Egypt. Jour. Paleontol., Vol. 1, 2001, p. 97-113

# SEA SHELLS AS POLLUTION INDICATORS, RED SEA COAST, EGYPT

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## ABSTRACT

In an attempt to study the reversal application of the uniformitarianism and use of shell chemistry to emphasize the environmental impacts, chemical analysis of some elements and oxides for *Nerita* (*Theliostyla*) *albecilla*, *Turbo* (*Batillus*) *radiatus*, *Cypraea staphylaea*, *Clanculus* (*C.*) *pharaonius*, *Conus virgo*, *Chama pacifica* and *Amphistegina lessonii* in Pleistocene and Recent sediments along the Red Sea coast, indicated a strongly enrichment of $P_2O_5$ and Zn and relative enrichment of Pb, Cu, Co, Cd, Ni and Mn in Recent sediments of El-Hamrawein area, in comparison with the Pleistocene sediments in the same area, as well as in Gemsha and Gebel Zeit areas.

The enrichment in concentration of the above mentioned traces and oxides in the study area were related to the shipping and proccessing of phosphorites, harbor activity, sewage sludge discharge to the sea and oil industry. As well as the high concentrations of Mn, Ni, Co and to a lesser extent Cu, which supplied from the mafic rocks of the coastal foreland as a weathering products.

## INTRODUCTION

Several recent works were done on the Red Sea coast, dealt with stratigraphy, paleontology, sedimentology and geochemistry, eg. Abdalla Hagab nad Abdel Aal (1983), Abdel Aal and Hassan (1988), Piller and Mansour (1990), Ziko *et al.* (1995), Mansour *et al.* (1997, 2000), Nawar *et al.* (1997), Douabul and Saeed (1999), Abd El-Shafy *et al.* (2000), Aref and Madkour (2000), Kora and Abdel Fattah (2000), and Refaat and Aref (2001).

Trials were done to monitor the pollution of some coastal sites using sea shells, which are believed to be good collectors for the concerned pollutants. The partitioning of a pollutant between water and shell depends on the type of the shell, the body area interaction, the porosity and permeability of shells, pH-Eh controls, the concentration of the specific pollutant in sea water, time of exposure and selectivity of shells among other factors.

El-Hamrawein, Gemsha and Gebel Zeit areas were selected for study (Fig. 1). Field observations indicate that the main source of pollution in El-Hamrawein area is originated from the industrial sewage, phosphate mining and shipping processes, especially at Safaga port and its suburb. Gemsha area was selected to represent pristine environment, where it is far from human activities. Finally, Gebel Zeit area is an area of oil-production and export; hence it is sustained to various kinds of pollution by hydrocarbons.

The studied samples include Recent and Pleistocene sea shells and sediments. The Pleistocene samples, which were taken from El-Hamrawein, only are expected to be pristine, concerning anthropogenic activities, and consequently could be used as a reference, to monitor pollution in the Recent ones. If one of the studied sea shell species is affected by pollution, the concentrations of the pollutant in its skeletal material will be higher than its Pleistocene counterpart fossil skeletons. The same concept is also valid for the Recent and Pleistocene sediments, where the

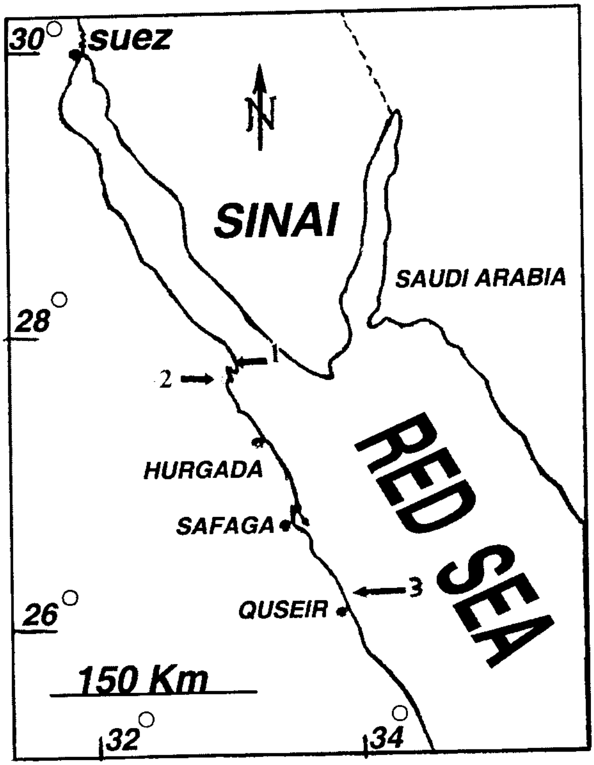



**Fig. 1: The Study Areas. 1 - Gebel Zeit. 2 - Gemsha. 3 - El Hamrawein**

later are already away from pollution as they are elevated as raised beaches. If other Recent species lives in environmentally clean and non-polluted province, it is expected that the concentrations of pollutants should be in the same range of the Pleistocene counterparts.

## MATERIAL AND METHODS

23 Pleistocene and Recent samples were ground and decomposed by addition of 2ml $HNO_3$ 65%, 3ml of HCl 35% and 1ml of HF 40% and then digested by microwave (Milstone type). The major oxide $P_2O_5$ was measured by spectrophotometer (Spectronic Geneys 2) by using molybdovandadate as reagent.

The elements Ca, Cd, Co, Cu, Fe, Mg, Mn, Ni, Pb, Sr and Zn were determined by atomic absorption spectrophotometer (GBC 932 AA type). The analyses were carried out in the laboratories of the Egyptian Nuclear Materials Authority. The analyses were also carried out in duplicates and the average data were considered.

## SYSTEMATIC DESCRIPTION

Phylum Mollusca CUVIER 1795
Class Gastropoda CUVIER 1797
Subclass Prosobranchia MILNE-EDWARDS 1848
Order Archaeogastropoda THIELE 1925
Family Trochidae RAFINESQUE 1815

Genus *Clanculus* MONTFORT 1810
*Clanculus (Clanculus) pharaonius* (LINNAEUS 1758)
(Pl. 1, Figs. 1, 2)

1900 *Clanculus* (*Clanculus*) *pharaonius* (LINNAEUS); Newton: 559, pl. xx, fig. 4.

1960 *Clanculus* (*Clanculus*) *pharaonius* (LINNAEUS); Moore: 1260.

1982 *Clanculus* (*Clanculus*) *pharaonium* (LINNAEUS); Abed: 267; pl. viii, figs.4 a-c.

1982 *Clanculus* (*Clanculus*) *pharaonius* (LINNAEUS); El-Shazly: 112, pl.12, figs. 2, 3.

1990 *Clanculus* (*Clanculus*) *pharaonius* (LINNAEUS); El-Sorogy: 147, pl. 14, figs. 1, 2.

1995 *Clanculus pharaonius* (LINNAEUS); Bosch, Dance, Moolenbeek and Oliver: 34, fig. 36.

Material: 6 shells.

Description: Shell small and trochoid-shaped. Spire low with 5 whorls. Sutures depressed. Aperture rectangular, outer lip thicken and inner one crenulated. Umbilicus shallow. Body whorl large. Sculptured by granulose taberculated spinal cords.

| | | |
|---|---|---|
| Dimensions: | Shell height (6) 17mm | 13-19mm. |
| | Body whorl height (6) 11mm | 9-12mm. |
| | Body whorl width (6) 10mm | 8-13mm. |
| | Spiral angle (6) 60 | |

Occurrence: Pleistocene raised reefs, El-Hamrawein and Gemsha. Recent accumulations, Gebel Zeit beach.

Distribution: Pleistocene and Recent, Red Sea coast, Gulf of Suez, Gluf of Aqaba, Sinai and Gulf of Oman.

Habitat: In sand between rocks.

Range: Pleistocene-Recent.

Family Turbinidae RAFINESQUE 1815
Genus *Turbo* LINNAEUS 1758
*Turbo* (*Batillus*) *radiatus* (GMELIN 1791)
(Pl. 1, Figs. 3, 4)

1900 *Turbo radiatus* (GMELIN); Newton: 545, pl. xx, fig. 1.

1982 *Turbo* (*Batillus*) *radiatus* (GMELIN); El-Shazly: 117, pl. 12, figs .5, 6.

1990 *Turbo* (*Batillus*) *radiatus* (GMELIN); El-Sorogy: 148, pl. 14, figs. 5, 6.

1995 *Turbo* (*Batillus*) *radiatus* (GMELIN); Bosch, Dance, Moolenbeek and Oliver: 41, fig. 93.

1997 *Turbo* (*Batillus*) *radiatus* (GMELIN); El-Sorogy: 32, pl. 12, fig.1.

1998 *Turbo* (*Marmarostoma*) *radiatus* (GMELIN); Abdel-Fattah: 107, pl. 22, fig.3.

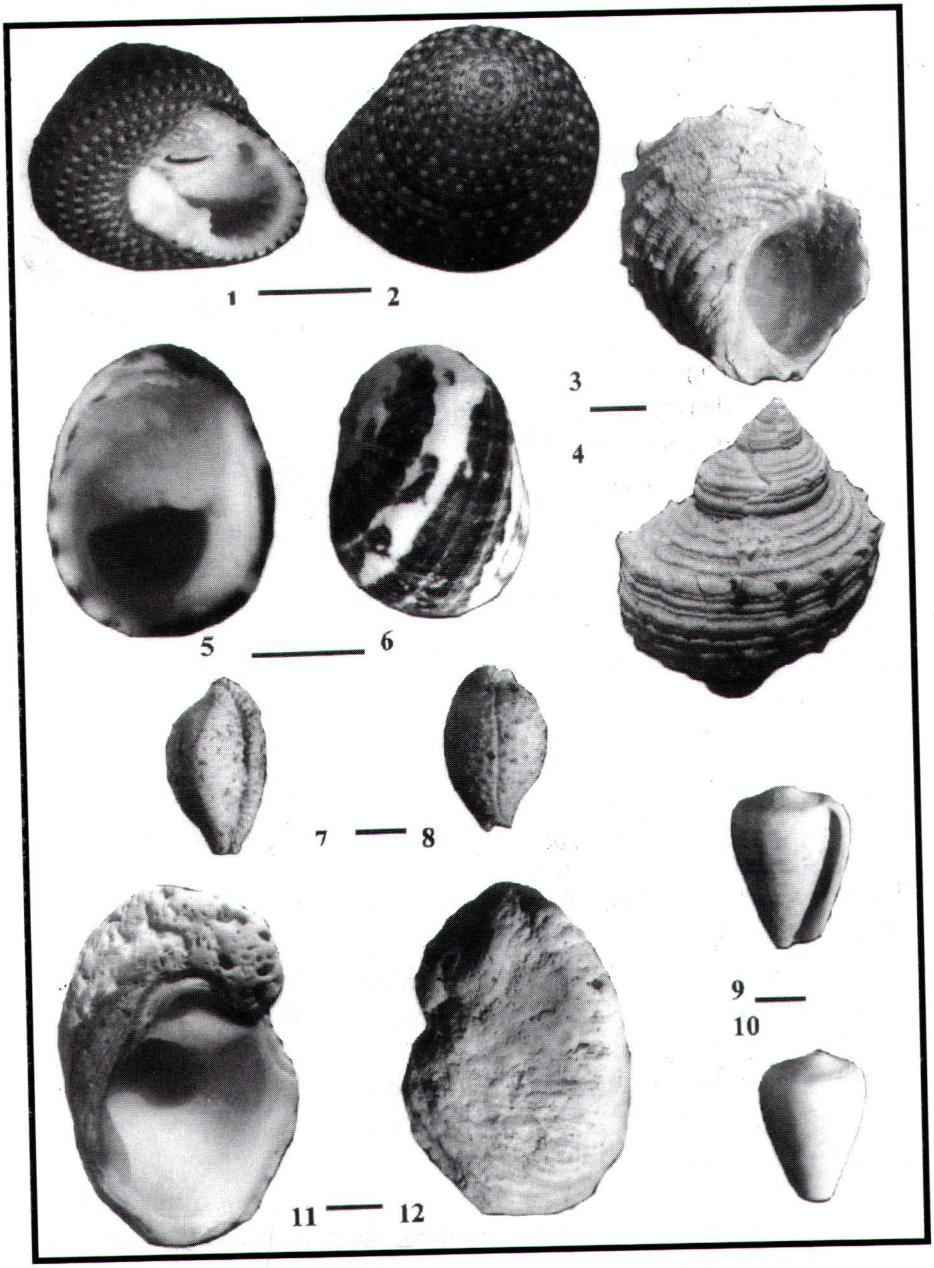
Material: 61 shells.

Description: Shell small to medium, thick and turbinate-shaped. Spire high with 3 whorls. Sutures depressed. Aperture rounded, outer lip smooth and inner lip flat, body whorl large. Sculptured by wavy growth lines and tubercles covered the

shoulders.

| | | |
|---|---|---|
| Dimensions: | Shell height (20) 41mm | 33-52mm. |
| | Body whorl height (20) 31mm | 27-41mm. |
| | Body whorl width (20) 32mm | 29-33mm. |
| | Spiral angle (20) 72°. | |

Plate 1

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Occurrence: Pleistocene, El-Hamrawein beach. Recent, Gebel Zeit and El-Hamrawein beaches.

Distribution: Pleistocene and Recent, Red Sea coast, Gulf of Oman and Arabian Gulf.

Range: Pleistocene-Recent.

Family Neritidae RAFINESQUE 1815
Genus *Nerita* LINNAEUS 1758
*Nerita* (*Theliostyla*) *albicilla* (LINNAEUS 1758)
(Pl. 1, Figs. 5, 6)

1982 *Nerita* (*Theliostyla*) *albicilla* (LINNAEUS); El-Shazly: 123, pl. 13, figs. 5-7, 11.

1986 *Nerita albicilla* (LINNAEUS); Abu Khadrah and Darwish: 174, pl. x, fig. 12.

1990 *Nerita* (*Theliostyla*) *albicilla* (LINNAEUS); El-Sorogy: 150, pl. 14, figs. 3, 4.

1995 *Nerita albicilla* (LINNAEUS); Bosch, Dance, Moolenbeek and Oliver: 43, fig. 102.

Material: 15 shells.

Description: Shell small. Spire low. Aperture D-shaped, outer lip and inner lip with fine four teeth. Body whorl large. Sculptured by fine growth lines and black and white bands and others red color.

| | | |
|---|---|---|
| Dimensions: | Shell height (15) 20mm | 15-23mm. |
| | Body whorl height (15) 15mm | 11-17mm. |
| | Body whorl width (15) 17mm | 12-20mm. |

Occurrence: Recent, Gebel Zeit, Gemsha and El-Hamrawein beaches.

Distribution: Pleistocene and Recent, Red Sea coast, South Africa, Madgascar and Arabian Gulf.

Range: Pleistocene-Recent.

Order Mesogastropoda THIELE 1925
Family Cypraeidae FLEMING 1828
Genus *Cypraea* LINNAEUS 1758
*Cypraea staphylaea* LINNAEUS 1758
(Pl. 1, Figs. 7, 8)

1995 *Cypraea staphylaea* LINNAEUS; Bosch, Dance, Moolenbeek and Oliver: 79, fig. 275.

**Explanation of Plate 1**

Figs. 1,2: *Clanculus (Clanculus) pharaonius* (Linnaeous 1758) 1 - Aperture view (bar = 2cm). 2 - Opposite view (bar = 2 cm), Recent Gebel Ziet.

Figs. 3,4 : *Turbo (Batillus) radiatus* (Gmelin 1791) 3 - Aperture view (bar = 1cm) 4 - Opposite view (bar = 1 cm), Pleistocene El Hamrawien

Figs. 5, 6: *Nerita (Theliostylea) albicilla* (Linnaeous 1758) 5 - Aperture view (bar = 2cm). 6 - Opposite view (bar = 2 cm), Recent Gemsha.

Figs. 7, 8: *Cypraea staphylaea* Linnaeous 1758 7- Aperture view (bar = 0.9cm). 8 - Opposite view (bar = 0.9 cm), Pleistocene El Hamrawein.

Figs. 9, 10: *Conus virgo* Linnaeous 1758 9- Aperture view (bar = 0.9cm). 10 - Opposite view (bar = 0.9 cm), Recent El Hamrawein.

Figs. 11, 12: *Chama pacifica* (Broderip 1835) 11- Internal View (bar = 2cm). 12 - External view (bar = 2 cm), Recent Gebel Ziet.

Material: Two shells.

Description: Shell solid, rounded to ovate. Spire low. Body whorl large, lipped margins poorly developed. Sulcus deeply incised. Teeth form flat-topped ridges, crossing entire base. Sculptured by small pimples.

Remarks: This species is recorded for the first time from the Red Sea, Egypt.

Dimensions: Shell height= 22mm.

Body whorl height= 22mm.

Body whorl width= 13mm.

Occurrence: Pleistocene rasied reefs, El-Hamrawein beach.

Distribution: Recent, Gulf of Oman.

Range: Pleistocene-Recent.

Family Conidae ADAMS 1849
Genus *Conus* LINNAEUS 1758
*Conus virgo* LINNAEUS 1758
(Pl. 1, Figs. 9, 10)

1900 *Conus virgo* LINNAEUS; Newton: 545.

1982 *Conus virgo* LINNAEUS; El-Shazly: 151, pl. 16, figs. 12, 13.

1990 *Conus virgo* LINNAEUS; El-Sorogy: 164, pl. 15, figs. 8, 9.

1995 *Conus virgo* LINNAEUS; Bosch, Dance, Moolenbeek and Oliver: 165, fig. 730.

1998 *Conus virgo* LINNAEUS; Abdel-Fattah: 117, pl. 23, fig. 8.

Material: 9 original shells.

Remarks: *Conus virgo* LINNAEUS differs from the other *Conus* spp. in that the spire low, relatively flatted and sculptured by weak growth lines.

Dimensions: Shell height (9) 32mm 22-44mm.

Body whorl height (9) 30mm 21-42mm.

Body whorl width (9) 19mm 13-23mm.

Spiral angle (9) 120°.

Occurrence: Recent accumulations, El-Hamrawein and Gebel Zeit beaches.

Distribution: Pleistocene and Recent, Red Sea coast, Aden, East Africa, Ceylon and Philippine.

Range: Pleistocene-Recent.

Class Bivalvia LINNAEUS 1758
Family Chamidae LAMARCK 1809
Genus *Chama* LINNAUS 1758
*Chama pacifica* (BRODERIP 1835)
(Pl. 1, Figs. 11, 12)

1982 *Chama* cf. *pacifica* (BRODERIP); El-Shazly: 100, pl. 8, figs. 2, 6, 10, pl. 10, fig. 3.

1990 *Chama* cf. *pacifica* (BRODERIP); El-Sorogy: 122, pl. 11, figs. 6, 7.

1997 *Chama* cf. *pacifica* (BRODERIP); El-Nahass: 311, fig. 13/6.

1998 *Chama* cf. *pacifica* (BRODERIP); Abdel-Fattah: 100, pl. 20, fig. 6.

Material: 41 right valves and 47 left ones.

Description: Shell moderate, ovate and thick. Umbo inflated. Hinge with large pachydont. Muscle scars anisomyarian. Internal margin finely crenulated. Sculptured by pitted concentric lines.

Dimensions: Left valves

| | |
|---|---|
| Length (10) 25mm | 20-32mm. |
| Height (10) 36mm | 31-39mm. |

Occurrence: Pleistocene, El-Hamrawein beach and Recent accumulations, El-Hamrawein, Gemsha and Gebel Zeit beaches.

Distribution: Pliocene, Pleistocene and Recent, Red Sea coast. Recent, Arabian Gulf and Kuwait.

Range: Pliocene-Recent.

## DISTRIBUTION OF TRACE AND MAJOR ELEMENTS

The chemistry of the skeleton and the processes by which it forms may strongly influence the environmental chemistry (Lowenstam 1974). In the present work, the concentration of the trace and major elements is normalized to the Pleistocene values. The normalization is conducted with respect to species and geographic occurrence, in order to throw some light on the role played by species selectivity and influence of human activity in each of the studied sites.

### Spatial distribution of elements

1. El-Hamrawein area

15 samples were analyzed, 5 gastropods (Pleistocene and Recent, except *Clanculus* (*Clanculus*) *pharaonius*, which is only of the Pleistocene), one pelecypod (Pleistocene and Recent), one foraminfera (Pleistocene and Recent) and one sediment (Pleistocene and Recent), (Table 1).

It is obvious that the Pb concentration in the Recent shells ranges from 62ppm in *Cypraea staphylaea* to 147ppm in *Chama pacifica*, averaging 87ppm. While in the Pleistocene, Pb ranges from 36ppm in *Cypraea staphylaea* to 84ppm in *Nerita* (*Theliostyla*) *albicilla*, averaging 61ppm. The enrichment of the Recent shells in Pb relative to those of the Pleistocene, can be interpreted as pollution. This pollution signature in shells is not clear in sediments.

Similar to Pb, the Recent *Chama pacifica* seems to have high selectivity for Zn (174ppm). The least concentration of Zn is encountered for *Nerita* (*Theliostyla*) *albicilla* (33ppm). While in the Pleistocene shells it ranges from 8ppm in *Amphistegina lessonii* to 45ppm in *Turbo* (*Batillus*) *radiatus*. This means that the concentration of Zn in the Recent shell is about three times higher than those of the Pleistocene.

Zn concentration is 171ppm in the Recent sediments, and 22ppm in the Pleistocene ones, This means that the concentration of Zn in the Recent sediments is about 8 times higher than the Pleistocene.

The Cu content in the Recent shells ranges from 16ppm in *Turbo* (*Batillus*)

*radiatus* to 129ppm in *Amphistegina lessonii*, with an average of 41ppm. The Pleistocene forms are relatively depleted in Cu, where *Turbo* (*Batillus*) *radiatus* contains 9ppm, while the highest content of Cu (33ppm) is recorded in *Cypraea staphylaea.* This means that the concentration of Cu in the Recent shells is about two-folds that of the Pleistocene samples. The same observation is also valid when comparing Recent sediments (29ppm, Cu) to Pleistocene sediments (15ppm, Cu).

The Co content in the Recent shells ranges from 12ppm in *Cypraea staphylaea* to 24ppm in *Nerita* (*Theliostyla*) *albicilla*, with an average of 17ppm. These contents are comparable to those of the Pleistocene shells where Co ranges from 14ppm in *Nerita* (*Theliostyla*) *albicilla*, *Cypraea staphylaea*, *Clanculus* (*Clanculus*) *pharaonius* and *Conus virgo* to 17ppm in *Turbo* (*Batillus*) *radiatus,* with an average of 14ppm.

**Table (1): Chemical analysis data of some Recent and Pleistocene shells and sediments**

| Sample | Fossil/rock | | | Oxides in wt. % | | | | Elements in ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Defination | Localities | Age | MgO | CaO | P2O5 | Fe | Pb | Zn | cu | Co | Cd | Ni | Mn | Sr |
| 1 | *Nerita* | El-Hamrawein | Recent | 1.41 | 50.3 | 0.34 | 2650 | 66 | 33 | 21 | 24 | 3.9 | 25 | 47 | 1780 |
| 2 | | Gemsha | Recent | 1.01 | 51.6 | 0.33 | 1940 | 53 | 20 | 24 | 14 | 3.1 | 16 | 19 | 1244 |
| 3 | | Gebel Zeit | Recent | 1.72 | 48.2 | 0.36 | 2947 | 44 | 78 | 46 | 18 | 3.2 | 15 | 54 | 1181 |
| 4 | | El-Hamrawein | Pleistocene | 1.69 | 53.3 | 0.3 | 5467 | 84 | 39 | 14 | 14 | 2.6 | 13 | 19 | 2036 |
| 5 | *Chama* | El-Hamrawein | Recent | 1.5 | 44.5 | 0.34 | 1429 | 147 | 174 | 29 | 15 | 2.5 | 17 | 19 | 1377 |
| 6 | | Gebel Zeit | Recent | 0.75 | 55.1 | 0.37 | 2428 | 51 | 45 | 13 | 16 | 2.7 | 15 | 37 | 1440 |
| 7 | | El-Hamrawein | Pleistocene | 1.1 | 55.4 | 0.34 | 2591 | 80 | 34 | 20 | 15 | 2.8 | 18 | 15 | 2010 |
| 8 | *Turbo* | El-Hamrawein | Recent | 2.1 | 50.8 | 0.38 | 1799 | 77 | 39 | 16 | 22 | 2.8 | 10 | 117 | 1564 |
| 9 | | Gebel Zeit | Recent | 1.8 | 40.8 | 0.32 | 3736 | 48 | 50 | 5 | 18 | 2.3 | 18 | 171 | 2469 |
| 10 | | El-Hamrawein | Pleistocene | 1.4 | 54.6 | 0.37 | 1918 | 44 | 45 | 9 | 17 | 2.7 | 11 | 42 | 1670 |
| 11 | *Amphistegina* | El-Hamrawein | Recent | 3.11 | 50.8 | 0.35 | 3090 | 93 | 129 | 89 | 18 | 2.8 | 25 | 43 | 2402 |
| 12 | | Gebel Zeit | Recent | 2.3 | 50.1 | 0.32 | 1906 | 54 | 74 | 17 | 21 | 2.6 | 11 | 57 | 1675 |
| 13 | | El-Hamrawein | Pleistocene | 3.2 | 53.4 | 0.3 | 3030 | 55 | 8 | 27 | 16 | 2.7 | 3 | 69 | 1855 |
| 14 | *Cypraea* | El-Hamrawein | Recent | 1.72 | 55.2 | 0.45 | 2314 | 62 | 96 | 32 | 12 | 2.5 | 14 | 49 | 2833 |
| 15 | | El-Hamrawein | Pleistocene | 0.73 | 55.6 | 0.29 | 2277 | 36 | 11 | 33 | 14 | 2.9 | 13 | 22 | 1755 |
| 16 | *Clanculus* | Gebel Zeit | Recent | 1.6 | 51.4 | 0.34 | 1152 | 30 | 192 | 63 | 15 | 1.8 | 17 | 9 | 1141 |
| 17 | | El-Hamrawein | Pleistocene | 0.58 | 51.9 | 0.26 | 2149 | 80 | 22 | 28 | 14 | 2.2 | 6 | 48 | 1613 |
| 18 | *Conus* | El-Hamrawein | Recent | 0.94 | 46.2 | 0.63 | 2539 | 70 | 45 | 64 | 16 | 3.2 | 16 | 33 | 2011 |
| 19 | | El-Hamrawein | Pleistocene | 1.13 | 48.7 | 0.42 | 2580 | 51 | 40 | 30 | 14 | 1.7 | 15 | 39 | 2214 |
| 20 | Sediments | El-Hamrawein | Recent | 2.1 | 44.3 | 1.6 | 4540 | 79 | 171 | 29 | 18 | 6.2 | 23 | 438 | 4398 |
| 21 | | Gemsha | Recent | 0.98 | 2.78 | 0.36 | 3150 | 146 | 73 | 24 | 15 | 3.1 | 15 | 317 | 428 |
| 22 | | Gebel Zeit | Recent | 2.5 | 36.3 | 0.3 | 2147 | 75 | 25 | 32 | 17 | 2.3 | 17 | 128 | 4570 |
| 23 | | El-Hamrawein | Pleistocene | 2.8 | 30.2 | 0.82 | 5200 | 79 | 22 | 15 | 15 | 2.8 | 25 | 170 | 5600 |

Co concentrations show no significant difference between the Recent and the Pleistocene sediments, where it attains 18ppm in the former and 15ppm in the later. The equivocal distribution of Co in both shells and sediments of Recent and Pleistocene reflects that cobalt in not a transition metal pollutant in the El-Hamrawein area.

The Cd content in the Recent shells ranges from 2.5ppm in *Chama pacifica* and *Cypraea staphylaea*, to a maximum of 3.9ppm in *Nerita* (*Theliostyla*) *albicilla*, with an average of 2.9ppm. While in the Pleistocene shells it ranges from 1.7ppm in *Conus virgo* to 2.9ppm in *Cypraea staphylaea* with an average of 2.5ppm. This means that the concentration of Cd in the Recent shells is slightly higher than the Pleistocene shells

Cd concentration of the Recent sediments is 6.2ppm and 2.8ppm in the Pleistocene which refers to significant pollution of the Recent environment by about 3-folds.

The Ni content in the Recent shells ranges from 10ppm in *Turbo* (*Batillus*) *radiatus* to 25ppm in *Nerita* (*Theliostyla*) *albicilla and Amphistegina lessonii*, with an average of 18ppm. While in the Pleistocene shells Ni ranges from 3ppm in *Amphistegina lessonii* to 18ppm, in *Clanculus* (*Clanculus*) *pharaonius*, with an average of 11ppm. This means that the concentration of Ni in the Recent shells is about two times that of the Pleistocene shells.

The comparison between Recent and Pleistocene sediments suggests that the recent environment in the El-Hamrawein area is not markedly polluted with respect to nickel.

The Mn content in the Recent shells ranges from 19ppm in *Chama pacifica* to 117ppm in *Turbo* (*Batillus*) *radiatus*, with an average of 51ppm. While in the Pleistocene it ranges from 15ppm in *Chama pacifica* to 69ppm in *Amphistegina lessonii*, averaging 36ppm. This means that the concentration of Mn in the Recent shells is 1.5 times than the Pleistocene ones.

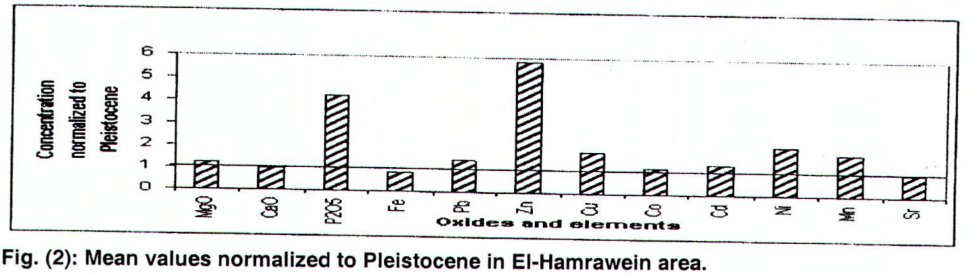


**Fig. (2): Mean values normalized to Pleistocene in El-Hamrawein area.**

Mn concentration of the Recent sediments is 438ppm, but it decreases to 170ppm in the Pleistocene, suggesting serious enrichment of the Recent environments by Mn (about 3-folds).

The $P_2O_5$ content in the Recent shells ranges from 0.34% in *Nerita* (*Theliostyla*) *albicilla*, *Chama pacifica* and *Clanculus* (*Clanculus*) *pharaonius* to a maximum of 0.63% in *Conus virgo*, with an average of 0.41%. The Pleistocene shells contain from 0.26% in *Clanculus* (*Clanculus*) *pharaonius* to 0.42% in *Conus virgo*, with an average 0.32%. This means that the concentration of $P_2O_5$ in the Recent is 1.3 times higher than the Pleistocene ones.

Summing up of El-Hamrawein area:

The Recent environment of the El-Hamrawein area is strongly imparted by pollution which is caused by shipping and processing of phosphorite. The immediate signatures of this pollution are the significant enrichment in $P_2O_5$, Cd and some transition metals as Zn, Cu and Ni, (Table 2 and Fig. 2).

The authors believes that the alkaline nature of the marine water prevented dissolution of phosphorus wastes; otherwise pollution could reach a catastrophic limit. According to Jeanjean *et al.* (1995) the sorption of cadmium, as well as other metal ions from aqueous solutions is a function of pH. The acid medium eases dissolution of the metals.

2. Gemsha area

Two samples were analyzed, one Recent gastropod and one sediment sample, (Table 1).

The obtained data suggest that the Recent shells of Gemsha area are slightly enriched in the heavy metals; Cu and Pb, while Zn displays relatively higher limit of enrichment (about three-folds).

**Table (2): Values normalized to Pleistocene (arranged according to locality).**

| Sample | Fossil/rock | | Oxides in wt. % | | | | Elements in ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Defination | Localities | MgO | CaO | P2O5 | Fe | Pb | Zn | Cu | Co | Cd | Ni | Mn | Sr |
| 1 | *Nerita* | El-Hamrawein | 0.83 | 0.94 | 1.13 | 0.48 | 0.79 | 0.85 | 1.50 | 1.71 | 1.47 | 1.92 | 2.47 | 0.87 |
| 5 | *Chama* | El-Hamrawein | 1.36 | 0.80 | 1.00 | 0.55 | 1.84 | 5.12 | 1.45 | 1.00 | 0.89 | 0.94 | 1.27 | 0.69 |
| 8 | *Turbo* | El-Hamrawein | 1.50 | 0.93 | 1.03 | 0.94 | 1.75 | 0.87 | 1.78 | 1.29 | 1.04 | 0.91 | 2.79 | 0.94 |
| 11 | *Amphistegina* | El-Hamrawein | 0.97 | 0.95 | 1.17 | 1.02 | 1.69 | 16.13 | 3.30 | 1.13 | 1.04 | 8.33 | 0.62 | 1.29 |
| 14 | *Cypraea* | El-Hamrawein | 2.36 | 0.99 | 1.55 | 1.02 | 1.72 | 8.73 | 0.97 | 0.86 | 0.86 | 1.08 | 2.23 | 1.61 |
| 18 | *Conus* | El-Hamrawein | 0.83 | 0.95 | 1.50 | 0.98 | 1.37 | 1.13 | 2.13 | 1.14 | 1.88 | 1.07 | 0.85 | 0.91 |
| 20 | Sediments | El-Hamrawein | 0.75 | 1.47 | 3.20 | 0.87 | 1.00 | 7.77 | 1.93 | 1.20 | 2.21 | 0.92 | 2.58 | 0.79 |
| | | Mean (n=7) | 1.23 | 1.01 | 1.5 | 0.84 | 1.45 | 5.80 | 1.87 | 1.19 | 1.34 | 2.17 | 1.83 | 1.01 |
| 2 | *Nerita* | Gemsha | 0.60 | 0.97 | 1.10 | 0.35 | 0.63 | 0.51 | 1.71 | 1.00 | 1.17 | 1.23 | 1.00 | 0.61 |
| 21 | Sediments | Gemsha | 0.35 | 0.09 | 0.44 | 0.61 | 1.85 | 3.32 | 1.60 | 1.00 | 1.11 | 0.60 | 1.86 | 0.08 |
| | | Mean (n=2) | 0.47 | 0.53 | 0.77 | 0.48 | 1.24 | 1.92 | 1.66 | 1.00 | 1.14 | 0.92 | 1.43 | 0.34 |
| 3 | *Nerita* | Gebel Zeit | 1.02 | 0.90 | 1.20 | 0.54 | 0.52 | 2.00 | 3.29 | 1.29 | 1.23 | 1.15 | 2.84 | 0.58 |
| 6 | *Chama* | Gebel Zeit | 0.68 | 0.99 | 1.09 | 0.94 | 0.64 | 1.32 | 0.65 | 1.07 | 0.96 | 0.83 | 2.47 | 0.72 |
| 9 | *Turbo* | Gebel Zeit | 1.29 | 0.75 | 0.86 | 1.95 | 1.09 | 1.11 | 0.56 | 1.06 | 0.85 | 1.64 | 4.07 | 1.48 |
| 12 | *Amphistegina* | Gebel Zeit | 0.72 | 0.94 | 1.07 | 0.63 | 0.98 | 9.25 | 0.63 | 1.31 | 0.96 | 3.67 | 0.83 | 0.90 |
| 16 | *Clanculus* | Gebel Zeit | 2.76 | 0.99 | 1.31 | 0.54 | 0.38 | 8.73 | 2.25 | 1.07 | 0.84 | 2.83 | 0.19 | 0.71 |
| 22 | Sediments | Gebel Zeit | 0.89 | 1.20 | 0.37 | 0.41 | 0.95 | 1.14 | 2.13 | 1.13 | 0.82 | 0.68 | 0.75 | 0.82 |
| | | Mean (n=6) | 1.23 | 0.96 | 0.98 | 0.83 | 0.76 | 3.92 | 1.58 | 1.15 | 0.94 | 1.8 | 1.86 | 0.87 |

Other environment-sensitive elements such as Cd, Co and Ni show no clear signs of enrichment in the Recent environment of Gemsha area. The available data, however, indicate that Gemsha area is lesser polluted relative to the El-Hamrawein area. This does not mean that Gemsha is a pristine environment, as signatures of pollution can be outlined, for instance the contents of Zn and Mn, among others, (Table 2 and Fig. 3).

3. Gebel Zeit area

Six Recent samples were analyzed, 3 gastropods, one pelecypod, one foraminfera and one sediment, (Table 1, Fig. 4).

The highest concentration of Pb in the Recent shells is recorded in *Amphistegina lessonii* (54ppm), while the lowest one in *Clanculus* (*Clanculus*) *pharaonius* (30ppm) with an average of 45ppm. The average Pb concentration in Recent sediments is 75ppm. The average Pb content of the Recent shells is about

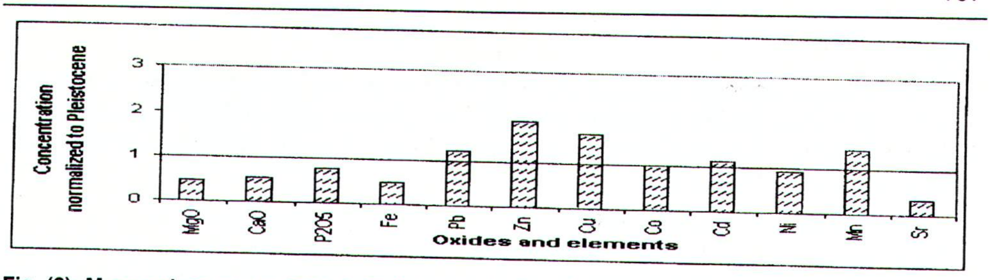


**Fig. (3): Mean values normalized to Pleistocene in Gemsha area.**

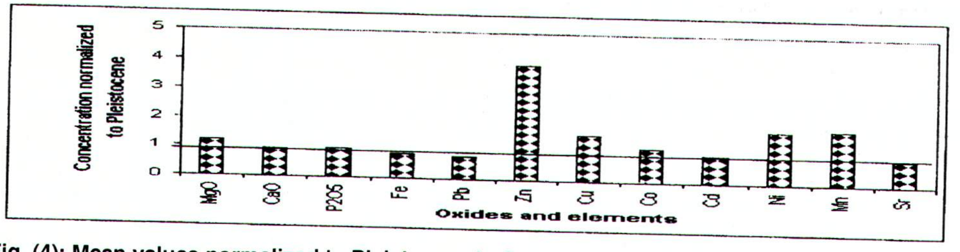


**Fig. (4): Mean values normalized to Pleistocene in Gebel Zeit area.**

1996) while the Recent sediments are five-times higher. The straightforward explanation of such drastic increase in Pb content is the fuel wastes of ships and machineries in an oil-producing area.

The highest concentration of Zn in Recent shells, is recorded in *Clanculus* (*Clanculus*) *pharaonius* is 192ppm, while the lowest one in *Chama pacifica* (45ppm), with an average of 88ppm. The average Zn concentration in Recent sediments is 25ppm.

The highest concentration of Cu in Recent shells is recorded in *Clanculus* (*Clanculus*) *pharaonius* (63ppm), while the lowest one in *Turbo* (*Batilus*) *radiatus* (5ppm) with an average of 28ppm. The average Cu concentration in Recent sediments is 32ppm.

The highest concentration of Co in Recent shells is recorded in *Amphistegina lessonii* (21ppm), while the lowest one in *Clanculus* (*Clanculus*) *pharaonius* (15ppm) with an average of 17ppm. The average Co concentration in Recent sediments is 17ppm.

The highest concentration of Cd in Recent shells is recorded in *Nerita* (*Theliostyla*) *albicilla* (3.25ppm), while the lowest one in *Clanculus* (*Clanculus*) *pharaonius* (1.85ppm) with an average of 2.5ppm. The average Cd concentration in Recent sediments is 2.3ppm. Cd is an important environment-sensitive element, owing to its very high toxicity. The average Cd content in the Recent shells of Gebel Zeit is about 12

sign of extensive pollution in the area.

The highest concentration of Ni in Recent shells is recorded in *Turbo* (*Batilus*) *radiatus* (18ppm), while the lowest one in *Amphistegina lessonii* (11ppm) with an average of 15.2ppm. The average Ni concentration in Recent sediments is 17ppm.

The highest concentration of Mn in Recent shells is recorded in *Turbo* (*Batillus*) *radiatus* (171ppm), and the lowest one in *Clanculus* (*Clanculus*) *pharaonius* (9ppm) with an average of 65.6ppm. The average Mn concentration in Recent sediments is

128ppm.

The highest concentration of $P_2O_5$ in Recent shells was recorded in *Chama pacifica* (0.37%), while the lowest one in *Turbo* (*Batilus*) *radiatus* and *Amphistegina lessonii* (0.32%) with an average of 0.34%. The average $P_2O_5$ concentration in Recent sediments is 0.3%.

Summing up of Gebel Zeit area:

The mean values of the concerned elements and oxides normalized to the Pleistocene ones in Gebel Zeit area (Table 3 and Fig. 4) reveal that, the Recent samples are enriched in Zn by factor of about four and in Cu, Ni and Mn by factor of two.

**Table (3): Values normalized to Pleistocene (according to genus and sediment)**

| Sample Number | Fossils/sediment Defination | Localities | Elements Oxides in wt. % in ppm MgO | CaO | P2O5 | Fe | Pb | Zn | Cu | Co | Cd | Ni | Mn | Sr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Nerita* | El-Hamrawein | 0.83 | 0.94 | 1.13 | 0.48 | 0.79 | 0.85 | 1.50 | 1.71 | 1.47 | 1.92 | 2.47 | 0.87 |
| 2 | *Nerita* | Gemsha | 0.60 | 0.97 | 1.10 | 0.35 | 0.63 | 0.51 | 1.71 | 1.00 | 1.17 | 1.23 | 1.00 | 0.61 |
| 3 | *Nerita* | Gebel Zeit | 1.02 | 0.90 | 1.20 | 0.54 | 0.52 | 2.00 | 3.29 | 1.29 | 1.23 | 1.15 | 2.84 | 0.58 |
| 5 | *Chama* | El-Hamrawein | 1.36 | 0.8 | 1.00 | 0.55 | 1.83 | 5.12 | 1.45 | 1.00 | 0.89 | 0.94 | 1.27 | 0.69 |
| 6 | *Chama* | Gebel Zeit | 0.68 | 0.99 | 1.08 | 0.93 | 0.63 | 1.32 | 0.65 | 1.07 | 0.96 | 0.83 | 2.47 | 0.72 |
| 8 | *Turbo* | El-Hamrawein | 1.50 | 0.93 | 1.03 | 0.94 | 1.75 | 0.87 | 1.78 | 1.29 | 1.04 | 0.91 | 2.79 | 0.94 |
| 9 | *Turbo* | Gebel Zeit | 1.29 | 0.75 | 0.86 | 1.95 | 1.09 | 1.11 | 0.56 | 1.06 | 0.85 | 1.64 | 4.07 | 1.48 |
| 11 | *Amphistegina* | El-Hamrawein | 0.97 | 0.95 | 1.17 | 1.02 | 1.69 | 8.00 | 3.30 | 1.13 | 1.04 | 4.00 | 0.62 | 1.29 |
| 12 | *Amphistegina* | Gebel Zeit | 0.72 | 0.94 | 1.07 | 0.63 | 0.98 | 4.50 | 0.63 | 1.31 | 0.96 | 3.67 | 0.83 | 0.90 |
| 14 | *Cypraea* | El-Hamrawein | 2.36 | 0.99 | 1.55 | 1.02 | 1.72 | 8.73 | 0.97 | 0.86 | 0.86 | 1.08 | 2.23 | 1.61 |
| 16 | *Clanculus* | Gebel Zeit | 2.76 | 0.99 | 1.31 | 0.54 | 0.38 | 8.73 | 2.25 | 1.07 | 0.84 | 2.83 | 0.19 | 0.71 |
| 18 | *Conus* | El-Hamrawein | 0.83 | 0.95 | 1.50 | 0.98 | 1.37 | 1.13 | 2.13 | 1.14 | 1.88 | 1.07 | 0.85 | 0.91 |
| 20 | Sediments | El-Hamrawein | 0.75 | 1.47 | 2.00 | 0.87 | 1.00 | 7.77 | 1.93 | 1.20 | 2.21 | 0.92 | 2.58 | 0.79 |
| 21 | Sediments | Gemsha | 0.35 | 0.09 | 0.44 | 0.61 | 1.85 | 3.32 | 1.60 | 1.00 | 1.11 | 0.60 | 1.86 | 0.08 |
| 22 | Sediments | Gebel Zeit | 0.89 | 1.20 | 0.37 | 0.41 | 0.95 | 1.14 | 2.13 | 1.13 | 0.82 | 0.68 | 0.75 | 0.82 |

Recent shells and sediments show marked environment in both Pb and Cd. This is interpreted to anthropogenic activities, particularly, these related to the oil-production in Gebel zeit area. Shells of *Clanculus* (*C.*) *pharaonius* seem to be least susceptible for pollution by Pb and Cd.

**Individual samples**

The geochemical analysis of the individual sea shell species and of the sediments show that there is a differential uptake of the same elements. The detailed analysis data are listed in table 3.

The following paragraphs deal with the distribution of the trace and major elements of the studied species, as well as of the sediment samples. In order to detect the influence of the recent environments, all values are (as mentioned before) normalized to the Pleistocene ones.

1- *Nerita* (*Theliostyla*) *albecilla* (Table 3 and Fig. 5)

Skeletons of *N.* (*Theliostyla*) *albecilla* are capable to concentrate positive values (>1) of $P_2O_5$, Zn, Cu, Co, Cd, Ni, and Mn.

2- *Chama pacifica* (Table 3 and Fig. 6)

The skeletons of this species, has high selectivity for the transition metals, according to the following order Pb > Cu > Zn > Cd.

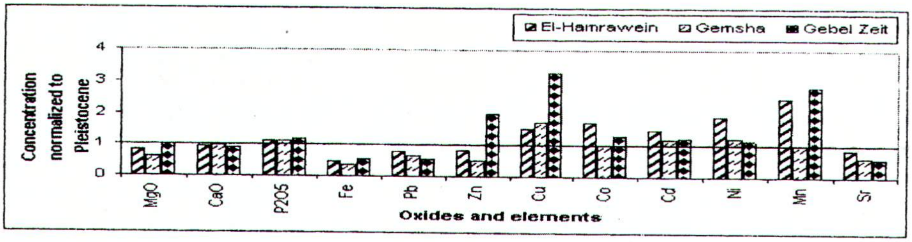


**Fig. (5): Concentration normalized values to Pleistocene in *Nerita (Theliostyla) albicilla*.**

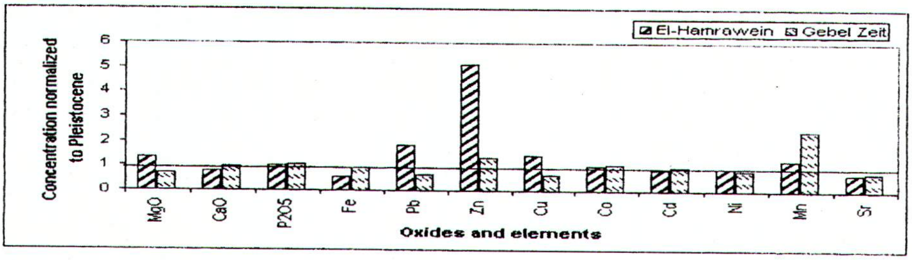


**Fig. (6): Concentration normalized values to Pleistocene in *Chama pacifica***

3- *Turbo (Batillus) radiatus* (Table 3 and Fig. 7)

*Turbo* skeleton has high positive values, in the following order Mn > Fe > Pb > Cu > Ni > Co > Sr.

4- *Amphistegina lessonii* (Table 3 and Fig. 8)

Testes of this foraminiferal species has high selectivity for the transition metals, in the following order Zn > Ni > Cu > Pb > Co > Sr. The enrichment of Zn is extremely high.

5- *Cypraea staphylaea* (Table 3 and Fig. 9)

The shells of this gastropod species show positive concentration in MgO, $P_2O_5$, Pb, Zn (very high), Mn, and Sr.

6- *Clanculus (Clanculus) pharaonius* (Table 3 and Fig. 10)

Skeletons of this gastropod species are capable to concentrate high values of Zn, Ni, MgO, Cu and $P_2O_5$.

7- *Conus virgo* (Table 3 and Fig. 11)

Skeletons of this gastropod species have high selectivity for the transition metals, according to the following order Cu > Cd > $P_2O_5$ > Pb > Zn > Ni.

8- Sediments (Table 3 and Fig. 12)

In general, the Recent sediments of El-Hamrawein and Gebel Zeit are relatively more imparted by pollution related to anthropogenic activities; while those of Gemsha appear to be the least polluted. The pollution in the El-Hamrawein area is mainly by phosphorites and their associaed trace elements, such as Zn, Cu, Cd and Mn, while Gebel Zeit is polluted by heavy metals. The sediments of Gemsha

show also some abnormality with respect to some transition elements.

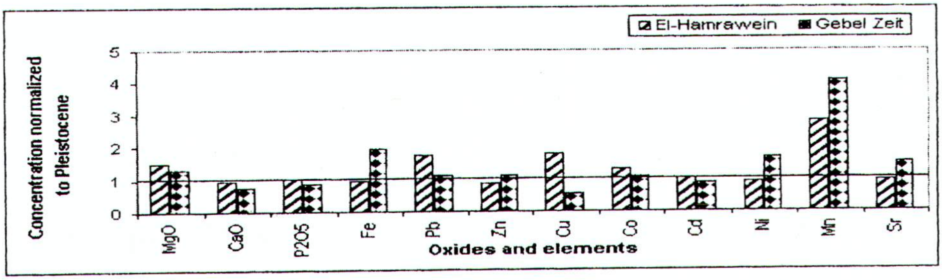


**Fig. (7):Concentration normalized values to Pleistocene in *Turbo (Batillus) radiatus.***

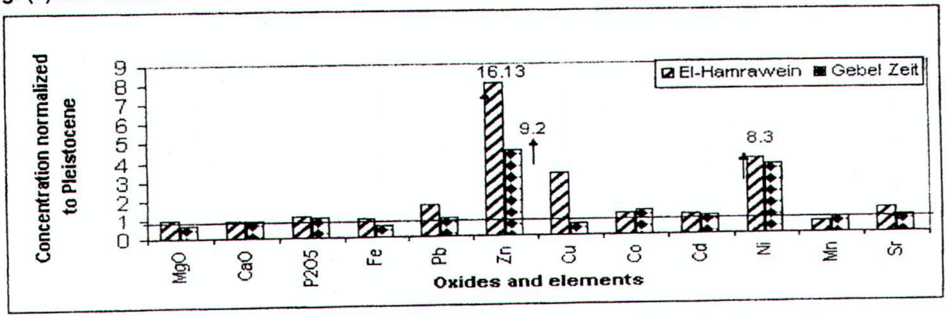


**Fig. (8): Concentration normalized values to Pleistocene in *Amphistegina lossenii.***

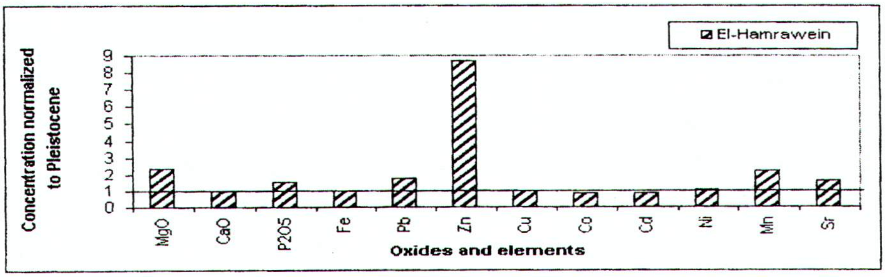


**Fig. (9): Concentration normalized values to Pleistocene in *Cypraea staphylaea.***

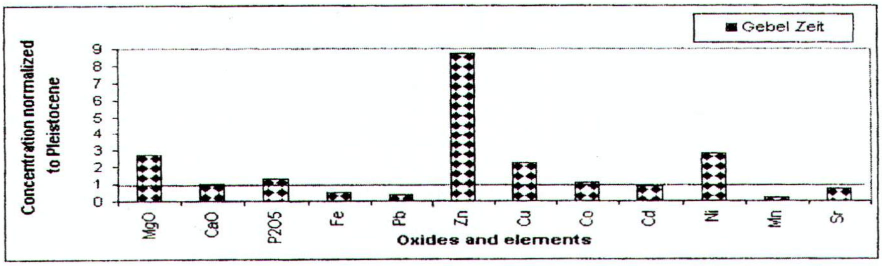


**Fig. (10): Concentration normalized values to Pleistocene in *Clanculus (C.) pharaonius.***

## Interpretation

The behavior of the heavy metals in the polluted areas is complex, and their impact on the human coastal environment is clearly reflected by their concentrations. In comparison with the average concentrations of Recent values,

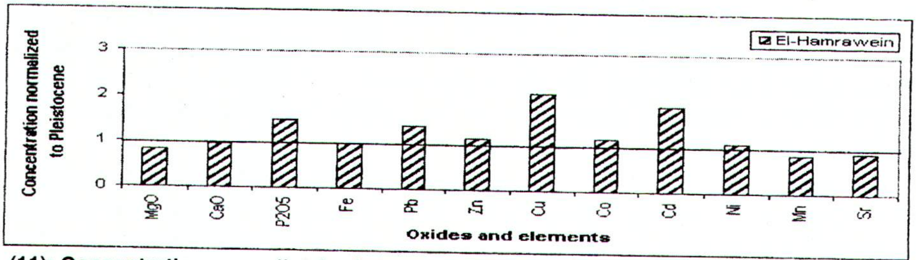


**Fig. (11): Concentration normalized values to Pleistocene in *Conus virgo*.**

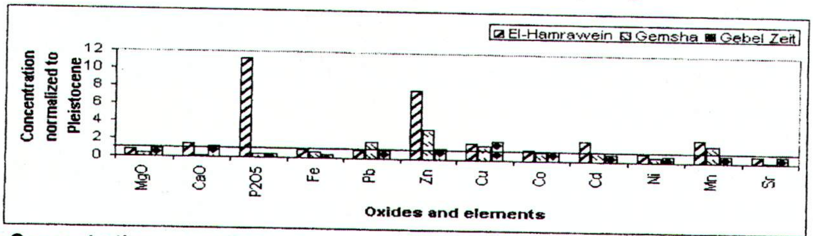


**Fig. (12): Concentration normalized values to Pleistocene in Sediment.**

the studied areas have some elements and oxides concentrations higher than the average of the Pleistocene sediments which were deposited under pristine environment with respect to human activities (Figs. 2-4).

1- El-Hamrawein area

The normalization of the major and trace elements to the Pleistocene values (Table 2), shows relative enrichment of Pb, Cu, Co, Cd, Ni and Mn while Zn and $P_2O_5$ are strongly enriched (Fig. 2). Both shells and sediments of the Recent environment of El-Hamrawein area are seriously imparted by the phosphate pollution which can be attributed to the frequent and close occurrences of phosphate mines along the Red Sea coast, as well as the washing and upgrading processes of the ore in the nearby factory and the close occurrence to Safaga Port, from which shipping and export of the ore take place.

2- Gemsha area

The major oxides and some of the trace elements concentrations normalized to the Pleistocene values (Table 2), show enrichment in Zn, Cu, Pb, Ni, Cd and Mn (Fig. 3). This enrichment is less than 2 times of the Pleistocene.

3- Gebel Zeit area

The Pleistocene-normalized concentrations of the major and some trace elements (Table 4); show relative enrichment in Zn, Cu, Co, Ni and Mn. Among these trace element concentrations of Zn is obviously high (Fig. 4).

The studied areas are subjected to pollution by heavy metals; especially in El-Hamrawein area as it represent the sites of intensive anthropogenic activities.

The differences in the distribution patterns of Co and Mn in the investigated areas are most probably due to post-depositional processes. Mn and Co are known as mobile elements and most sensitive to redox changes in depositional environment (Elderfield 1977). Mn deposits are usually associated with high concentrations of Cu, Ni and Co. Some phosphorites are also known as good accumulator for Cd. The geochemistry of Cd as an important environment-sensitive

element in natural phosphorite deposits was discussed by Nathan *et al.* (1997). They concluded that the exposure to oxic conditions leads to mobilization of the sulfide-bound Cd. Scouring activity, bioturbation, and recycling and transportation of stirred-up phosphate corpuscles in an oxidizing environment appear to be effectual for removing Cd.

The most conspicuous sources of pollution in the study area are the shipping and processing of phosphorites, harbor activity, sewage sludge discharge to the sea and oil industry. Moreover, pollutant could also be derived from the weathering of particular metal-rich deposits on land (Rose *et al.* 1979). The later possibility is well documented for the sediments and shells of the studied areas where mafic rocks of the coastal foreland supply high background concentrations of Mn, Ni, Co and to a lesser extent Cu which show anomalies related to geologic sources and their weathering products.

Finally, pollutants may reach levels that cause toxicity to marine organisms like fish and shrimps, which may transfer to human. So the concentrations of these metals in the Recent sea shells and sediments are legacy for the future and can be used as a tracer to modern sediment dynamics, hence to monitor the anthropogenic impacts. This leads to better assessing the needs for remediation by detecting any changes, from the existing level expected with operation of future activity. The sea shells being a good collector for heavy and toxic elements, more studies are suggested to monitor and mitigate pollution in coastal areas.

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