ($r = -0.147$, $P \leq 0.05$) in the Suez Gulf, whereas in Red Sea there was an inverse relationship between temperature and fecal streptococci (FS) ($r = -0.17$, $P \leq 0.05$). The present study suggested that *E. coli* was the most appropriate indicator during the course of study concerning variation in time and locations. Equivalent to 80% of analyzed samples compliance with the current standard, 30 sites (75%) of 40 studied sites were unpolluted whereas 25 sites (91%) of 28 recreational areas was recommended as unpolluted and approved for safe recreational activities.

1. INTRODUCTION

The combination of calm seas, clear water and rich marine life of subtropical marine beaches of Red Sea region are an important and unique recreational resource. They attract large numbers of tourists from all over the world throughout the year. More than 4.5 million people visit Red Sea region annually to sunbathe, surf, swim, skin-dive and scuba-dive. Tourism activities in this region contribute an important source for the hard currencies, consequently to the national income. The rapid increase in coastal utilization for recreational purposes and ecoturism infrastructure, three international airports, new resorts in many new areas, population growth and increasing tourism activities may stress the coastal water quality. The main sources of bacterial contamination to our coastal waters are sewage discharge, harbor activities, boats and vessels and heavy recreational activities. There is increasing evidence that the rate of marine-associated infections are proportional to the microbial pollution levels and duration of expose (Corbett *et al.,* 1993; Kay *et al.,* 1994) several studies have attempted to define the levels of risk flowing expose to different concentrations of pathogens and indicator organisms in recreational waters (Cabelli, 1989; Cabelli *et al.*,1982; Cheung *et al.,* 1990 and 1991 Cheung *et al.,* 1991; Flisher *et al.,* 1998; Haile *et al.*, 1999; Henrichkson *et al.*, 2001; Prieto *et al.,* 2001). However, very few information is available on the water quality of this region: therefore, an environmental management is highly desired. The Environmental Information and monitory Program (EIMP), directed by the Egyptian Environmental Affair Agency (EEAA) and International Development Assistance (Danida) has been established to initiate monitoring and make database system, using quality Assurance and quality control work for the sustainable development of the Egyptian costs of Aqaba Gulf, Suez Gulf and Red Sea science 1998.

The aim of the present study is to describe and compare the fluctuation of different microbial indicators in relation to time and location to determine the degree of fecal contamination of beach waters especially in recreational areas. Establish a baseline and database system to assess the sanitary and aesthetic quality of coastal waters for the sustainable use and development is another goal.

2. MATERIALS & METHODS

2.1. Study area

Red Sea is a deep semi-enclosed and narrow basin, lies between 12 ^{o} -30^{o} N and 32^{o} -44^{o} E and has a length of about 1930 km and an average width of 280 km (Morcos, 1970). It connected to the Indian Ocean throw Bab El-Mandab strait and extends north word to Sinai Peninsula which divides it into the shallow Suez Gulf (250 km long, average width of 32 km and average depth of 64 m) and deep Aqaba Gulf (150 km long, average width of 16 km and average depth of 650 m). The average depth of the Red Sea is 490 m (Murty and El-Sabh, 1984). Forty sampling sites were fixed to represent the recreational areas as well as towns, ports, fishing ports and some protectorate areas. Twelve sites were in the Aqaba Gulf (A), fourteen sites in the Suez Gulf (S) and fourteen stations along the Red Sea proper (R) (Fig. 1). The location of each sampling site was determined using global position system (GPS). List of code numbers and names of different coastal sites are listed in Table 1.

2.2. Sampling

A total of 1400 duplicate water samples were collected from forty sites five times/year in January, March, May, July, and September during seven years (1998-2004). Sea water sampling technique was done according to the international standard (ISO 5667/9, 1992) using 500 ml sterile bottles and special sampler, on 50 cm below water surface in a shallow of about 1m deep.

2.3. Visual Observations

Visual observations concerning to the aesthetic quality of coastal beach zones specially those using for recreational purposes, including the concentrations of beach users, recreational activities, weathering conditions, wind, oil, feces, sewage disposal, general and harmful liters and seaweeds, were recorded during the sampling time.

2.4. Microbiological analysis

The traditional bacterial indicators total coliform (TC) *E. coli* (EC) and fecal streptococci (FS) were performed in situ after sampling in mobile laboratory. To achieve this, methodology and culture medium proposed by (ISO 9308/1, 1990) for TC and EC, and (ISO 7899/2, 1984) for (FS) using the membrane filtration technique (Gelman 0.45 μm membranes). Appropriate volumes of samples were filtered and the following media (Difco) and incubation temperatures were used. For TC, m-Endo-les agar and incubation at 73^{o}C for 24h; for EC, m-FC agar and incubation at 44.5^{o}C (water bath) for 24h; for (FS), m-Enterococcus agar and incubation at 37^{o}C for 48h. Ten random characteristic colonies from each sample/media were subcultured and confirmed. The confirmatory tests of microscopic examination, gas production, indole production, oxidase test, asculine hydrolysis and catalase test were done. The final counts for all bacteria were calculated as colony forming units (cfu/100 ml). All confirmatory tests were done at the National Institute of Oceanography and Fisheries (NIOF) laboratories in Suez and Hurghada.

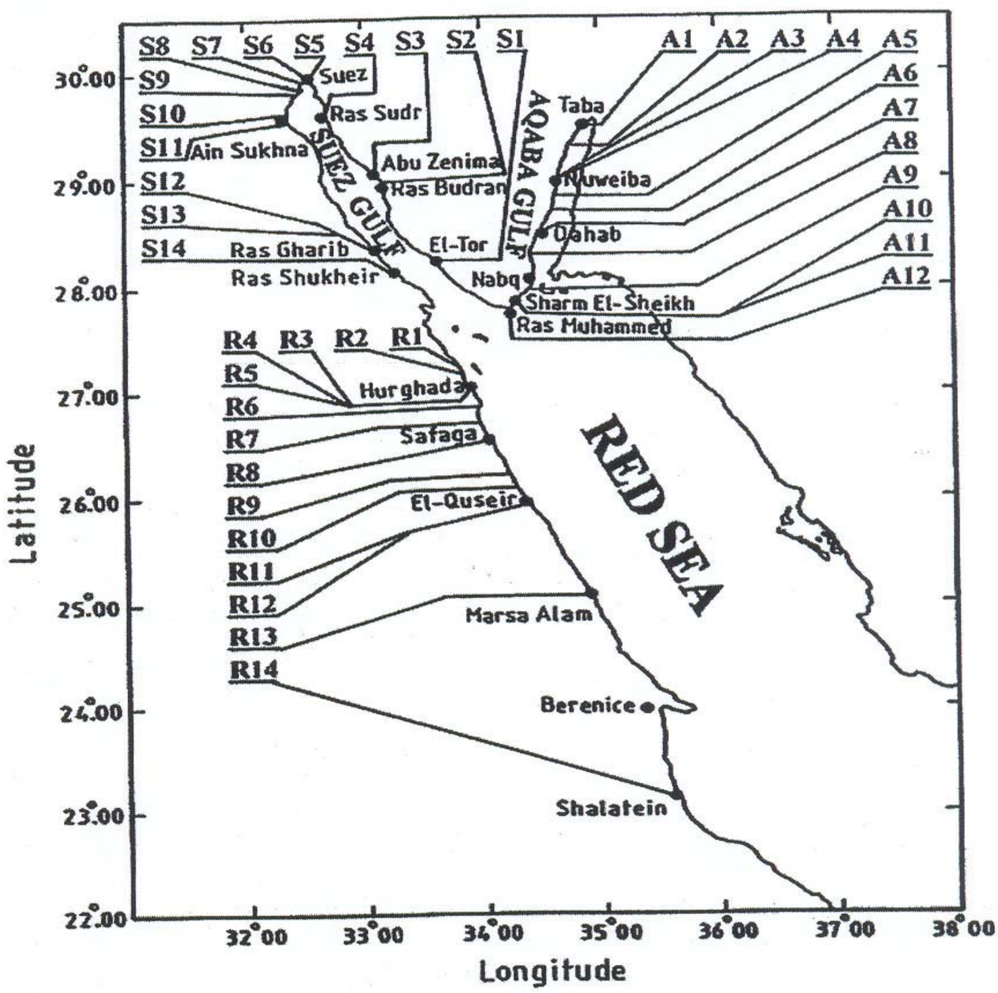

Fig. (1): Map showing the names and sites code of sampling locations for Aquaba (A), Suez (S) Gulfs and Red Sea (R).

Table (1): Percentage of possitive bacterial tests* recorded in fourty sampling sites along Aqaba Gulf (A), Suez Gulf (S) and Red Sea proper (R) during seven years (1998-2004).

No.		List of stations	Site code	Percentage of possitive bacterial tests*							
				1998	1999	2000	2001	2002	2003	2004	Average
1		Taba	A1	0	0	60	40	13	6	0	17
2		Mersa Muqibila	A2	0	0	0	0	0	13	0	2
3		Nuweiba - city	A3	0	0	20	7	0	0	0	4
4		Nuweiba - Harbour El-saidin	A4	0	0	30	33	0	33	47	21**
5		Ras Mamlah	A5	0	0	0	0	0	0	0	0
6	Aqaba Gulf	Hiebiq - Ras Nubar	A6	0	0	0	0	0	0	0	0
7		Dahab - Laguna beach	A7	0	0	0	0	0	6	0	1
8		Nahlat Al-Tel	A8	0	0	0	0	0	0	0	0
9		Sharm El-Sheikh - Na'ama bay	A9	0	0	15	20	13	20	67	20
10		Sharm El-Sheikh - Marine sport club	A10	7	7	10	7	13	0	0	6
11		Sharm El-Sheikh - Marina-Sharm	A11	47	53	70	60	47	40	67	55**
12		Sharm El-Sheikh - Ras Mohamed	A12	0	0	6	0	0	0	0	1
13		El-Tour - Public beach	S1	0	0	0	13	0	13	27	8
14		Ras Budran	S2	0	0	0	0	0	0	0	0
15		Abu Zenima	S3	0	0	0	0	0	0	0	0
16		Ras El-Sudr	S4	7	27	0	20	0	20	3	11
17		Suez North - Port-Tawfik	S5	0	0	0	0	20	13	0	5
18		Suez North - Rix beach	S6	0	0	45	27	73	20	47	31**
19	Suez Gulf	Suez North - Kabanoon beach	S7	0	0	90	73	100	66	80	60**
20		Suez Middle - Ataka NIOF	S8	0	0	0	0	0	0	0	0
21		Suez South - Adabiea Port	S9	0	27	60	33	0	26	60	30**
22		Ain Sukhna North - Sumid Petr. Co.	S10	0	0	0	0	0	6	0	1
23		Ain Sukhna South - Hotel	S11	0	0	15	7	0	0	0	3
24		Ras Gharib - City	S12	100	100	100	100	100	100	100	100**
25		Ras Gharib - Harbour	S13	7	0	0	0	0	0	0	1
26		Ras Shukheir - GAPCO Petr. Co.	S14	0	0	31	7	47		20	15
27		Abu-Sha'r - El-Guna resorts	R1	7	7	0	0	0	26	67	15
28		Hurghada City - NIOF Al-Ahyaa	R2	0	0	0	0	20	0	0	3
29		Hurghada City - Public beach	R3	0	0	0	0	0	13	13	4
30		Hurghada City - Sea horse beach	R4	0	0	0	0	0	26	13	6
31		Hurghada City - Sheraton Hotel	R5	0	0	26	33	47	0	27	19
32		Sal Hashish - El-Dabaa	R6	0	0	10	0	0	0	0	2
33	Red Sea	Safaga North - Suma Bay	R7	0	0	15	33	33	6	20	16
34		Safaga Middle - Phosphate Co.	R8	0	0	20	27	33	26	73	23**
35		El-Hamarawein	R9	0	0	0	0	0	0	0	0
36		Quseir North - Movenpik resort	R10	13	13	39	100	40	13	53	39**
37		Quseir Middle - city	R11	0	0	6	60	40	0	0	15
38		Quseir South - public beach	R12	0	13	10	73	93	20	33	35**
39		Mersa Alam - Marine Sport club	R13	0	0	0	0	0	0	0	0
40		Bir-Shalatin - Fishing port	R14	0	27	92	87	100	80	87	69**

* Positive bacterial tests: that exceeded the acceptable levels of current standard for the presence of one or more indicator bacteria (TC, EC, FS).

** Polluted sites: which over 20% of their samples exceeded the acceptable levels of current standred.

2.5. Hydrographical Measurements

Hydrographical parameters including water temperature (^oC), salinity ($S‰_o$), dissolved oxygen (DO) mg/L and (pH) were measured in situ at each site using CTD (YSI-6000).

2.6. Statistical analysis

Correspondence analysis as well as stepwise multiple regression analysis were performed using NCSS statistical package described by (Gray *et al.,* 1988) for testing the relations between variables. Raw data for bacteria were transformed by adding value of 0.1 to all scores in order to eliminate zero.

3. RESULTS & DISCUSSION

The water quality parameters (temperature ^oC, salinity $‰_o$, pH and dissolved oxygen mg/l) characteristic the Aqaba and Suez Gulfs and Red sea coastal waters were measured in all samples during the course of study. These parameters were usually showed same trends through the seven years of study. Figs. 2&3 showed the seasonal and annual fluctuation of these parameters during 2002 as example).

Water temperature showed seasonal variation represented high records in July and September and low in January. It showed fluctuation between 20.8^{o}C and 28.6^{o}C, 17.7^{o}C and 28.2^{o}C and 20.2^{o}C and 28.1^{o}C for Aqaba Gulf, Suez Gulf and Red Sea respectively. The macro variations of temperature is strictly related to seasonal conditions and the Southern part of Red Sea proper was characterized by a noticeable increase in its water temperature. The same results were noted by (Fahmy, 2001 and 2003; Fahmy *et al.,* 2003 and EIMP, 2003). The geographic and seasonal distribution patterns of salinity showed minor variations. It ranged between 39.50$‰_o$ and 40.20$‰_o$, 39.70$‰_o$ and 42.50$‰_o$ and 39.0$‰_o$ and 40.40$‰_o$ for Aqaba Gulf, Suez Gulf and Red Sea respectively. The values of pH were always very stable and the mean records were 8.15, 8.17 and 8.13 for the same regions respectively. Dissolved oxygen levels never even close to being depleted throughout the course of study. It registered absolute variations (6.4-7.6) 7.00, (6.3-8.7) 7.3 and (6.7-7.3) 7.0 mg/L for the above regions respectively.

The interest of microbiology in marine ecosystems is very old. The highest risk to human health occurs during recreational use of contaminated waters was recommended. (Haile *et al.,* 1999). The quality of the coastal waters with respect to levels of pathogenic bacteria showed a highly variable picture across the Egyptian Coast of Aqaba and Suez Gulfs and Red Sea from uncontaminated coastal waters specially in protectorate areas to very high degree of contamination allover the year in areas receiving raw sewage (Table 1 and Fig. 4).

Using the Egyptian and European standards for marine recreational waters which has guide values of 500, 100 and 100 cfu/100 ml for TC, EC and FS respectively (Ministry of Health, Egypt, 1996 and EC, 1997) and any sample which its bacterial counts exceeded the guidelines was considered a fecally polluted sample. Generally the levels of detected bacteria recorded low numbers during 1998-1999; increasing from 2000 to 2004 (Table 1) the studied area considered as low populated areas, but undergoing considerable pressure because of increasing anthropogenic inputs due to increasing tourism activities may be the reason of increasing bacterial levels from The year 2000 to 2004.

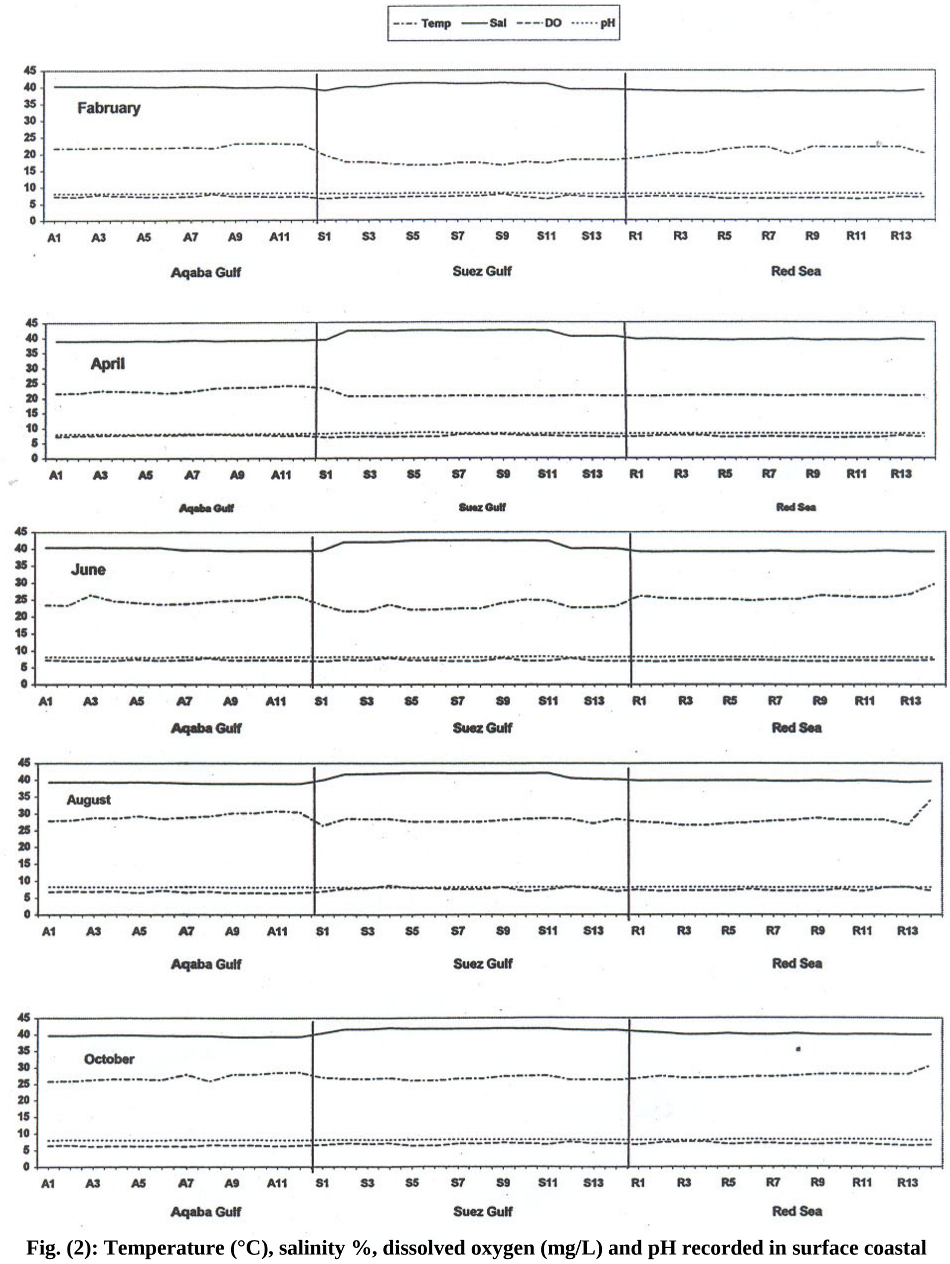

Fig. (2): Temperature (°C), salinity %, dissolved oxygen (mg/L) and pH recorded in surface coastal waters of Aqaba Gulf (A), Suez Gulf (S) and Red Sea (R) during 2002.

Temp.: Temperature **Sal.: Salinity** **Do.: Dissolved oxygen**

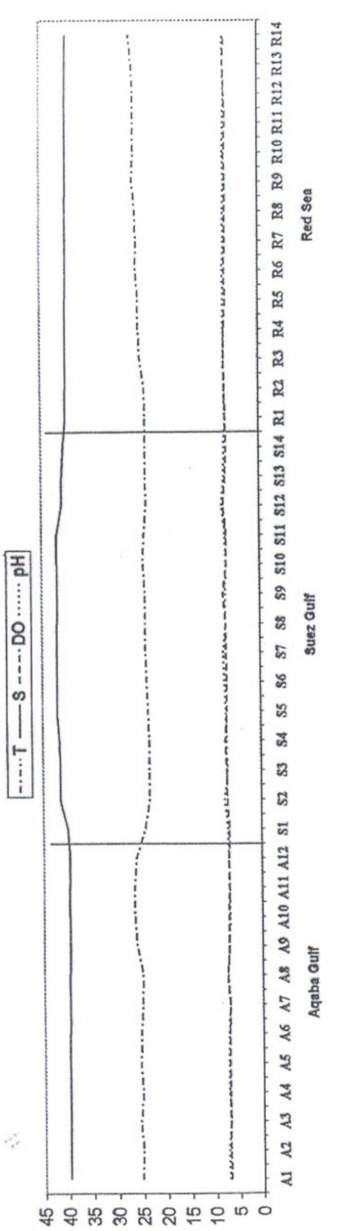

Fig.3. Annual mean values of T (temperature°C), S (salinity ‰), DO (dissolved oxygen mg/l) and pH recorded in surface coastal waters of Aqaba Gulf (A), Suez Gulf (S) and Red sea (R) during 2002.

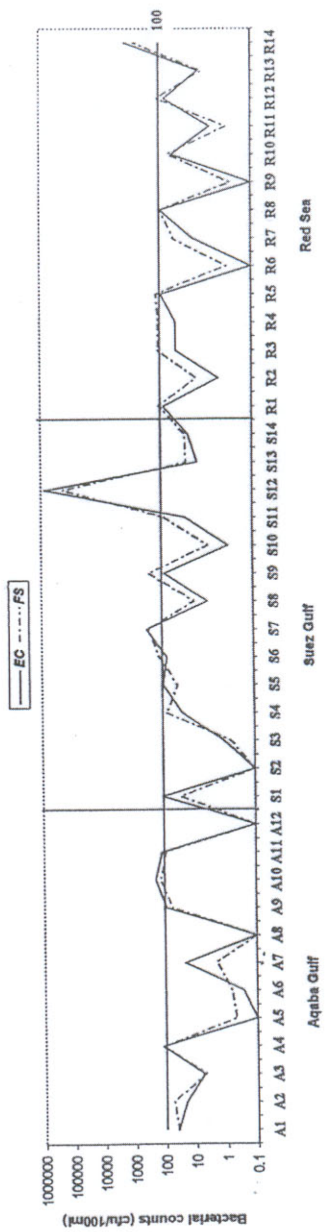

Fig.6. Annual means of bacterial counts (cfu/100ml) recorded in surface coastal waters of Aqaba Gulf (A), Suez Gulf (S) and Red sea (R) during 2002.

EC: *E. coli* bacteria FS: fecal streptococci bacteria

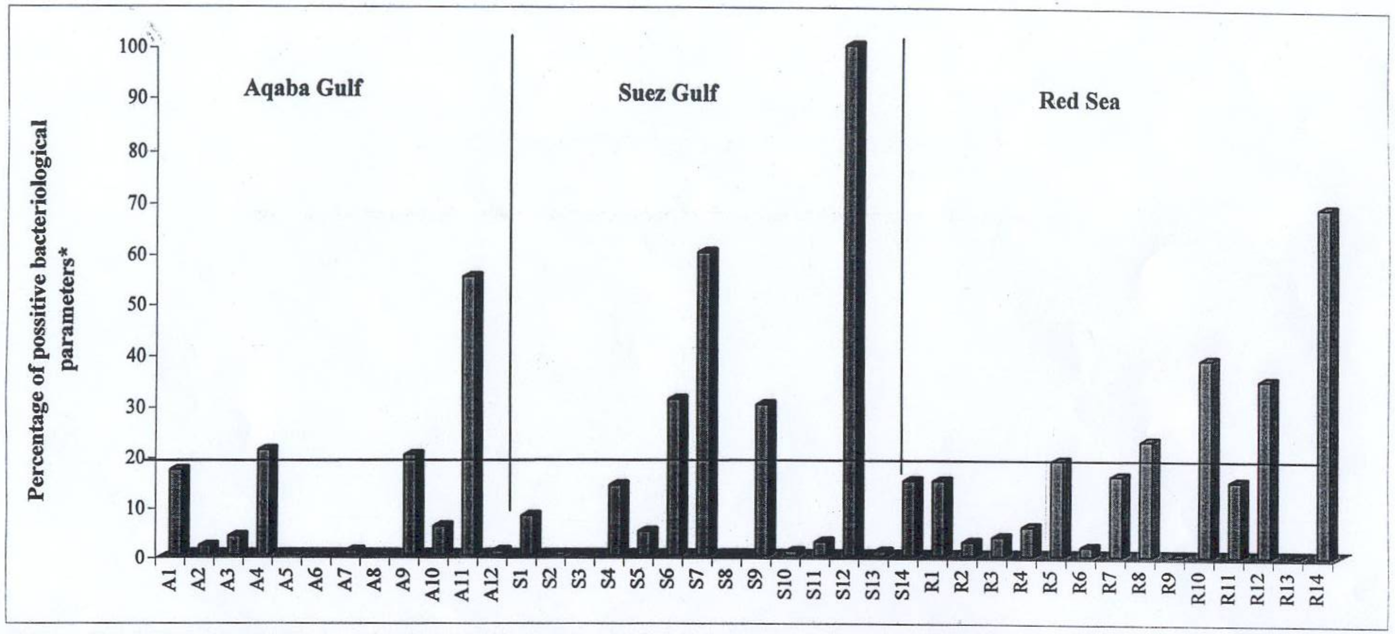

Fig. 4. Percentage of possitive tests bacterial indicators* recorded in fourty sampling sites along Aqaba Gulf (A), Suez Gulf (S) and Red Sea proper (R) during seven years (1998-2004).

* that exceeded the acceptable levels of current standard for the presence of one or more indicator bacteria (TC, EC, FS).

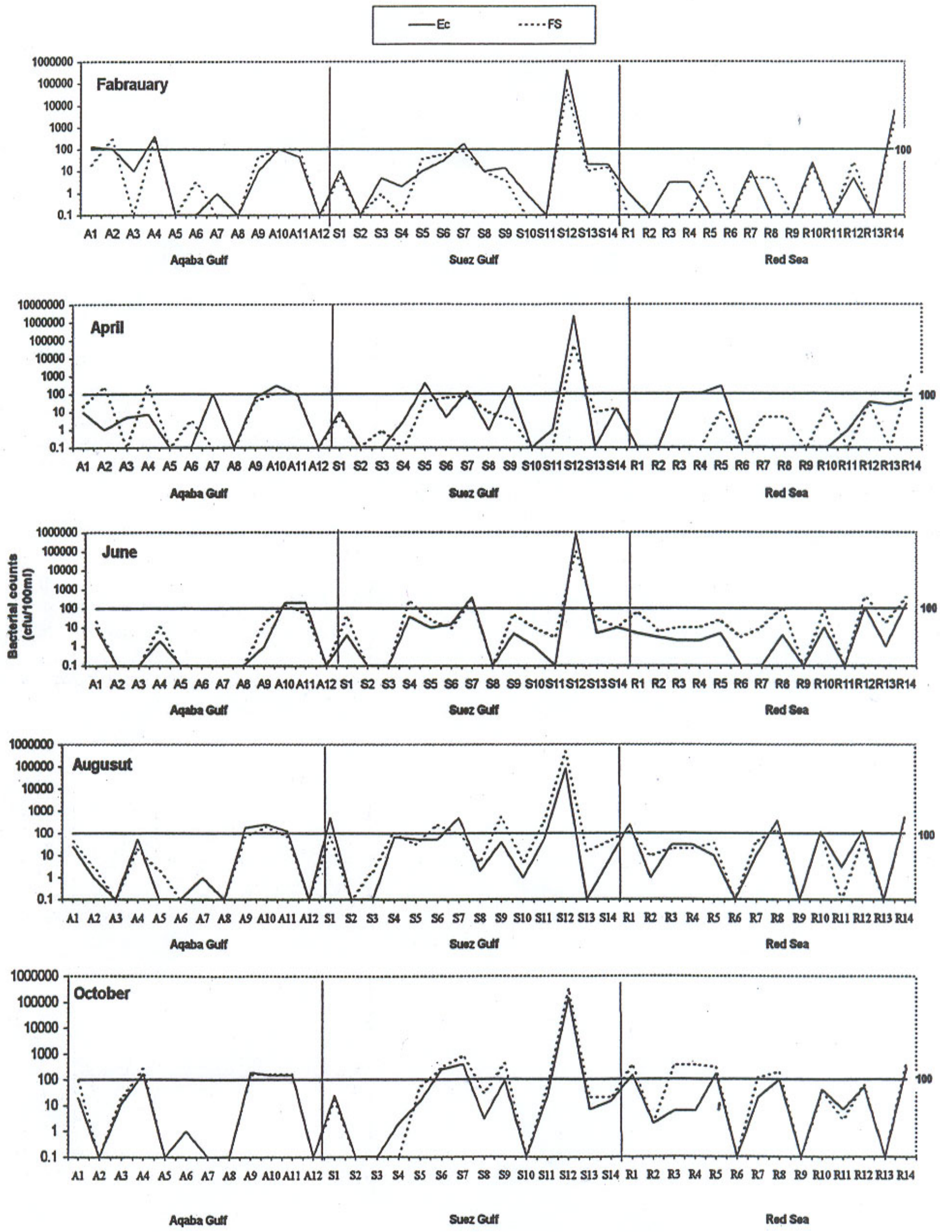

Fig.5. Bacterial counts (cfu/100ml) recorded in surface coastal waters of Aqaba Gulf (A), Suez Gulf (S) and Red Sea (R) during 2002.

EC: *E. coli* bacteria FS: fecal streptoccoci bacteria

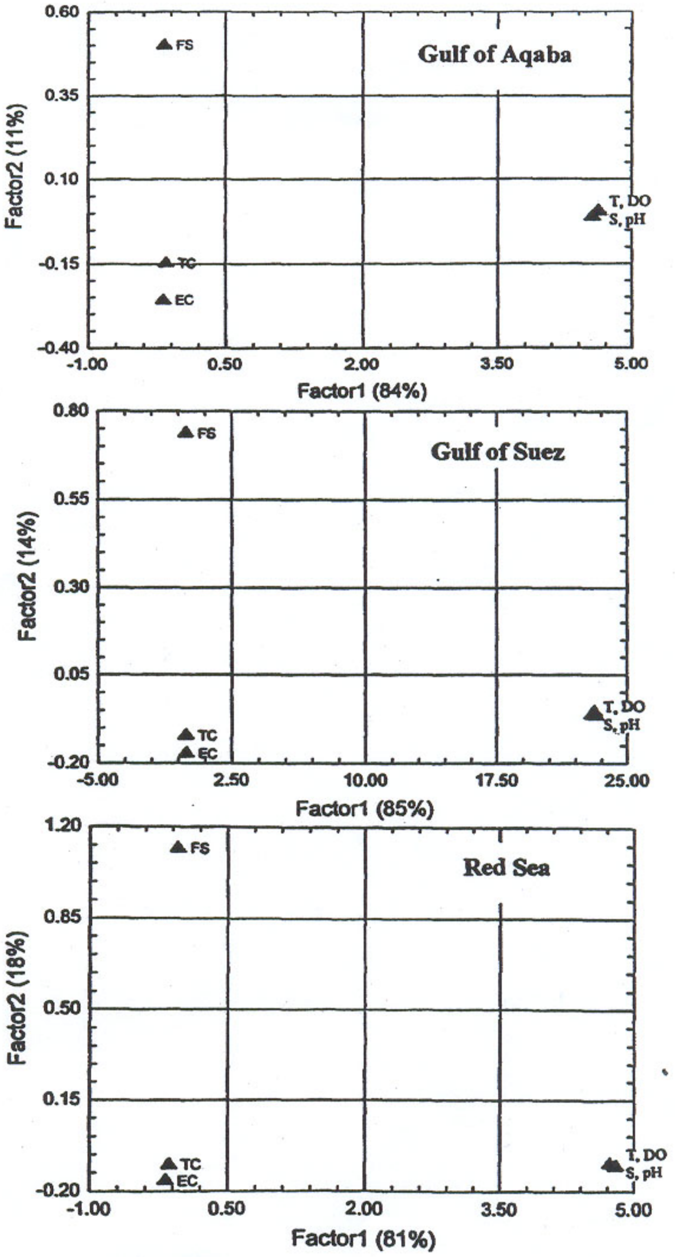

Fig.7. Correspondence plot (program computer package NCSS)
TC: total coliforms, EC: *E. coli*, FS: Fecal streptococci,
T: temperature, DO: dissolved oxygen, S: salinity.

The levels of bacteria showed very low numbers in many protectorate areas (A2, A5, A6, A8, A12) as well as areas with very low populations (S2, S3,S8, S13) and virgin beaches (R2, R6, R9) (Table 1 and Fig. 4). However the studied bacteria increased dramatically allover the year between several Ras Gharib City (S12). The increase in boats anchored in Sharm El-Sheikh - Marina Sharm (A11) and Quseir public beach (R12) (about 90 boats in Sharm El-Sheikh and more than 30 boats in Quseir without waste water treated system) and the high numbers of primitive boats (more than 80 boats) anchored in Shalatin fishing port (R14) may the reason of dramatic increase in bacterial counts.

In several popular beaches (A3, A10, S1, R3, R4, R12) as well as many villages, hotels and resort beaches (A1, A3, A7, A9, S4, S11, R1, R2, R5, R6, R7, R10) the levels of indicator bacteria ranged from acceptable to slight above and sometimes higher than the current standards (Table 1, Fig. 4) according to the visitors/tourists movements.

Figures 5 and 6 showed seasonal and annual fluctuation of bacteriological examination (EC and FS) during 2002 with increasing levels during summer season in popular beaches due to increase human presence for recreational purposes from near local residence, whereas in villages, hotels and resort beaches the levels of bacteria increase over late Autumn and early winter (Tourism season) due to the increased tourist movement and their recreational activities. The same seasonal fluctuation was noted all over the all study period.

This study suggests that bathing beaches may be subjected to increase microbiological pollution during months of excessive human presence and activity despite the increase of day light (more than 14 hours) and solar radiation in this subtropical area which may affect the die-off rate of microorganism (Fattal *et al.,* 1983).

The statistical analysis of correspondence plot made by program computer package NCSS (Fig. 7) showed that in all studied areas during the study period (seven years), TC and EC are close to each others, whereas FS is separated. However the hydrographical parameters seem to affecting TC and FC more than FS levels. The stepwise multiple regression equations showed inverse relationship between salinity and each of TC ($r = -0.149$, $P \leq 0.05$) and EC ($r = -0.147$, $P \leq 0.05$) in the Gulf of Suez. The same relationship was noted by (Solic and Krstulovic, 1992) and (Chigbu *et al.,* 2004). In Red Sea there was an inverse relationship between FS levels and temperature ($r= -0.17$, $P \leq 0.05$). (Chigbu *et al.,* 2004) reported negative relationship between temperature and fecal coliform levels in Mississippi Sound, although some studies reported that fecal coliform bacteria death rate increased with temperature from < 5^{o}C to 35^{o}C in marine waters (Auer and Niehaus, 1993).

Seawater quality criteria proposed by the world health organization and other international foundations are usually suggested total coliforms, *E. coli* and fecal streptococci as microbiological pollution indicator (WHO, 1994; Pike, 1993). The combination of several indicators is likely to present a global picture of water quality (seyfried *et al.,* 1985). The results of present study in Table (2) showed that during the course of study *E. coli* represented 46.1% of positive samples compare to 40.1% and 29.5% for fecal streptococci and total colifrom respectively, suggesting that *E. coli* are the most appropriate indicator during the course of study concerning variation in time and locations. World wide, there is no agreement on the best indicators of public health risks from contaminated marine waters. For example, the United States currently monitors enterococcus or coliforms (Haile *et al.,* 1999), Hong Kong monitors *E. coli* (Cheung *et al.,* 1990). United Kingdom monitors fecal streptococci (key *et al.,* 1994).

From the microbiological point of view, the limits of acceptability equivalent to 80% of analyzed samples compliance with the current standard (WHO/UNEP, 1977), the results showed 30 sites (75%) of 40 studies sites can be classified as unpolluted. However in bathing beaches, 25 beaches (91%) of 28 beaches were recommended as unpolluted, and approved for safe recreational activities. Three of studied beaches (S6, R14, R12) can be classified as relatively polluted, as over 20% of their samples sometimes were above acceptable levels only in heavily visited seasons (Table 1 and Fig. 4).

Red Sea, Gulf of Aqaba and Gulf of Suez are highly valued as recreational resources. Therefore the maintenance, preservation and restoration of its water quality are integral to address appropriate management strategies and sustainable development in the future. To achieve this; (1) the sanitary monitoring program in terms of microbial contamination must be continued to make database system. (2) disciplinary approach for increasing public awareness of preserving marine ecologic health is needed. (3) Awareness for personal hygiene and use of clean towels on the beaches. (4) Regular cleaning of beaches from fecal material, litters and sharp material. (5) Do not give an award to resort beaches that allowed dogs, camels and horses specially during the recreational seasons.

In general the results of this study will help in (1) Providing relevant baseline data for any comparative studies on the ecology of microbial indicators. (2) Making focus on polluted areas. (3) Drawing attention that agglomerations nearby bathing areas that producing waste water must be connected to waste water treatment plant.

ACKNOWLEDGMENT

Supports of the steering committee of the Egyptian Environmental Affair Agency (EEAA) and Danish International Development Assistance (Danida) should be acknowledged. Thanks are also extended to Mr. Hemily (NIOF) for partial technical assistance and Dr. Abdel Mola (NIOF) for statistical analysis.

Table (2): Percentage of positive tests* of each bacterial parameter from 1998-2004.

Year	Total coliforms (TC)	*E. Coli* (EC)	Fecal streptococci (FS)
1998	23.3	36.7	30.0
1999	31.4	37.1	40.0
2000	34.5	42.6	30.9
2001	34.3	45.7	42.9
2002	48.2	60.0	40.0
2003	14.5	30.9	34.5
2004	20.0	71.1	62.2
Average	**29.5**	**46.3**	**40.1**

* postive tests: that exceeded the acceptable levels of current standards.

REFERENCES

Auer, M.T. and Niehaus, S.L.: 1993, 'Modeling of fecal coliform bacteria –1. Filed and laboratory determination of loss kinetics', *Water Research* **27**: 693-701.

Cabelli, V.J.: 1989, 'Swimming-associated illness and recreational water quality', *Water Sience and Technology* **21**: 13-21.

Cabelli, V.J.; Dufour, A.P.; McCobe, L.J.; Levin, M.A.: 1982, 'A marine recreational water quality criterion consistent with indicator concepts and risk analysis' *Journal of water pollution control Federation* **55**: 1306-1314.

Cheung, W.H.; Chang, K.C.; Hug, R.P.: 1991, 'Variations in microbial indicator densities in beach waters and health-related assessment of bathing water quality'. *Epidemiology and Infection* **106**: 329 – 344.

Cheung, W.H.; Chang, K.C.; Hung, R.P.; Kleevens, J.W: 1990, 'Health effects of beach water pollution in Hong Kong', *Epidemiology and Infection* **105**: 139-162.

Chigbu, P.; Gordon, S.; Strange, T.: 2004, 'Influence of inter-annual variations in climatic factors on fecal coliform levels in Missippii Sound', *Water Research* **38**: 4341-4352.

Corbett, S.J.; Rubin, G.L.; Curry, G.K. Kleinbaum, D.G.: 1993, 'The health effects of swimming at Sydney beaches',. *Amirian Journal of Health.* **83**: 1701-1706.

EC, (European commission):1997, 'Quality of bathing water', *Technical Report*, Document EUR 18166, European Commission, Brussels.

Fahmy, M.A.: 2003, 'Water quality in the Red Sea coastal waters, Egypt. Analysis of spatial and temporal variability', *Chemistry and Ecology* **19**: 67- 77.

Fahmy, M.A.: 2001, 'Preliminary study on the hydrochemistry of the Egyptian coastal water of Aqaba Gulf, as unique ecosystem during year 2000', Bulltein Institue of Oceanography and Fisheries. Egypt. **27**: 95-112.

Fahmy, M.A.; Aboul Soeaud, A. El-Shabrawy, A.: 2003, 'Hydrochemical characteristics of the Suez Gulf coastal waters, Egypt during year 2000', *Association for the Advanced of Modeling and simulation techniques in Inter Prises*. **64C**: 1-14.

Fattal, B.; Vasl, R.G.; Katzenelson, E. Shuval, H.I.: 1983, 'Survival of bacterial indicator organisms and enteric viruses in the Mediterranean costal waters of Tel-Aviv', *Water Research* **17**:397-402.

Fleisher, J.M.; Kay D. Godfree, M.D.: 1998, 'Estimates of the severity of illnesses associated with bathing in marine recreational waters contaminated with domestic sewage', *International Journal of Epidemiology*. **27**: 722-726.

Fleisher J.M.; Kay, D.; Salmon, R.L; Jones, F.; Wyer, M.D.; Geolfnee, AF.: 1996, 'Marine waters contaminated with domestic sewage: nonenteric illnesses associated with bather exposure in the united kingdom. American Journal of Public Health **86**, 1228-1234.

Gray, J.S.; Aschan, A.; Carr, M.R.; Clarke, K.R.; Green, R.H.; Pearson, T.H.; Rosenberg, R. and Warwick, R.M. (1988) Analysis of community attributes of the benthic marcrofauna of frierfjord/langesundfjord and in a mesocosm experiment', *Marine Ecological Program Series.* **46**: 151-165.

Haile, R.W.; Witte, J.S; Gold, M.; Gressey, R.; McGeec Millikan, R.C.; Glasser, A. Harawa, N.: 1999, 'The health effects of swimming in Ocean Water contaminated by storm drain runoff', *Epidemiology* **10**: 355-363.

Henrickson, S.E.; Wong, T.; Allen, P.; Tim, F. Epstein, P.R.: 2001, 'Marine swimming related illness: implications for monitoring and environmental policy', *Health Perspectives* **109**: 64.5-650.

ISO (International Organization for Standardization) No. 5667/9: 1992, 'Water Quality-Sampling-part 9: Guidance on sampling from marine waters', *Technical Report*, Geneva, Switzerland.

ISO (International Organization for Standardization) No. 7899/2: 1984, 'Water Quality-Detection and enumeration of streptococci-part 2: Methods by membrane filtration', *Technical Report*,. Geneva, Switzerland.

ISO (International Organization for Standardization) No. 9308/1: 1990, 'Water Quality-Detection and enumeration of coliform organisms, thermotolernat colifrom organisms and presumptive *Escherichia coli* – Part 1: Membrane filtration method', *Technical Report*, Geneva, Switzerland.

Key, D.; Fleisher, J.M.; Salmon, R.L; Wyer, M.D; Godfree, A.F; Zelenauch-Jacquotte, Z.; Shore, R.: 1994, 'Predicting likelihood of gastroenteritis from sea bathing: results from randomized expose', *Lancet* **344**: 905-909.

Ministry of Health, Egypt.: 1996, 'Microbiological standards of the Egyptian recreational waters', *Technical Report*. Report No. 64, Cairo, Egypt.

Morcos, S.A.: 1970, 'Physical and chemical oceanography of the Red Sea', *Oceanogr. Marine Biology. Annual Review.* **8**: 73-202.

Murty, T.S. and El-Sabh, M.T.: 1984, 'Weather system storm surges and sea state in the red sea and the Gulf of Aden', *Proceeding Symbosium coral Reef Environment. Red sea*. Jeddah. Saudi Arabia. pp. 8-38.

Pike, E B.: 1993, 'Recreational use of coastal waters: development of health related standards'. *Journal of IWEM.* **7**: 162-167.

Prieto, M.D.; Lopez, B.; Juanes, J.A.; Revilla, J.A.; Llorca, J. Delgado-Rodriguez, M.: 2001, 'Recreational in coastal waters: health risks associated with bathing in sea water', *Journal Epidemiology. Community Health* **55**: 442-447.

Sayfried, P L.; Tobin, R S; Brown, N E. Ness, P.F.: 1985, 'A prospective study of swimming related illness. II. Morbidity and the microbiological quality of water', *American Journal of Public health* **75**: 1071-1074.

Solic, M. and Krstulovic, N.: 1992, 'Separate and combined effects of solar radiation, temperature, salinity and pH on survival of fecal coliforms in sea water', *Marine Pollution Bulltein.* **24**: 411-416.

WHO, (Regional Office for Europe): 1994, 'Guidelines for health-related monitoring of coastal recreational and shellfish areas, Part II', *Technical Report,* Copenhagen.

WHO/UNEP: 1977, 'Health criteria and epidemiological studies related to coastal water pollution, world Health Organization', *Technical Report,* Copenhagen.