CATRINA (2010), 5 (1): 97 -103

Implications of Environmental Monitoring of Oil Pollution in Sharm El-Maya Bay, Sharm El-Sheikh, Egypt

Mona A. Morsy [(1)], Farouk A. Soliman [(1)], Rafat M. Khattab [(2)], Mohamed A. Rashed [(3)], and Nabil N. El-Masry [(4)]

[(1)] Geology Department, Faculty of Science, Suez Canal University, 41522 Ismailia, Egypt
[(2)] Marine Science Department, Faculty of Science, Suez Canal University, 41522 Ismailia, Egypt
[(3)] Geophysics Department, Faculty of Earth Sciences, King Abdul-Aziz University, 21589 Jeddah, Saudi Arabia
[(4)] Geological Hazards Research Unit, Faculty of Earth Sciences, King Abdul-Aziz University, 21589 Jeddah, Saudi Arabia

ABSTRACT

The peculiar environment of Sharm El-Sheikh area, upon which its tourism industry is based, is undoubtedly threatened by different sources of pollution that are directly related to the rapid growth of the city, the influx of millions of tourists every year, and to the increased maritime activities in the Gulf of Aqaba and the Red Sea. The 1999's oil spillage in Sharm El-Maya Bay represented an extreme example of one of these threats. Although the spillage itself was promptly contained, only few studies were conducted to investigate the source of the pollution and its spatial and temporal variations. The present study, therefore, aimed to determine the extent of the pollution, its spatial variation, and its source. Three different types of samples were collected and analyzed for petroleum hydrocarbons. They included sediment samples from the headland, and samples of seabed sediments and seawater from the subtidal zone. Total hydrocarbons were determined using conventional gravimetric techniques. The results showed that the average concentration of the total hydrocarbons was 661.7±383.16 µg/g in the headland, 170±128.59 µg/g in the seabed, and 37.99±17.45 mg/L in the seawater. The results also indicated that the average content of total hydrocarbons in seawater samples was considerably higher than that estimated earlier. Spatial and temporal variations in the total hydrocarbon contents are suggestive of a land-based source of pollution related to damaged-underground fuel-storage tanks and pipelines that are actively polluting the bay.

Key words: Gravimetric analysis, Hydrocarbons, Oil pollution, Seawater samples, Sediment samples, Sharm El-Sheikh, Sharm El-Maya

INTRODUCTION

In the last thirty years, Sharm El-Sheikh has developed from a small resort located in the southern coast of Sinai Peninsula to an internationally famed city visited by millions of tourists every year. As the city has become the focal point of tourism industry in Egypt, concerns have risen about the effects of various anthropogenic activities on the quality of its environment.

Sharm El-Maya Bay is rather a small semi-circular bay located in the southern suburb of Sharm El-Sheikh City between latitudes N 27° 51' 21.13" and N 27° 51' 45.19" and longitudes E 34° 17' 20.57" and 34° 17' 54.42" (Figure 1). It occupies an approximate area of 0.387 km2 and has a narrow southern entrance to the Red Sea about 310 meters in width. It is bounded by two headlands; the most conspicuous one, known as Ras Umm-Sidd, is located in the north and delimits the eastern margins of the bay. The southern headland, however, defines the western and the southern margins of the bay. It forms a shoe-shaped promontory projecting into the Red Sea. It separates Sharm El-Maya Bay from the neighboring Sharm El-Sheikh Bay and markedly shelters the two bays from the waves of the open sea. The two headlands form an elevated tract of near-flat land surface bounded seaward by prominent sea cliffs, which border the eastern and southern margins of the bay as well as the waterway to its mouth. The sea cliffs range in height between 15 and 30 meters above sea level. The cliffs are composed of alternating beds of clastic sedimentary rocks and coralline limestone.

In 1999, nonetheless, Sharm El-Maya Bay area was confronted with an extensive spill of petroleum hydrocarbons directly affecting the beaches and the water of the bay itself as well as its southern headland where the old power plant was installed. The spillage incident took place almost eight months after the components of the old power plant, such as the power generators and the aboveground fuel-storage tanks, were dismantled.

Figure (1): Location map of Sharm El-Maya Bay area and its surroundings. (Sources: satellite image from Google™ Earth, 2010; insert from MODIS/MODLAND/ Descloitres, 2000).

* *Corresponding Author: nelmasryn@yahoo.com*

Other incidents of oil spills were also reported in Sharm El-Sheikh area. One of these incidents took place in 1982 when a cargo ship (Lanai) ran aground on the Woodhouse reef in the Strait of Tiran spilling 700 tones of fuel oil over a length of 50 km of the coastline (Callum and Sheppard, 1988). Some of this oil was trapped in the southwestern sheltered part of Sharm El-Maya Bay (Khattab *et al.,* 2006). In 1994, three separate incidents of oil spills were reported in Sharm El-Sheikh area that were also caused by the accidental release of oil from tankers navigating through the Strait of Tiran (Pilcher and Abou Zaid, 2000).

These incidents not only represented a direct threat to the fragile ecosystem of the bay, which is the concern of the scientists, but it also represented a major blow to the economy of the area which capitalizes on the concept of clean environment. The millions of pounds invested in building hotels, tourist villages, and recreational centers in the bay area as well as the livelihood of the hundreds who work in these facilities were therefore equally threatened.

The ecological significance of Sharm El-Maya Bay, however, stems from its role as the nursery ground for some commercially valuable fishes and from the presence of some ecologically sensitive ecosystems, particularly sea grass and coral patches (Alwany *et al.*, 2007). The semi-closed nature of the bay and its shallow depth (a maximum of 6 meters) may considerably limit water circulation and cause the entrapment of sediments and organic particles of various origins (Alwany *et al.,* 2007). Therefore, any oil spill could damage the reproductive system of corals, interfere with the production of larvae, induce feeding and behavioral changes among fauna, and interrupt the photosynthetic cycle of specific coral reefs (Loya and Rinkevich, 1980; Al-Halasah and Ammary, 2007). There are also potential health risks concomitant with oil contamination. Benzene, a key component of gasoline, is a known human carcinogen causing acute myelogenous leukemia and lymphomas (Goldstein, 2010).

In the ensuing months of the 1999's oil spillage, extensive investigations were carried out to determine the source of the oil contamination and to evaluate its extent (Carl Bro International, 1999; Suez Canal University, 1999; Cairo University, 2001; Suez Canal University, 2001; Khattab *et al.,* 2006). Prompt mitigation plans were consequently adopted to constrain the damage and to clean-up the coastal area of the bay.

A field visit to Sharm El-Maya Bay area in April 2008 disclosed, however, the widespread distribution of dark-colored spots of seeped oil on the southern headland and on the beach in addition to the presence of a strong smell of petrol, which thickens the air both on land and in the sea. These signs of a persistent pollution that is still damaging the area and the absence of any on-going monitoring or evaluation programs have made it quite necessary to reexamine the situation.

The present study is primarily concerned with determining the source and the level of the pollution caused by petroleum hydrocarbons, which have widely affected the study area. Therefore, samples of the headland sediments, the seabed sediments, and the seawater were collected and analyzed, using conventional gravimetric techniques, to determine the concentration and the spatial distribution of the hydrocarbon materials in the northern part of the southern headland and its shore.

MATERIALS AND METHODS

Three different types of samples were collected from the study area. They included sediment samples from the elevated headland and its narrow shore, seawater samples, and seabed sediment samples. Each type of these samples was treated in accordance with the procedures recommended by UNESCO (1976) and UNEP/IOC/IAEA (1992).

Sample Collection

Sediment samples were collected from forty-seven different sites on the headland and the adjacent shoreline. Sample collection targeted primarily dark-colored spots of contaminated sediments (Figures 2 and 3). Most of the samples were collected along a number of profiles that were properly set to cover the study area. Sample sites were precisely determined using a GPS device (Garmin's GPSMAP® 60cs), a tape measure, a Brunton® compass, and a set of Google™ Earth images. A folding shovel was used to dig holes ranged from 15 to 20 cm in depth. Representative sediment samples, about 500 to 1000 grams each, were then carefully obtained from that depth and were put in firmly sealed plastic bags wrapped with aluminum foil. The collected samples were stored in an icebox, at 4°C, for further treatments in the laboratory.

Seawater samples were collected from eleven different sites in the subtidal zone at depths ranging between one and two meters. Clean bottles of glass, which have small mouth (2-3 cm inside diameter) and contain 50 ml of dichloromethane as a solvent, were immersed to the required depth for seawater sampling. Upon retrieval, the bottles were shaken up vigorously for about five minutes to disperse the solvent. They were immediately stored in an icebox for subsequent treatments in the laboratory.

Figure (2): Dark-colored spots of oil-contaminated sediments and concrete foundations of the dismantled power plant units as shown in the northern part of the southern headland.

Figure (3): Dark-colored spots of oil- contaminated beach sands restrained by a makeshift, rectangular-shaped, concrete groundsill at the northern shoreline of the southern headland.

Seabed sediment samples were collected from eight different sites in the subtidal zone. The topmost three-to-five centimeters of seabed sediment were spooned into clean firmly sealed plastic bags wrapped with aluminum foil and kept in an icebox for subsequent laboratory studies.

Additional samples were collected from a partly exposed succession of varicolored sub-horizontal beds of friable sandstones. The succession comprised conspicuous beds of red-colored ferruginous sandstone and dark-colored manganiferous sandstone (Figure 4).

Sample Treatment

Headland sediment samples were treated to determine the concentration of the total hydrocarbons using conventional gravimetric techniques. Two consecutive runs of treatment were used to extract the hydrocarbon materials entrapped in each sample. Fifty grams of a

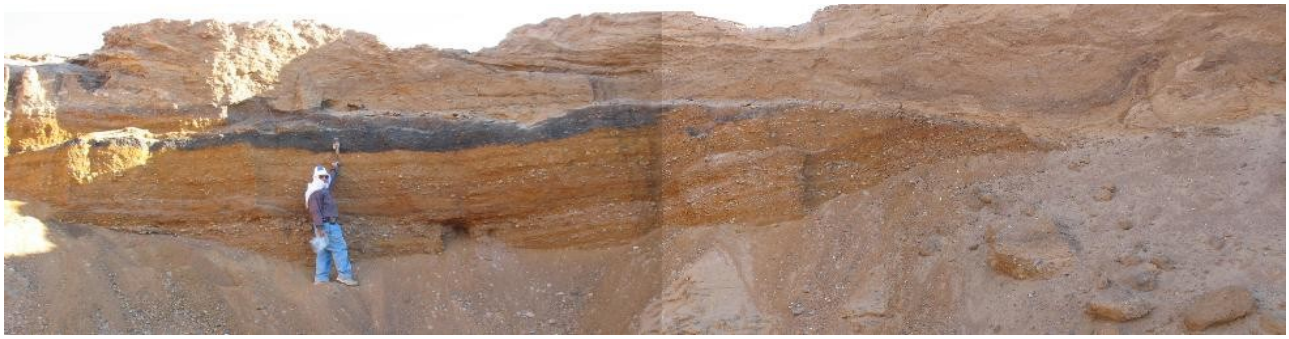

Figure (4): A succession of varicolored sub-horizontal beds of ferruginous (red-colored) and manganiferous (dark-colored) friable sandstones.

sediment sample was put in a clean flask for about twenty-four hours with a mixture composed of equal proportions of dichloromethane and n-hexane, 25 ml each. Extracts of hydrocarbons and solvents were separated in a clean flask using a clean glass funnel and a filter paper. The sediment sample left over from the first run was treated one more time by the same mixture of solvents to obtain another extract. The two extracts were collected in one flask and heated to about 45°C to remove all existing solvents. The remaining dry residue was re-dissolved in a minimum amount of dichloromethane and was stored in a covered glass vial after allowing the added solvent to be completely evaporated. The weight of the extracted hydrocarbon materials was determined using a digital balance. Vials were kept in a dark compartment for further analyses.

Seawater samples were analyzed according to the standardized procedures suggested by UNESCO (1976). Hydrocarbon extraction from seawater samples was performed during and after sample collection by adding 100 ml of dichloromethane in two successive runs, 50 ml each. As mentioned earlier, the first 50 ml of the solvent was added before retrieving the sample from the sea. In the laboratory, the extract of solvent and hydrocarbons were separated in a clean flask using a separating funnel. The second 50 ml of the solvent was then added to the sample left over from the first run. After shaking the mixture of seawater and solvent vigorously in the separating funnel, the second extract was once more isolated in the same flask with the first extract. The two extracts were dried over anhydrous sodium sulphate and heated on a hot plate to dryness at 45°C. The residue was re-dissolved in a minimum volume of dichloromethane and was stored in a covered labeled glass vial. The total hydrocarbon concentration in each sample was obtained by using a digital balance.

Seabed sediment samples were dried in an oven at 45°C. Fifty grams of each sample were used for extracting the hydrocarbon materials following the same analytical procedure described earlier for the headland sediment samples.

RESULTS

The complete set of analyses concerned with the total hydrocarbon concentrations determined in the collected samples of the headland and the seabed sediments and the seawater are statistically summarized in table (1). Spatial variations in the concentrations of the total hydrocarbons extracted from the examined samples are represented on computer-generated contour maps using Surfer® 8.0 provided by Golden Software Inc., 2002 (Figures 5, 6, 7, and 8).

Table (1): Summary statistics of the total hydrocarbon concentrations determined in the headland sediments, seawater samples, and the seabed sediments of Sharm El-Maya Bay area

Statistics	Headland sediments			Seawater		Seabed sediments		
	Concentration							
	mg/g	*ppm*	*%*	*mg/L (ppm)*	*%*	*mg/g*	*ppm*	*%*
Mean	*0.66*	*661.7*	*0.066*	*37.99*	*0.0038*	*0.17*	*170*	*0.017*
Standard Error	0.19	190.4	0.019	7.83	0.00078	0.054	54.38	0.0054
Standard Deviation	*1.31*	*1305*	*0.13*	*25.97*	*0.0026*	*0.15*	*153.81*	*0.015*
Coefficient of Variation	1.97	1.97	1.97	0.68	0.68	0.90	0.90	0.90
Kurtosis	9.99	9.99	9.99	0.72	0.72	-0.43	-0.439	-0.43
Skewness	3.11	3.11	3.11	0.96	0.96	1.18	1.18	1.18
Range	*6.12*	*6120*	*0.612*	*85.97*	*0.0086*	*0.38*	*380*	*0.038*
Minimum	*0*	*0*	*0*	*8.24*	*0.0008*	*0.04*	*40*	*0.004*
Maximum	*6.12*	*6120*	*0.612*	*94.20*	*0.0094*	*0.42*	*420*	*0.042*
Count	47	47	47	11	11	8	8	8
Confidence Level (95.0%)	*0.38*	*383.16*	*0.0383*	*17.45*	*0.0017*	*0.13*	*128.59*	*0.013*

The average concentration of the total hydrocarbons is 0.66±1.31 mg/g, and the estimated coefficient of variation is 1.97. A coefficient of variation greater than one indicates the presence of some erratic high sample values that may have some impact on the final estimates (Isaaks and Srivastava, 1989). The range of the hydrocarbon concentrations is 6.12 mg/g, which is delimited by a minimum value of 0 mg/g and a maximum value of 6.12 mg/g.

Skewness and kurtosis are shape parameters (Bohm and Zech, 2010). Kurtosis measures the peakedness of a distribution (Spiegel, 1972) and its coefficient is equal to zero for normal distribution (Bohm and Zech, 2010). Skewness measures the asymmetry of a distribution with respect to its mean; its coefficient is zero for the normal distribution, but quite sizable for the exponential distribution (Bohm and Zech, 2010). The values of kurtosis and skewness shown in table (1) indicate that the total hydrocarbon concentrations have a positively-strongly skewed leptokurtic distribution. The confidence level for the mean is determined at two standard error intervals (95%). It defines the confidence limits of the population mean concentration at 0.66±0.38 mg/g.

The computer-generated contour map shown in figure (5) indicates the presence of three maxima at 0.26, 0.52, and 0.56% around which semi-circular contour lines close unless they are truncated by the shoreline or any manmade structure. A north-south trough of relatively widely spaced contour lines separates the two maxima located in the central part of the map. The two maxima, however, have closely spaced concentric contour lines depicting a relatively steep northern gradient where the highest data value (either 0.52 or 0.56%) is very close to the lowest data value (0%). The truncated contour lines of the northern maximum (0.26%) located at the sandy beach have a relatively gentle southern gradient. They are separated from their counterparts in the south by an ENE-WSW trending trough of low-values contour lines.

Figure (5): A contour map showing the spatial variations of the total hydrocarbon concentrations (%) determined in the headland sediments of Sharm El-Maya Bay area. Contour interval is 0.02%.

Seawater

The average concentration of the total hydrocarbons is 37.99±25.97 mg/L, and the calculated coefficient of variation is 0.68. The range of the hydrocarbon concentrations is 85.97 mg/L, which is defined by a minimum value of 8.25 mg/L and a maximum value of 94.20 mg/L. The values of kurtosis and skewness shown in table (1) indicate that the total hydrocarbon concentrations have a positively skewed leptokurtic distribution, which is more symmetric than that for the headland sediments. The confidence interval for the population mean is 37.99±17.458 mg/L. The computer-generated contour map shown in figure (6) depicts five alternating highs and lows of closed contour lines separated by parallel, evenly spaced, contour lines. The central north-south trough clearly defines the two maxima. The closeness of the contour lines, however, indicates that it has a gentle gradient with the western maximum, which has a high value of 0.0061%, but a much steeper gradient with the eastern maximum, which has a high value of 0.0091%.

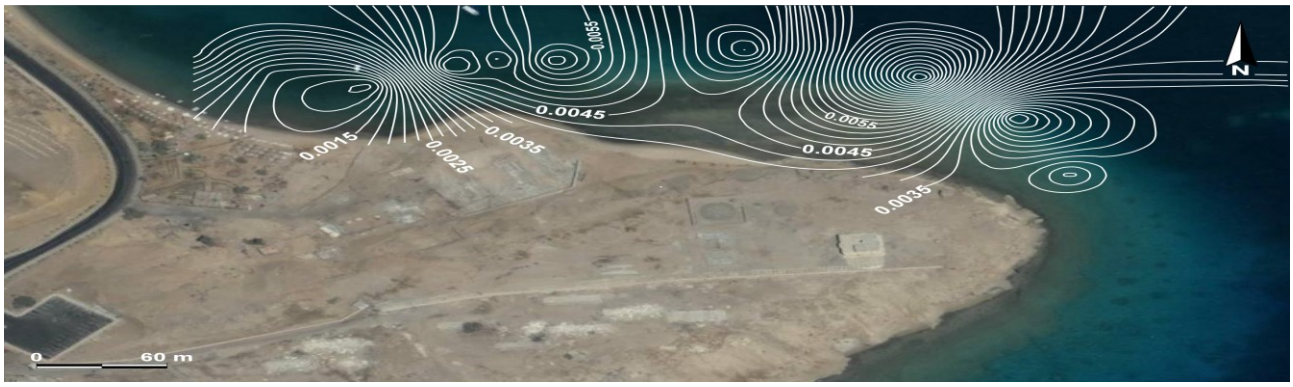

Figure (6): A contour map showing the spatial variations of the hydrocarbon concentrations (%) determined in the seawater of Sharm El-Maya Bay. Contour interval is 0.0002%.

Seabed Sediments

The average concentration of the total hydrocarbons is 0.17±0.15 mg/g, and the calculated coefficient of variation is 0.90. The range of the hydrocarbon concentrations is 0.38 mg/g, which is defined by a minimum value of 0.04 mg/g and a maximum value of 0.42 mg/g. The values of kurtosis and skewness shown in table (1) also indicate that the total hydrocarbon concentrations have a positively skewed platykurtic distribution. The confidence interval for the population mean is 0.17±0.13 mg/g.

The computer-generated contour map shown in figure (7) illustrates one localized set of closed contour lines, which has a maximum value of 0.041%. Spacing of the contour lines indicates that the gradient is steep toward the minimum values located to the east and west of the closed contour lines, but it is much gentler toward the shoreline located to the south.

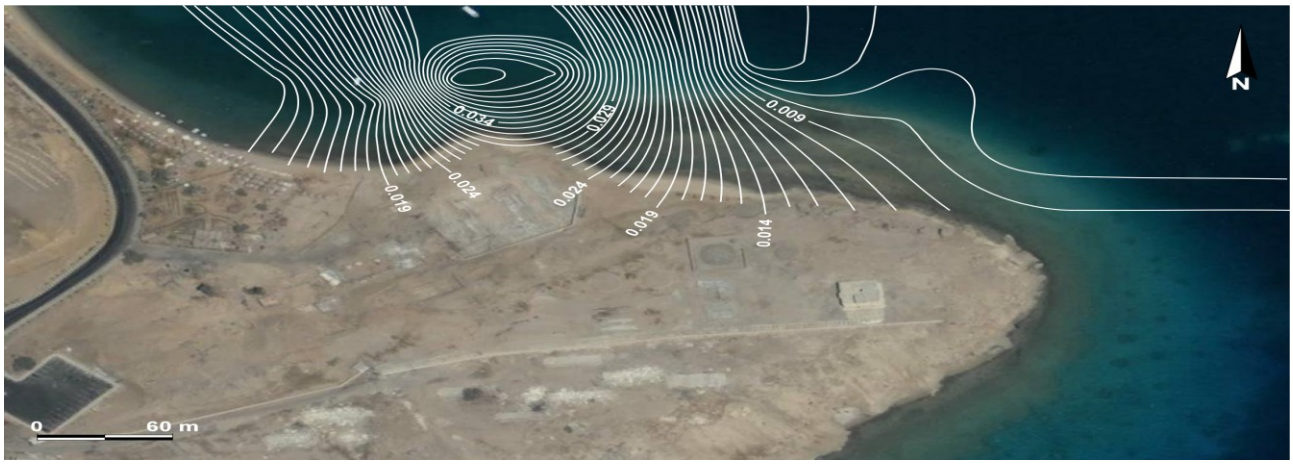

Figure (7): A contour map showing the spatial variations of the hydrocarbon concentrations (%) determined in the seabed of Sharm El-Maya Bay. Contour interval is 0.001%.

Spatial variations in the hydrocarbon concentrations of the headland and the seabed sediments are collectively shown in figure (8). The location of the three concentric sets of contour lines strongly suggests that there is a close association between a land-based source of petroleum hydrocarbons in the headland area and the pollution levels recorded in the headland and in the seabed and seawater of the bay as well. The two central maxima are apparently related to damaged-underground structures in which unknown amounts of petroleum hydrocarbons are still stored. The third northernmost maximum located at the beach, however, is related to either the few numbers of control points or most likely to local variations in the porosity and permeability of the beach sediments.

Clean, well-sorted, loosely packed sands of beaches have high porosities and permeabilities (Tucker, 1981). As the grain size decreases offshore from beaches (Tucker, 1981), the comparatively mature beach sediments of the study area would change laterally across the intertidal zone to finer, less permeable, sediments in the subtidal zone. This may in turn constrain most of the percolating petroleum hydrocarbons from the high grounds of the headland area in its foreshore sediments.

Porosity determines the storage capacity of the sand, whereas permeability determines the ease of flow of fluids through the pores (Blatt *et al*., 2006). The poorer the sorting (lower textural maturity) and the finer the grain size of loose sand, the lower are the porosity and the permeability (Pettijohn *et al.*, 1987; Blatt, 1992).

Figure (8): A contour map showing the spatial variations of the hydrocarbon concentrations (%) determined in the headland and the seabed sediments of Sharm El-Maya Bay area. Contour interval is 0.02%.

DISCUSSION AND CONCLUSION

The main purpose of this study was to determine the concentration and the spatial variation of petroleum hydrocarbon pollutants in Sharm El-Maya Bay area. Therefore, samples from the headland sediment, the seabed sediment, and the seawater were collected and analyzed for total hydrocarbons.

Previous studies carried out by Suez Canal University (1999) and Cairo University (2001) concluded that the 1999's oil spillage in Sharm El-Maya Bay was caused by a land-based source. They suggested that the underground fuel-storage tanks of the dismantled electric power plant leaked diesel fuel into the bay. Other sources of the oil spillage in the bay, particularly those related to sea-based activities, such as spilled crude oil and boat diesel fuel, were tested by Khattab *et al.* (2006). Although the results of their study were not conclusive, Khattab *et al.* (2006) suggested that oil contamination could be ascribed to spilled crude oil, dumped oil wastes, and leaked fuel either from boats or from the dismantled power plant.

This study showed that the average concentration of the total hydrocarbons decreased from 661.7±383.16 µg/g (ppm) in the headland, to 170±128.59 µg/g (ppm) in the seabed, and to 37.99±17.45 mg/L (ppm) in the seawater. The spatial variations in the total hydrocarbons determined in the headland and the seabed sediments indicated that there are three concentric sets of contour line maxima, two of which were located in the headland and were apparently related to damaged-underground fuel-storage facilities, such as storage tanks and pipelines. The third set, however, was located at the beach. Lateral variations in the permeability of beach sediments across the intertidal zone towards finer and consequently less permeable sediments seawards may have entrapped most of the percolating petroleum hydrocarbons occupying available pore spaces in friable sandstones and loose beach sands. Moreover, fractures and northward dipping of the beds, as mentioned in the Suez Canal University's report (1999), may have markedly contributed to the observed anomalous concentrations in the foreshore sediments.

The results of this study, however, are in some contradiction with those of Khattab *et al.* (2006). Firstly, the average concentration of the total hydrocarbons in the intertidal zone decreased from 1263.5 µg/g in its surface sediments (<20 cm) (Khattab

et al., 2006) to 170±128.59 µg/g in the current study. This could be ascribed to biodegradation processes caused by unknown endogenous strains of hydrocarbon-degrading bacteria. Secondly, the total hydrocarbon content determined in the seawater of the bay (37.99±17.45 mg/L) is significantly higher than that estimated a decade ago by Khattab *et al.* (2006) for its surface- and deep-water layers (351.3 and 295.3 µg/L, respectively). This, however, may indicate that the study area is under threat from a persistent source of oil contamination despite all the protective measures taken to prevent its environment from further deterioration.

The results of this study suggest that a land-based source for petroleum hydrocarbons is still actively polluting the bay. It seems improbable, however, that sea-based sources for oil pollution could have contributed to the observed temporal variations in the concentration of the total hydrocarbons in the seawater of Sharm El-Maya Bay. This is because leisure boats were prohibited in the bay, the marine port was transferred many years ago to the neighboring Sharm El-Sheikh Bay, and finally no serious accidents related to any type of sea-based oil spillage were recorded prior to or during the course of this study.

Therefore, the present study suggests that an artificial low-permeability barrier should be created in the narrow strip of land between the lower slopes of the headland and the beach to prevent more oil from seeping into the bay. This could be done either by digging a number of trenches filled with clays or by drilling a number of carefully distributed boreholes through which clays are forcefully injected down the drill pipes. The study recommends that an integrated geophysical surveying of the headland involving magnetic, gravity, and ground penetrating radar (GPR) should also be carried out to elucidate the nature of the subsurface structures that may have caused the pollution and controlled its spatial distribution.

REFERENCES

AL-HALASAH, N. and AMMARY, B. Y. 2007. Potential risk and control of contamination in the Gulf of Aqaba-Jordan. In: I. Linkov, R. J. Wenning, G. A. Kiker {Eds.}, Managing Critical Infrastructure Risks. Proceedings of the NATO Advanced Research Workshop on Management Tools for Port Security, Critical Infrastructure, and Sustainability, Venice, Italy, March 2006. NATO Science for Peace and Security Series C: Environmental Security, Springer, Dordrecht, The Netherlands, 435-444 (464 pp.)

ALWANY, M. A., HANAFY, M. H., KOTB, M. M., and GAB-ALLA, A. A.-F. 2007. Species diversity and habitat distribution of fishes in Sharm El-Maiya Bay, Sharm El-Sheikh, Red Sea. Catrina, **2** (1): 83-90.

BLATT, H. 1992. Sedimentary Petrology, Second Edition. W. H. Freeman and Company, New York, USA.

BLATT, H., TRACY, R. J. and OWENS, B. E. 2006. Petrology: Igneous, Sedimentary and Metamorphic, Third Edition. W. H. Freeman and Company, New York, USA.

BOHM, G. and ZECH, G. 2010. Introduction to Statistics and Data Analysis for Physicists. Verlag Deutsches Elektronen Synchrotron,http://wwwlibrary.desy.de/elbook.html.

CAIRO UNIVERSITY. 2001. Cleaning up Sharm El-Maya, Sharm El-Sheikh, southern Sinai, from the petroleum materials (Final Report). Center for Environmental Hazards Mitigation, Giza, Egypt.

CALLUM, R. and SHEPPARD, C. 1988. Oil spill at Sharm-El-Sheikh. Marine Pollution Bulletin, **19** (3): 92-93.

CARL BRO INTERNATIONAL a/s. 1999. Mitigation Measures for Environ-mental Problems in Sharm El-Maya Bay, Sharm El-Sheikh, Egypt (Final Report).

GOLDSTEIN, B.D. 2010. Benzene as a cause of lymphoproliferative disorders. Chemico-Biological Interactions, **184** (1-2): 147-150.

ISAAKS, E. H. and SRIVASTAVA, R. M. 1989. An Introduction to Applied Geostatistics. Oxford University Press, New York, USA.

KHATTAB, R. M., TEMRAZ, T. A., KOTB, M. M., and HANAFY, M. H. 2006. Assessment of oil pollution in Sharm El-Maiya Bay, Sharm El-Sheikh, South Sinai, Egypt. Catrina, **1** (1): 33-40.

LOYA, Y. and RINKEVICH, B. 1980. Effects of oil pollution on coral reef communities. Marine Ecology Progress Series, **3**: 167-180.

PETTIJOHN, F. J., POTTER, P. E., and SIEVER, R. 1987. Sand and Sandstone, Second Edition. Springer-Verlag, New York.

PILCHER, N. J. and ABOU ZAID, M. 2000. The Status of Coral Reefs in Egypt. Global Coral Reef Monitoring Network (GCRMN); PERSGA Technical Series Report, Jeddah.

SPIEGEL, M. R. 1972. Theory and Problems of Statistics in SI Units. Schaum's Outline Series, McGraw-Hill Book Company, New York, USA.

SUEZ CANAL UNIVERSITY. 1999. Experts Committee Report to the High Appeal Court of Ismailia, Egypt, Case No. 290/ 26.

SUEZ CANAL UNIVERSITY. 2001. Environmental Monitoring Program for Sharm El-Maya Bay (Final Report). Faculty of Science, Marine Biology Department, Ismailia, Egypt.

TUCKER, M. E. 1981. Sedimentary Petrology: An Introduction. Blackwell Scientific Publications, Oxford, UK.

UNEP/IOC/IAEA. 1992. Determination of petroleum hydrocarbons in sediments. Reference Methods for Marine Pollution Studies No. 20, UNEP 1992, 75 pp.

UNESCO. 1976. Guide to operational procedures for the IGOSS pilot project on marine pollution (petroleum) monitoring. Manuals and Guides, No 7, 50 pp.

Received January 13, 2011
Accepted April 4, 2011