*Foraminifers as Monitoring Tool for Sea Water Pollution at Al Hariga Harbor in Tobruk, NE Libya

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Abstract

The benthic foraminifera is considered an excellent tool to monitor seawater pollution in coastal and marginal marine settings. A pilot study aims to scrutinize the effect of pollution on benthic foraminifers, which was carried out on sediment samples collected at water depths ranging from 0.5m to 7m along the coastal area of Al Hariga harbor of Tobruk in northeast Libya. The investigated area is characterized by sand-sized calcareous grains, gravel-sized grains, in addition to appreciable numbers of quartz and feldspars. The sediments also include abundant forms of seashells debris, foraminifers, and few ostracods. The benthic foraminifer's assemblages were separated counted and identified to the species level whenever possible. This study shows that the benthic foraminifers recovered were abundant with low diversity and characterized by eighteen genera in which Adelosina, Rosalina, Peneroplis, Quinqueloculina, and Ammonia were the most dominant taxa. Although most of the recovered specimens show a normal test size and shape, whereas some individuals per sample displayed a degree of abnormalities, reported abnormalities in benthic foraminifers were reflected in coil twisting, deformed chamber size, disturbed suture, dislocated - abnormal apertures, and twinned individuals. However, the post- morten smoothing and polishing of test surface, dissolution, or chambers corrosion are also present. The relationship between the key indicator taxa for pollution and the natural environment is discussed. This study emphasizes that the accumulation of oil seepage from the oil tankers and the domestic wastes (notably, heavy metals) in the sediments along the shore are responsible for the malformation of the studied foraminiferal tests.

Extended abstract

Benthic foraminifers "microorganisms belonging to kingdom of Protista" are an important member and most common microorganism in the marine environment and occupy different environmental settings from shallow to deep marine. The infaunal elements occupy the shallow, intermediate, and deep-dwelling species (Corliss 1991). They are very sensitive to slight environmental changes and can reflect the health of the ecosystem they inhabit. They are increasingly used as bio-indicators for pollution at various levels of investigation (Alve 1995). The suitably of the benthic foraminifers for their use as reliable bio-monitors of the marine environment has been confirmed by Ferraro et al., (2009). The effect of pollution on foraminifera is expressed in the following parameters; abundance, diversity, and test abnormalities, which

have been used by many researchers to monitor different types of pollution in coastal areas (Alve 1995; Pati and Patra 2012). In coastal habitats, foraminiferal diversity and abundance are sensitive to food availability and water clarity, making them ideal bio-indicators of water quality (Schaffer 2000; Prazeres et al. 2020). Several studies have been conducted related to using foraminifera as a bio-indicator of pollution (Yanko et al. 1998; Coccioni 2000; Samir and El-Din 2001; Frontalini et al. 2009; Caruso et al. 2011; Frontalini and Coccioni 2011; Melis and Covelli, 2013; El Baz 2014; Capotondi et al. 2015; Elshanawany et al. 2018). This study aims to investigate the effect of untreated wastes from industrial (refinery of Al Hariga) and domestic sewages on the marine environment at Al Hariga Harbor of Tobruk in NE Libya using benthic foraminifers. The Al Hariga Harbor is located in northeast Libya in Cyrenaica province, that has been subjected to sampling at a depth range from 0.5m to 7m, twenty-two samples from twelve localities (Fig. 1).

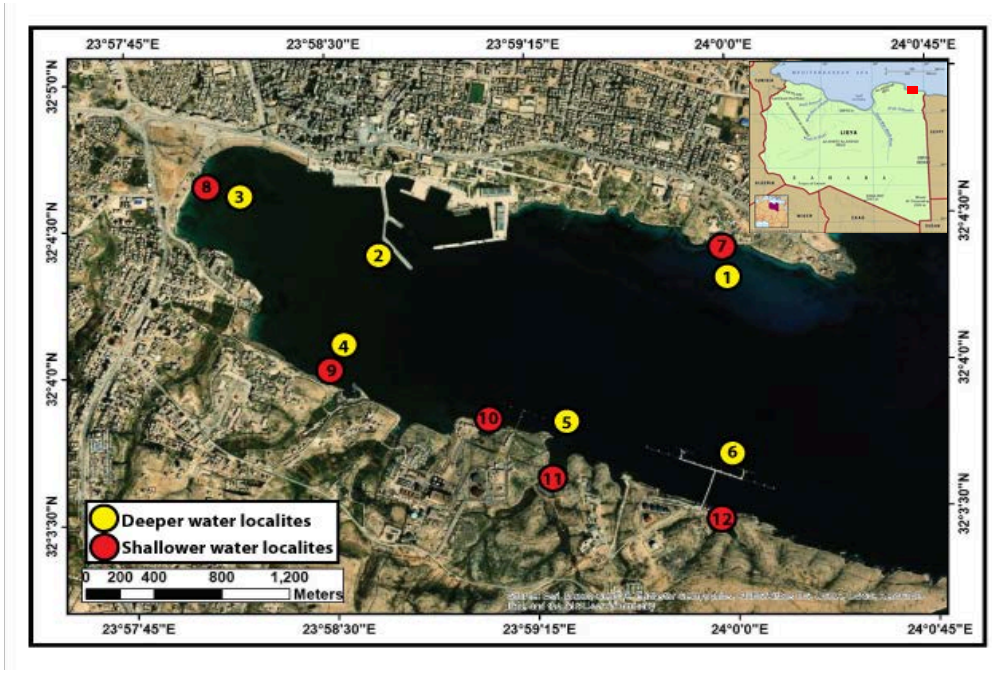

Figure 1. The study area "Tobruk oil harbor in NE Libya" and sampling stations (modified from http://www.earth.google.com).

The studied samples have been prepared for their foraminiferal content. Firstly, the samples have been washed through a series of sieves (> 2mm–0.063mm) using a mild current of water until the undesired materials such as gravel, sand, and mud have been removed. Secondly, the samples were dried on a hot plate at 50 °C and then a total of 30g of each dried sample was taken and investigated under a stereoscopic microscope for the foraminifer's content. The foraminifera of each sample have been quantitatively estimated, and the deformed tests have been picked out and mounted on labeled slides. A selected representative specimen of each type of test deformation against a healthy test has been

photographed using an MD-500 eyepiece camera attached to OSK Microscope and displayed in Figure 2. The samples have been deposited in the micropaleontology laboratory of the Geological engineering department of Bright Star University. The studied samples were mainly composed of calcium carbonate-rich in sea shells, where the percentage of calcium carbonate ranged from 60% to 95% in all stations. As for the percentage of quartz, feldspar, and some other components, it ranged between 5% to 40%.

The foraminiferal suite of the shallower depth (<0.5m) consists of Spiroloculina depressa, Amphisorus hemprichii, Ammonia cf. inflata, Amphistegina cf. lessonii, Lobatula lobatula, Spiroloculina cf. corrugata, Peneroplis cf. pertusus, Ammonia sp., Peneroplis planatus, and Pyrgo sp. The average number of individuals for each species in one sample is 30 individuals. The average total number of individuals for all species in all studied samples amounted to 300 individuals belonging to ten species reflecting notably a low level in both diversity and abundance. Obviously at this shallower depth small black spots on the walls of some foraminifera tests (Fig. 2. 17) and a low percentage of abnormal tests are reported which attributed to pollution.

The deformations of the reported tests are reflected in some inflation, twisting (Fig. 2, 16), the reverse coiling, odd chambers size, and odd chamber shape. The abnormality percentage at this shallower depth reached 10%. On the other hand, the foraminiferal suite of the deeper depth consists of Amphistegina lessonii, Peneroplis planatus, Peneroplis pertusus, Quinqueloculina sp., Spiroloculina sp., Amphisorus hemprichii, Rosalina bradyi, Sorites orbiculus, Sorites variabils, Patellina corrugata, Adelosina sp., Adelosina dubia, Adelosina mediterraneansis, Ammonia beccarii, Ammonia convexa, Cycloflorina sp., Quinqueloculina disparilis, Miliolina sp., Coscinospira hemiprechi, Elphidium macellum, Elphidium crispum, Elphidium sp., Vertebralina striata, Spiroloculina ornata, Polymorphina sp., Triloculina affins, Planorbulina mediterraneansis, Cibicides refulgens, Lobatula lobatula and Textularia bocki. The average number of individuals for each species in one sample is 45 individuals. The average total number of individuals for all species is 1350 individuals belonging to thirty species reflecting notably a moderate level of diversity and relatively high abundance, with an abnormality percentage reaching 35%. The higher percentage of abnormal tests may justified as transported elements from the shallower depth down to deeper depths via bottom currents. The tests deformations are reflected as, chamber protrudes, twisting, twining, abnormal and/or double apertures, decrease or increase in chamber size, loose coiling, and corroded tests (Fig. 2, 1-15).

The sources of pollution recognized in the Al Hariqa harbor is anthropogenic in nature and include the wastes of oil and petroleum products from the refinery and leaks from the oil shipping tankers (Fig. 3a), in addition to domestic sewage from nearby residential apartments which are disposed directly to the sea (Fig. 3b). However several studies from different parts of the world using benthic foraminifera conducted on sites polluted by oil spills and other contaminants demonstrate the effectiveness of benthic foraminifers as a tool to monitor the health of the marine ecosystems; Aloulou et al. (2011) using benthic foraminiferal assemblages as pollution proxies in the northern coast of Gabes Gulf, Tunisia and they conclude the benthic foraminiferal assemblages' density, diversity, and taxonomic makeup may be influenced by these contaminants, according to statistical study (bivariate correlation and hierarchical cluster analysis). Arslan et al. (2017) performed a study concerned with the boat harbor in Askar, Bahrain that suffered pollution by nutrients, organic matter, and hydrocarbons. Foraminiferal density is found to be higher at the polluted site compared with a nearby unpolluted site, suggesting a possibly higher amount of available nutrients for

the benthic foraminifera. Young et al. (2021) used benthic foraminifera as bioindicators of the 2010 Deep-water Horizon (DWH) event with an 80–93% decline in density coinciding with the oil spill, and species exhibit shape abnormalities in response to the oil and oxygen levels reduction. They confirmed the importance of the benthic foraminiferal morphological response to the DWH oil spill.

Selected mediterranian harbours in monitoring the impact of the different pollutants using different tools such in the examined samples from the Naples harbor in the eastern Tyrrhenian Sea margin at the Naples harbor, Southern Italy by Ferraro et al (2009) showed reduced number and low diversity of benthic foraminiferal specimens due to the impact of the organic and inorganic contaminants on the marine ecosystem, as well as the TOC content which also have a strong impact on the distribution of Ammonia tepida, with a substantial independence with VOCs, TRPHs and SPCB. While hydrocarbons concentrations Quinqueloculina spp., Elphidium spp. show an opposite covariance only with VOCs and an apparently limited effect of the other organic compounds Ferraro et al (2009). Another mediterranean site in the Saronikos Gulf, Greece at polluted coastal environment of Drapetsona-Keratsini where, Dimiza et al., (2018) found relatively low-diversity assemblage, dominated by stress tolerant benthic foraminifers Ammonia tepida Bolivina spathulata and Bulimina elongata in the silty substrate of the Drapetsona coast and the Keratsini port central basin, where high levels of organic carbon content, aliphatic and polycyclic aromatic and trace metal, however, miliolid dominated the sandy substrate. Notably, rotaliid dominated assemblage is recorded in the slightly-polluted sedimentary bottom of the inner and western part of the Keratsini port. Aloulou et al., (2011) reported abundant Ammonia tepida and Haynesina germanica in association with Ammonia beccarii, Ammonia parkinsoniana, Elphidium crispum, Elphidium williamsoni, Elphidium advenum, Peneroplis planatus, and Peneroplis pertesus from the northern coast of Gabes Gulf in Tunisia.

This study concluded with the followings:

1. The present study proved that Al Hariga Harbor suffered from anthropologic pollution due to the wastes of the Al Hariqa refinery and leaks from oil shipping activity and domestic sewage.

2. The pollution has been detected via foraminiferal empty tests in form of diversity, abundance, and tests abnormalities. The estimated abundance and diversity in deeper depth samples are higher than that of the shallower depth samples which indicates environmental pollution. Although the estimated test abnormality is higher in deeper depth samples than in the shallower 35% and 10% respectively, this controversial result may be argued as transported elements from shallow to deeper depths via bottom current action.

3. These selected studied examples confirmed the deterioration of the wildlife of marine bottom assemblage due to such harbors activity.

4. This study recommended running a geochemical analysis using heavy metals and TOC measurement to assess the degree of pollution by toxic elements. The living foraminiferal tests will be included in the future examination of this site.


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15
16
Quinqueloculina sp.
0.5 mm
Amphisorus sp.
1 mm
17

Figure 2. photomicrographs of selected deformed benthic foraminiferal tests against normal tests from the studied samples (1-15) from the deeper zone and samples (16-17) from the shallower zone at Al Hariqa Harbor. 1. Peneroplis pertusus shows a size reduction of the last chambers. 2 Lobatula lobatula exhibits complex form. 3 Peneroplis pertusus shows a test twisting. 4 Peneroplis pertusus exhibits aberrant test shape. 5 Peneroplis pertusus exhibits aberrant protrude. 6 Ammonia convexa exhibits aberrant chamber shape and size. 7 Peneroplis pertusus with twinned tests. 8 Sorites orbiculus exhibits aberrant protrude and corroded test. 9 Cycloflorina sp. exhibits a loosely coiling test. 10 Peneroplis planatus exhibits aberrant size of last chambers. 11 Peneroplis pertusus exhibiting highly deformed aperture. 12. Quinqueloculina sp. with double apertures.13 Ammonia sp. shows a reduction in chamber size. 14 Peneroplis pertusus with a reduction of the size of the last three chambers. 15 Peneroplis pertusus with corroded chambers. 16. Peneroplis planatus with deformed chamber 17 Quinqueloculina sp. and Amphisorus sp. stained with oil spots. (Scale bar = 500µm).

Figure 3 Sources of pollution in the Al Hariqa Harbor; 1) oil Accumulation; 2) domestic sewage.

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