EJAR

Radioisotope levels in some recent corals of the northern Red Sea, Egypt

Mahmoud A. Dar[1] and Abeer A. El Saharty[2]

[1]*National institute of Oceanography and Fisheries, Red Sea, Egypt.*
Correspondence author: E-mail: mahmoud_rady@yahoo.com
[2]*National institute of Oceanography and Fisheries, Alexandria, Egypt.*

Received 8th May 2010, Accepted 4th November 2010

Abstract

The natural radioisotopes ^{238}U, ^{231}Th and ^{40}K as well as the artificial radioisotopes ^{137}Cs, ^{238}PU and ^{90}Sr were measured using high resolution ϒ-spectrometry in some living corals that growing in tidal flat areas of Hurghada, Safaga and Shlateen along the Red Sea coast. *Stylophora* sp. recorded the highest ^{238}PU activity (25.20Bqkg^{-1}dw), *Favia lacuna* recorded the highest ^{232}Th activity (16.20Bqkg^{-1}dw), while the highest ^{40}K activity was recorded in *Platygyra crosslanda* (996.00Bqkg^{-1}dw). The artificial radioisotopes recorded very low activities relative to the marine sediments; ^{90}Sr recorded the highest activity in the hydrocoral *Millipora dechtoma* (5.57Bqkg^{-1}dw), ^{238}P was observed only in some massive species at Hurghada and Shlateen (Av ≈ 0.03±0.00 and 0.12±0.06Bqkg^{-1}dw respectively) and ^{137}Cs activities were insignificant in all coral species (<0.1Bqkg^{-1}dw). Safaga locality shows the highest average contents for; ^{238}U (15.26±6.14Bqkg^{-1}dw), ^{232}Th (9.52±3.89Bqkg^{-1}dw); ^{40}K (677.18±284.71Bqkg^{-1}dw) and ^{90}Sr (2.02±1.59Bqkg^{-1}dw) while Shalteen recorded the highest average of ^{238}PU indicating that the natural radioisotope accumulations in coral reefs is highly affected by the phosphate inputs from mining, grinding and shipping operations and other terrestrial inputs while the artificial radioisotopes may be accumulated from the planktonic particulates from the sea. The study showed that the interspecific variations of the radioisotopes in the coral skeletons were controlled by the changes of carbonate ion content of the seawater, salinity and alkalinity influences, pH, seasonal influences, the substitution mechanism based on substitution of Ca^{2+} and the amounts of particulates in the water column and influence of temperature. In addition to some other biological factors as; the growth rate of the coral skeletons, the exposing surface area, skeleton bulk densities and the organic matrices thickness. The natural and artificial radioisotopes may be mineralized as ionic forms with the skeleton formation and/or included as independent particulates inside the aragonitic skeletal frameworks.

1. Introduction

Coral reefs are the most important hermatypic organisms. They play a key role in forming the structure of coral reefs and in providing substrate and shelter for a wide variety of organisms (Esslemont *et al.,* 2000). The reef building corals are composed of small, calcifying coral polyps that together build complex architectures (Mistr and Bercovici, 2003). During their lifetime, the reef building corals are continually secrete calcium carbonate skeleton below a thin surface layer of living tissue, these secretions result in annual growth bands that provide an important information about the environmental conditions during the time of skeleton formation (Scott and Davies, 1997). Corals have regulated the concentrations of some metals in their tissues, while their skeletons show promise as long-term proxy monitors reflect the surrounding environmental factors as the anthropogenic inputs and the natural flood discharges (Esslemont *et al.,* 2000) as well as the lattice bound metals reflects the metal concentrations in the seawater (Inoue *et al.,* 2004).

The concentrations of radioisotopes in oceans are determined by the horizontal and vertical movements of water masses in the ocean, particle formation processes and radioactive decay. The removal of radioisotopes from seawater by the radioactive decay (e.g. scavenging, etc.) depends on radioelement chemistry and the involvement of radionuclides in biogeochemical processes occurring in the sea (Povinec *et al.*, 2005). The radioisotope studies (natural and artificial) provide the basic information about any future abnormality in the radionuclide concentrations in the marine environment (El Saharty and Dar, 2010). The natural radioisotopes are mainly resulting from the weathering and recycling of terrestrial minerals and rocks that give rise to ^{40}K, ^{232}Th, ^{238}U, whereas, the marine sediments are known to be good receptacles of radioactivity compared with other marine materials (Noureddine *et al.,* 1998). For example, uranium contents in the coral skeletons possibly provide a key to estimate physical and chemical conditions (i.e., seawater temperature and uranium concentration) in which coral grew (Shen and Dunbar, 1995). Also, uranium has been targeted as a possible indicator of past oceanic oxygen levels owing to its removal in anoxic sediments (Russell *et al*., 1994). U-series isotopes including thorium and radiocarbon are extensively used for dating and as tracers of various processes during the late Quaternary (Sam *et al*., 1998; Yokoyama and Esat, 2004).

The aim of the present study is to determine the radioactive levels of the artificial and natural isotopes in skeletal framework of some recent corals in the northern Red Sea to provide the essential baseline data for monitoring the radioactive levels in the Red Sea.

1.2. Environmental and geomorphic settings

Hurghada coast consists of raised Quaternary terrace with tidal flat has a width varying between 100m to more than 5 kilometers. The tidal flat homogeneity is disrupted by many shallow water lagoons. Also, it is protected from the intensive wave actions by a series of rocky islands extending parallel to the coastline. The tidal flat, the lagoon edges and the lee sides of the coastal terrace were covered in most areas with healthy and biodiverse fringing coral reef communities. These coral communities were dominantly affected by the different anthropogenic stresses (i.e. coastal activities, landfilling, diving, oil exploration and maritime activities).

At Safaga, the coral communities were distributed in the inner part of extended tidal flat reaching to about 1200m at the southern limit of Safaga Bay 10km south of Safaga City (Figure 1). This area was protected from the high wave and wind actions by Safaga Island. Relative to the wind direction, this area supplies huge amounts of particulate sediments and other pollutants from phosphate grinding and shipping, high landfilling, shipyards as well as the maritime and coastal activities that increase the turbidity rates in the locality then led to high mortality rates between the coral communities and other benthos.

The coral reefs at Shlateen were distributed in the back reef and fore reef zones at the end of the wide rocky tidal flat that extends for more than 600m. The tidal flat of the locality is very shallow and completely exposed in the low tide time. It consists of Quaternary raised coral terrace covered with thin layer of terrestrial and marine sediments which increase in thickness landward. The coastal zone includes small fishing port and crossed by drainage pipeline of Shalateen desalination plant (10,000 m^3/day capacity). The reject seawater reaches about 20,000 m^3/day with salinity range between 52‰ and 56‰ drained directly outside the shoreline. The continuous brine water discharge in the coastal area causes intensive erosion along the beach and the nearest tidal flat zone that increasing turbidity in the investigated marine area.

2. Materials and methods

During the years 2008-2009; a total of 13 hard coral reef species were collected from three localities under different natural and anthropogenic conditions; Hurghada, Safaga and Shalateen. They were; *Goniastrea pectinata, Echinopora gemmacia, Porites myary, platygyra* sp., *Favia lacuna, Favia albidus, Platygyra corsslanda, Porites columna, Stylophora* sp., *Stylophora pistillata, Porites solida Tubipora musica* and *Millipora dichtoma*. The coral species were identified according to Sheppard and Sheppard (1991) and Veron (2000).

The freshly collected specimens were gently washed with tap water to remove the attached sediments, algae and other strange materials. The overlying organic matrices of the coral specimens were bleached using a mixture of 15% sodium hypochlorite and hydrogen peroxide (Esslemont *et al.,* 2000; Dar, 2004). About 50gm of the bleached skeletons were powdered in agate mortar to lesser than 80 mesh. The powdered samples were bottled in 50ml containers and stored for about four weeks to reach the equilibrium state (El-Arabi, 2005). These samples were analyzed at the Atomic Energy Authority, Egypt, Second Research Reactor ETRR2, Abu Zaabal, Egypt. The samples were measured using low-level gamma-ray spectrometer with high purity germanium detector. This detector has a relative efficiency of about 30% with resolution energy of 1.95keV FWHM for the 1332 keV gamma transition of ^{60}Co (El-Arabi, 2005). The estimated data were corrected using background counts based on measurement spectrum analysis program.

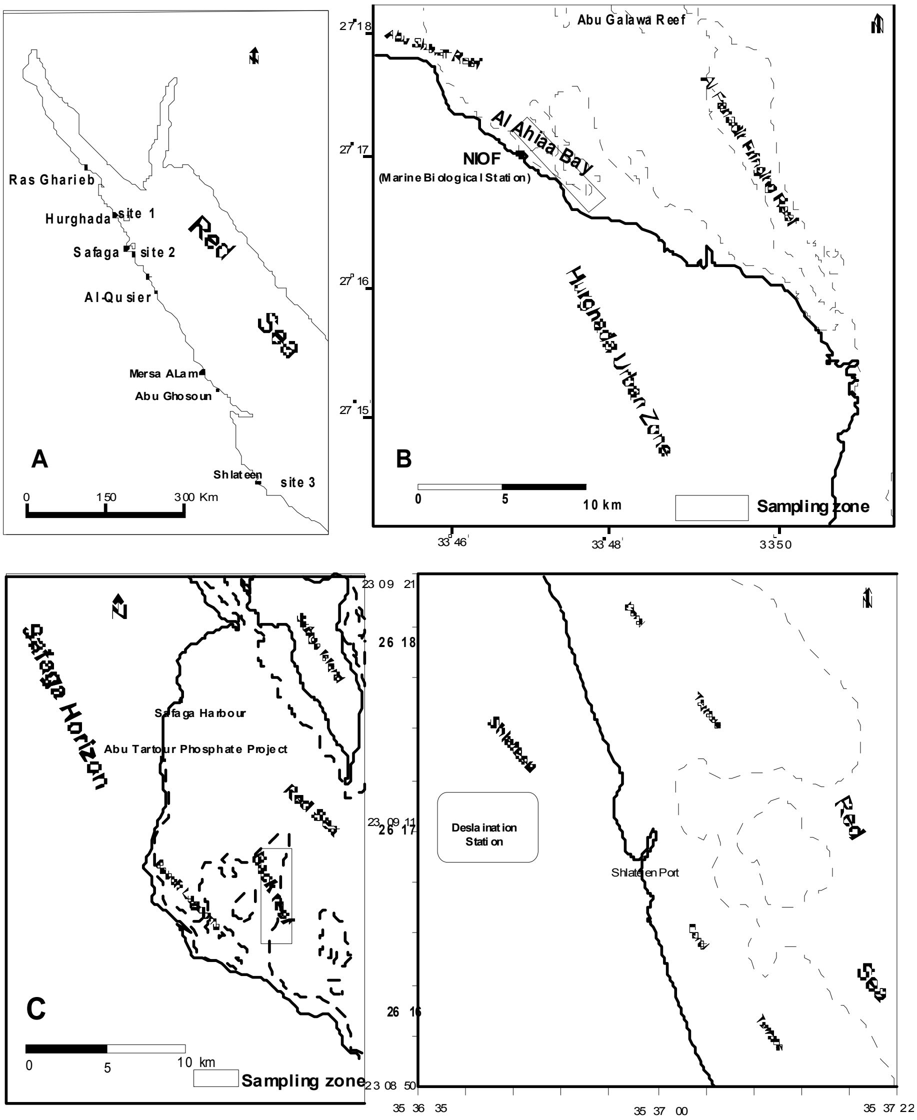

Figure 1. Location map shows the different studied localities.

3. Results and Discussion

3.1. Natural radioisotopes

The very low thorium content in the seawater is due to its absorption and fixation onto particulate material and sediments, subsequently, the living corals have negligible thorium abundances (Yokoyama and Esat, 2004). Some of young reef-building corals in open-ocean environments can have relatively high thorium concentrations (Cobb *et al.,* 2003). These are defined thorium sources in the living and young corals at the central tropical pacific as; wind-blown dust, seawater in the forms of dissolved and particulate Th and carbonate sands that are produced by ongoing erosion of the coral reef. Any changes in wave activity, dust loading, and upwelling strength could affect the average thorium ratios in corals. ^{40}K is dominantly of terrestrial origin and it can be considered as the essential constituent of the lightest minerals in the earth's crust resulting from weathering and recycling of terrestrial minerals and rocks (Noureddine *et al.* 1998).

Safaga locality recorded the highest activities of the natural radioisotopes in the coral species; *Stylophora* sp. recorded the highest ^{238}U activity (25.20Bqkg^{-1}dw), *Favia lacuna* recorded the highest ^{231}Th activity (16.20Bqkg^{-1}dw) and *Millipora dichtoma* recorded the highest ^{40}K activity (1082.00Bqkg^{-1}dw) while *Porites columna* recorded the lowest ^{238}U, ^{231}Th and ^{40}K activities (1.60, 1.40 and 119.00Bqkg^{-1}dw respectively) (Figure 2). At Hurghada, *Platygyra* sp. recorded the highest ^{238}U and ^{231}Th activities (18.4 and 7.5 Bqkg^{-1}dw respectively), *Goniastrea pectinata* recorded the highest ^{40}K activity (122 Bqkg^{-1}dw) and these radioisotopes were not detected in *Porites myary* (Figure 2). *Porites solida* recorded 9.7 and 15.00 Bqkg^{-1}dw for ^{238}U and ^{40}K at Shlateen.

Safaga locality corals recorded the highest average activity of ^{238}U (15.26±6.14 Bqkg^{-1}dw), ^{231}Th (9.52±3.89 Bqkg^{-1}dw) and ^{40}K (677.18±284.71 Bqkg^{-}

^{1}dw). ^{238}U and ^{231}Th activities reached about two folds of the average activities in the coral species at Hurghada (8.65±6.91, 4.59±2.06 Bqkg^{-1}dw), while ^{40}K reached about 9 times its average activity at Hurghada (81.75±39.92Bqkg^{-1}dw) (Figure 3). Mean while Shalteen corals recorded the lowest average activities for ^{238}U (9.70±0.00 Bqkg^{-1}dw), ^{40}K (56.25±37.94 Bqkg^{-1}dw) and ^{231}Th was not detected (Table 1).

The measured activities of the natural radionuclides differ widely in the marine environment depending on the physical, chemical, geochemical properties and the pertinent environment in the biological process (Sam *et al.,* 1998). Because of the filter-feeding organisms like the coral reefs need large volumes of water to obtain enough energy from living and non-living organic particulate material for maintenance, growth and reproduction, the radioisotopes may be introduced to the skeletal framework in particulates and/or ionic forms. The uptake of radioisotopes by bottom or suspended sediments in the marine environment is a definite step in the biological cycle of the artificially introduced radio activity (Aston and Duursma (1973). Suspended sediments and phytoplankton are the dominant contributors to turbidity, implying that the sediment nature may be as important to corals as the sedimentation rates (Edinger *et al.,* 2000). These particulates and suspended sediments are the main feeding source for the corals (Anthony, 1999) because of the feeding habit is one of the essential biological factors that affect the uptake of radioisotopes in marine organisms (Lowman, 1959). The capacity to feed on fine particulate matter is positively correlated with the particle availability and depends on the amount and the form of stable isotope present. Consequently, these particulates may be considered the essential source for the radioisotopes uptakes in the coral reefs. The recorded ^{238}U, ^{231}Th and ^{40}K in corals indicate that these coral species are highly affected by the particulate loads in the water column much more than the extraction of the radioisotopes in ionic forms especially for ^{231}Th and ^{40}K.

The other calcifying mechanism in the skeletal framework of corals is the ionic reactions by radioisotope carbonate formation and/or Ca^{+2} substitution (Swart and Hubbard, 1982; Russell *et al.,* 1994). The ionic forms of the chemical elements from seawater are incorporated into the coral skeleton in coincidence with the aragonite skeleton precipitation (Buster and Holmes, 2006). The living parts of corals may trap and concentrate Ca^{+2} ions and other ions electro-statically for mineral deposition or act as template for epitaxial growth (David, 2003). These elements and some isotopic ratios are thought to be related to numerous environmental factors including water chemistry, sedimentation, pollution and sea-surface temperature (SST).

According to (Armid *et al.,* 2008), during the calcification process of corals, some metal ions are able to be incorporated into carbonate lattice through the ion exchange mechanism between metal and calcium ions. Uranium was mineralized in calcite (e.g., Foraminifera, speleotherms) or aragonite as in molluscs and coral reefs (Shen and Dunbar, 1995). The accumulated data on uranium abundance in coral skeletons suggest most prevalent values of 2-3.5 ppm (Swart and Hubbard, 1982). Shen and Dunbar (1995) reported that the range in the coral/seawater uranium distribution coefficient is 0.8-1.0 once uranium concentration is 13.4 nM.

The skeletal variation of uranium in the coral reefs is controlled by the changes of carbonate ion content of the surface water, salinity and alkalinity influences, influence of temperature and the uranium uptake from the seawater as well as the growth rate of the coral skeleton (Shen and Dunbar, 1995). They added, that, it is difficult to identify the chemical species of uranium involved in biogenic precipitation. In corals, the actual participants are likely determined by the chemical conditions within the coral endoderm. Reef-building corals secrete $CaCO_3$ (aragonite) and uptake uranium (UO_2^{2+}) as impurity by replacing calcium (Ca^{2+}). Swart and Hubbard (1982) pointed out that in the coral skeletons free from the organic tissue, uranium was found to exchange readily with the coral skeleton and/or to be precipitated along trabecular axes and skeletal margins. The annual variation in the U/Ca of Porites coral skeletons shows a linear equation of temperature data (Min *et al*., 1995). Shen and Dunbar (1995) reported that the possible control over uranium uptake in corals relates to the existence of uranium primarily as carbonate complexes in seawater. On the other hand, at pH of 8, about of 90% of dissolved uranium exists as uranyl carbonate complexes (Djogic *et al.,* 1987).

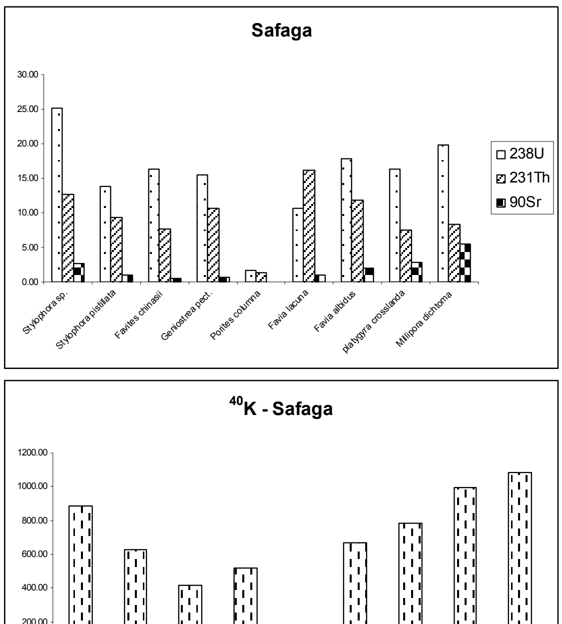

Figure 2. Radioisotopes distribution in the different coral species of Safaga.

Table 1: Natural and artificial radioisotopes distribution in corals in the different localities.

Species		^{238}U	^{231}Th	^{40}K	^{137}Cs	^{238}Pu	^{90}Sr
Safaga Corals	*Stylophora* sp.	25.20	12.70	886.00	<0.1	ND	2.72
	Stylophora pistillata	13.80	9.40	630.00	<0.1	ND	0.94
	Favites chinasii	16.40	7.60	413.00	<0.1	ND	0.52
	Geniostrea pect.	15.50	10.70	516.60	<0.1	ND	0.62
	Porites columna	1.60	1.40	119.00	<0.1	ND	ND
	Favia lacuna	10.70	16.20	670.00	<0.1	ND	0.96
	Favia albidus	17.90	11.80	782.00	<0.1	ND	1.96
	platygyra crosslanda	16.30	7.50	996.00	<0.1	ND	2.87
	Millipora dichtoma	19.90	8.40	1082.00	<0.1	ND	5.57
	Av.	15.26	9.52	677.18	<0.1	ND	2.02
	SD	6.14	3.89	284.71	-	-	1.59
Hurghada Corals	*Goiastrea pectinata*	-	-	122	<0.1	-	0.274
	Echinopora gemmacia	3.25	3.18	25.8	<0.1	-	-
	Porites myary	-	-	-	<0.1	0.033	-
	Platygyra sp.	18.4	7.5	62.2	<0.1	0.0236	0.463
	Tubipora musica	4.3	3.1	117	<0.1	-	-
	Av.	8.65	4.59	81.75	<0.1	0.03	0.37
	SD	6.91	2.06	39.92	-	0.00	0.09
Shalten Corals	*Porites myary*	-	-	97.5	<0.1	0.116	-
	Porites solida	9.7	-	15	<0.1	-	-
	Av.	9.70	-	56.25	<0.1	0.12	-
	SD	0.00	-	37.94	-	0.06	-

3.2. Artificial radioisotopes

Anthropogenic radioactivity comes out from atmospheric explosions since 1945 and from emissions produced by nuclear and radioactive facilities (Baeza *et al.,* 1994; Cooper *et al.*, 1998), discarded nuclear wastes (Fisher *et al.,* 1999), as well as other nuclear accidents (Aumento *et al.,* 2005). The anthropogenic radioisotopes; ^{90}Sr, ^{137}Cs and ^{239,240}Pu are the most abundant anthropogenic radioisotopes in the marine environment and can lead to the highest radiation doses to humans and marine biota (Povinec *et al.,* 2005). As the ocean is a dynamic system, radionuclides introduced to surface seawaters by wet and dry deposition do not stay in steady-stay conditions, but due to currents and processes in the water column, they have been transported to different regions, as well as to bottom waters and sediments (Povinec *et al.,* 2005). The conservative nature of ^{90}Sr and ^{137}Cs in the water column is responsible for the fact that their distribution is primarily related to the mixing processes in the oceans. They are mainly present in soluble form and their concentrations peak in subsurface or surface water, and decrease with depth (Nakano and Povinec, 2003; Hirose and Aoyama, 2003). Plutonium as a particle-reactive radionuclide in contrast to ^{137}Cs attaches to biogenic particles in surface water (Hirose and Sugimura, 1993), sinks with the particles, and regenerates in deeper water as a result of the remineralisation of the particles (Hirose, 1997). On the contrary Pu will be impacted by scavenging processes, more similar to some extent to Th, although the forms of Pu remaining in the ocean surface seem more conservative (Povinec *et al.,* 2005). On the other side, the accumulation of radionuclides, such as ^{137}Cs and ^{90}Sr, depends on salinity, pH, and calcium levels, as well as environmental levels of these radionuclides (Bojanowski and Pempkowiak, 1977; Marchyulenene, 1978).

Millipora dichtoma recorded the highest ^{90}Sr activity (5.57Bqkg^{-1}dw) followed by *Platygyra crosslanda* (2.87Bqkg^{-1}dw) and *Stylophora* sp. (2.72Bqkg^{-1}dw) and it was not detected in *Porites columna* at Safaga locality (Figure 2). The highest ^{90}Sr activity was recorded in *Platygyra* sp. at Hurghada (0.463 Bqkg^{-1}dw) (Figure 3) and was not detected in the other coral species. Also, ^{90}Sr was not detected in Shlateen corals. ^{238}Pu was not detected in the coral species at Safaga but it was observed in *Porites myary* (0.033 Bqkg^{-1}dw) and *Platygya* sp. (0.0236 Bqkg^{-1}dw) at Hurghada and *Porites myary* at Shlateen (0.116 Bqkg^{-1}dw). ^{137}Cs was insignificant in all coral species at the different localities (<0.1). Safaga recorded the highest average activity of ^{90}Sr (2.02±1.59) while shalteen recorded the highest ^{238}Pu (0.12±0.09) Table (1).

The significant high ^{90}Sr activities at Safaga locality indicate that such isotope has restricted natural source from phosphate operations (mining, grinding and shipping) in the locality, while ^{238}P and ^{137}Cs sources couldn't be delineated. The recorded values of ^{90}Sr are higher than the past recorded values in some other invertebrates and flora in East and West Coasts of USA (Valette-Silver and Lauenstein 1995), Irish Sea (Ryan *et al.*, 2003), Hong Kong (Li and Yeung, 2003; Jones *et al.,* 2004) and Japan (JCAC, 2004) (Table 2) that may indicate that phosphate inputs may contain relatively high ^{90}Sr levels (Table 2).

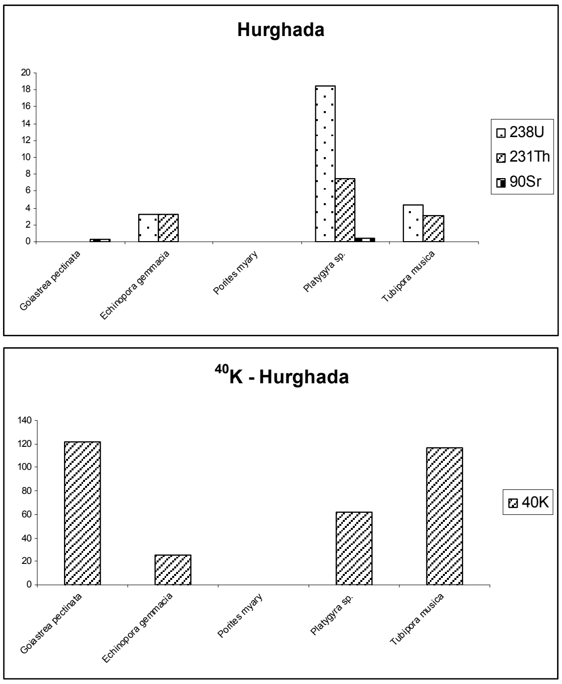

Figure 3. Radioisotopes distribution in the different coral species of Hurghada.

3.3. Mechanisms of radioisotopes accumulation and mineralization in coral skeletons

There were different mechanisms for the metal incorporation in the coral skeletons; substitution of dissolved metal species into the crystal lattice, adsorptive (Inoue *et al.,* 2004) trapping of particulate (detritus) matter within skeletal cavities, uptake of organic matter from the coral tissue and coral feeding or the detritus may be incorporated into corals by direct deposition on skeleton through polyp damage or surface lesions (Fallon *et al.,* 2002). Auemheimer and Chinchon (1997) recorded that the minor elements exist in the invertebrate skeletons by substitution for the calcium in the calcite or aragonite structure in accordance with the ionic radius. Scott and Davies (1997) attributed the metals incorporation into the coral skeletons to two main mechanisms actually occur in nature; predominant-deposition during skeletogenesis and entrapment during damage and exposure of the skeleton to seawater.

The particulate and ionic forms incorporations are the distinctive mechanisms of natural and artificial radioisotopes accumulation in the skeletal framework of the coral reefs which are indicating to two definite sources; terrestrial and marine sources. The terrestrial source is restricted in the particulate and fine particle sediments due to the anthropogenic activities along the coastal area of the Red Sea in addition to the natural inputs epically for ^{231}Th and ^{40}K and ^{90}Sr. The marine source involves the ionic form of substitution and/or independent metal mineralization inside the aragonite framework especially for ^{238}U, ^{238}PU and ^{137}Cs in addition to the particulate and plankton assimilation by the organic tissue of corals.

The incorporation and mineralization operations of the natural and artificial radioisotopes inside the skeletal framework of the coral reefs are controlled by some biological factors that can be summarized as:

1. Annual classification rate increases with increasing the surface area and tissue thickness (Lough and Barnes, 2000).
2. Bulk density has an inverse relation with the metal incorporation in the coral skeleton because the porosity decreases with the bulk density increasing (Bucher *et al.,* 1998) that means the pore spaces are reduced, subsequently, the metal transfer intensities are obviously declining.
3. The organic matrix has superior effect in the ionic and particulate metals incorporation to the coral skeletons. The composition of the organic matrix in corals has simulated interest in the mechanism of skeleton formation, however lipid components contained in the skeletal organic matrix may play an important part in the mineralization on calcifiable framework (Isa and Okazaki, 1987).
4. The availability of particulate and ionic forms in the surrounding water column. There is a clear relation between metal exposure and metal accumulation in the living tissue and skeleton (Bastidas and Garcia, 1999). The distribution coefficient of the metal ions and the metal/Ca ratios in the seawater (Ramos *et al.,* 2004).
5. The average annual density, annual extension and annual calcification (Fallon *et al.*, 2002).

4. Conclusion

6. The natural radioisotopes; ^{238}U, ^{231}Th and ^{40}K as well as the artificial radioisotopes; ^{90}Sr, ^{238}Pu and ^{137}Cs were studied in the living coral reefs in Hurghada, Safaga and Shlateen along the Red Sea coast.

Table 2. Artificial radioisotope levels measured in some marine biota.

	^{137}Cs	^{90}Sr	^{238}Pu	Locality	Reference
Coral reefs	<0.1	2.02±1.59	-	Safaga, Red Sea	Present Study
Coral reefs	<0.1	0.37±0.09	0.03±0.0	Hurghada, Red Sea	Present Study
Coral reefs	<0.1	-	0.12±0.06	Shalteen, Red Sea	Present Study
Bivalves	0.250	0.170	0.003	West Coast, USA	Valette-Silver and Lauenstein (1995)
Bivalves	0.140	0.2	0.006	East Coast, USA	Valette-Silver and Lauenstein (1995)
Molluscs	0.26	-	-	Irish Sea	Ryan et al. 2003
Crustaceans	0.62	-	-	Irish Sea	Ryan et al. 2003
Seaweeds	2.00	0.05	-	Hong Kong	Li and Yeung, 2003
Crustaceans	0.1	-	-	Hong Kong	Jones et al., 2004
molluscs	0.1	0.1	-	Hong Kong	Jones et al., 2004
Seaweed	0.1	0.1	-	Hong Kong	Jones et al., 2004
Seaweeds	ND	0.024	-	Japan	JCAC (2004)

1. The coral reef species at Safaga recorded the highest activities and the highest average activities for ^{238}U, ^{231}Th, ^{40}K and ^{90}Sr, while Shlateen recorded the highest ^{238}Pu activities. ^{137}Cs was insignificant in all samples (Figure 4).
2. The recorded ^{238}U, ^{231}Th and ^{40}K in corals indicate that these coral species were highly affected by the particulate loads in the water column much more than extraction the radioisotopes in ionic forms especially for ^{231}Th and ^{40}K.
3. Phosphate mining, grinding and shipping may be considered the main source of ^{238}U, ^{231}Th,
4. ^{40}K and ^{90}Sr while ^{238}Pu couldn't determine.
5. Particulates and ionic substitutions are the main accumulation mechanisms of the radioisotopes in the skeletal framework of corals.
6. The incorporation and mineralization operations of the natural and artificial radioisotopes inside the skeletal framework of the coral reefs were controlled by; the annual classification, bulk density of corals, organic matrices thickness and the availability of particulate and ionic in the surrounding water column.

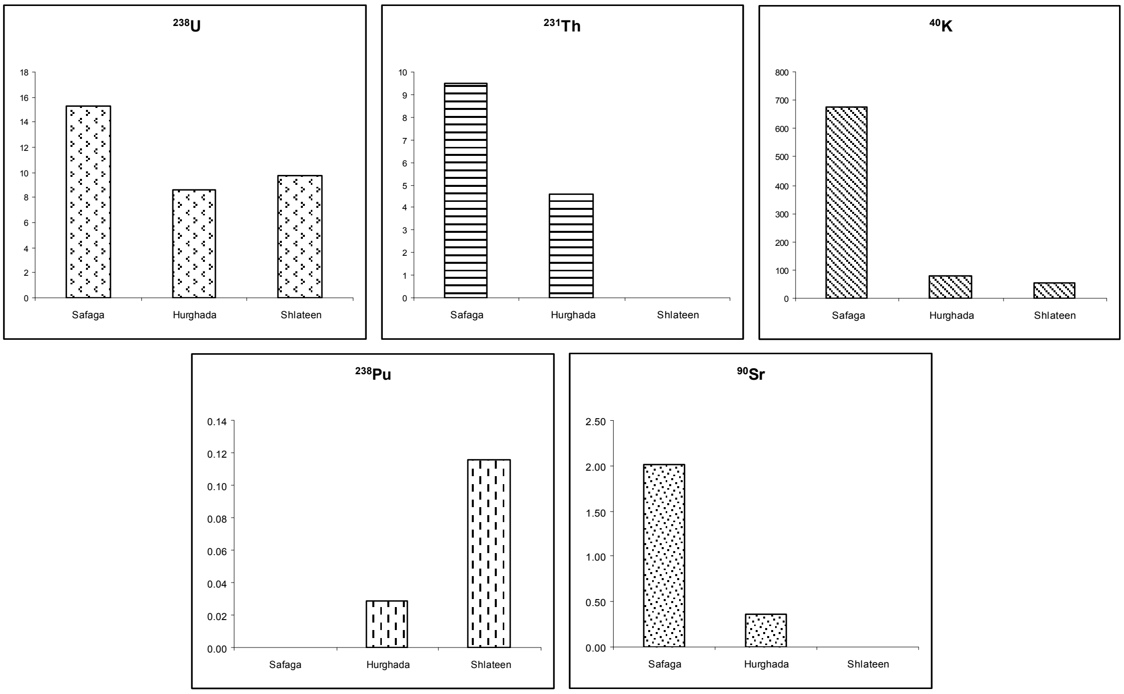

Figure 4. The average activities of the Radioisotopes of corals in the different localities.

Acknowledgement

The authors wish to send the grateful thanking to Prof. Dr.\ Hamed El-Kady - the X-former chairman the Atomic Energy Authority of Egypt (AEAE) and Prof. of radiation biology for the generous help in sample analyses and reorienting the authors in the correct path of data treatment.

References

Anthony, K.R.N.: 1999, Coral suspension feeding on fine particulate matter. *Journal of Experimental Marine Biology and Ecology,* 232: 85-106.

Armid, A. ; Takaesu, Y.; Fahmiati, T.; Yoshida, S.; Hanashiro, R.; Fujimura, H.; Higuchi, T.; Taira, E. and Oomori, T.: 2008, U/Ca as a possible proxy of carbonate system in coral reef. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, USA,7-11 July.

Aston, S.R. and Duursma, E.K.: 1973, Concentration effects on ^{137}Cs, ^{65}Zn, ^{60}Co and ^{106}Ru sorption by marine sediments, with geochemical implications. *Netherlands Journal of Sea Research*, 6(1-2): 225-240.

Auemheimer, C. and Chinchon, S.: 1997, Calcareous skeletons of sea urchins as indicator of heavy metals pollution. Portman Bay, Spain. *Environmental Geology*, 29(1-2): 71-83.

Aumento, F., Donne, K.L. and Eroe, K.: 2005, Transuranium radionuclide pollution in the waters of the La Maddalena National Marine Park. *Journal of Environmental Radioactivity* 82, 1-93.

Bastidas, C. and Garcia, E.: 1999, Metal content of the reef coral *Porites asteroides*: an evaluation of river influence and 35 years of chronology. *Marine Pollution Bulletin*, 38: 899-907.

Bojanowski, R. and Pempkowiak, J.: 1977, Accumulation of ^{90}Sr, ^{137}Cs, ^{106}Ru, ^{144}Ce and ^{239,240}Pu in Baltic seaweeds. *Oceanologia* 7: 89-104.

Bucher, D.J.; Harriott, V.J. and Roberts, L.G.: 1998, Skeletal micro-density, porosity and bulk density of Acroporid corals. *Journal of Experimental Marine Biology and Ecology*, 228: 117-136.

Buster, N.A. and Holmes C.W.: 2006, Magnesium content within the skeletal architecture of the coral *Montastraea faveolata*: locations of brucite precipitation and implications to fine-scale data fluctuations. *Coral Reefs*, 105: 243-253.

Cobb, K.M.; Charles, C.D.; Cheng, H.; Kastner, M., Edwards, R.L.: 2003, U/Th-dating living and young fossil corals from the central tropical Pacific. Earth and Planetary Science letters 210: 91-103.

Cooper, L.W.; Beasley, T.M.; Zhas, X.L.; Doto, C., Vinogradova, K.L.; Dunton, K.H.: 1998, Iodine-129 and plutonium isotopes in arctic kelp as historical indicators of transport of nuclear fuel-reprocessing waters from mid-to-high latitudes in the Atlantic Ocean. Marine Biology 131: 391-399.

Dar, M.A.: 2004, Heavy metals variability and the bioaccumulation mechanism in the recent corals, Hurghada, Red Sea, Egypt. *Sedimentlogy of Egypt*, 12: 119-129.

David, C.P.: 2003, Heavy metal concentrations in growth bands of corals: a record of mine tailings input through time (Marinduque Island, Philippines). *Marine Pollution Bull.*, 46: 187-196.

Djogic , R.; Kniewald, G. and Branica, M.: 1987, Uranium in the marine environment: A geochemical approach to its hydrologic and sedimentary cycle. I. theoretical consideration. In Radioactivity and Oceanography, pp. 171-182. Cherbourg.

Fisher, N.S., Fowler, S.W., Boisson, F., Carroll, J., Rissanen, K., Salbu, B., Sazykina, T.G., Sjoeblom, K.L.: 1999, Radionuclide bioconcentration factors and sediment partition coefficients in Arctic Seas subject to contamination from dumped nuclear wastes. *Environmental Science and Technology* 33, 1979-1982.

Edinger, E.N.; Limmon, G.V.; Jompa, J.; Widjatmoko, W.; Heikoop, J. and Risk, M.: 2000, Normal coral growth rates on dying reefs: are coral growth rates good indicators of reef Health?. *Marine pollution Bulletin*, 40(5): 404-425.

El-Arabi A.M.: 2005, Natural radioactivity in sand used in thermal therapy at the Red Sea Coast. *Journal of Environmental Radioactivity,* 81: 11-19.

El-Saharty, A.A. and Dar, M.A.: 2010, The concentration levels of some isotopic radionuclides in the coastal sediments of the Red Sea, Egypt. *Isotope and Radiation Research,* 42(1): 73-89.

Esslemont, G.; Harriott, V.J. and McConchie, D.M.: 2000, Variability of trace metal concentrations within and between colonies of *Pocillopora damicornis*. *Marine Pollution Bulletin*, 40(7): 637-642.

Fallon, S.J.; White, J.C. and McCulloch, M.T.: 2002, *Porites* corals as recorders of mining and environmental impacts: Misima Island, Papua New Guinea. *Geochimica et Cosmochimica Acta*, 66(1): 45-62.

Hirose, K.: 1997, Complexation scavenging of plutonium in the ocean. In: Germain, P., Guary, J.C., Guegueniat, P., Metivier, H. (Eds.), Radionuclides in the Oceans. Part 1. Inventories, Behaviour and Processes. Radioprotection e colloques, 32, pp. C2-225-C2-230.

Hirose, K. and Sugimura, Y.: 1993, Chemical speciation of particulate ^{238}U, ^{239,240}Pu and thorium isotopes in seawater. *Science of the Total Environment,* 130/131: 517-524.

JCAC: 2004, Radioactivity Survey Data in Japan environmental and dietary Material, Japan Chemical Analysis Center, report 139.

Jones, K., Simmonds, J. and Jones, A.: 2004, Distinguishing between impacts of current and historic radioactive discharges to sea from UK nuclear sites. Department for Environment, Food and Rural Affairs (DEFRA), Commissioned Research for Radioactive Substances Division. DEFRA Report No. DEFRA/RAS/03.001.

Inoue, M.; Suzuki, A.; Nohara, M.; Kan, H.; Edward, A. and Kawahata, H.: 2004, Coral skeletal tin and copper concentrations at Pohnpei, Micronesia: possible index for marine pollution by toxic anti-biofouling paints. *Environmental Pollution*, 129: 399-407.

Isa, Y. and Okazaki, M.: 1987, Some observations on the Ca^{+2} binding phospholipids from scleractinian coral skeletons. *Comparative Biochemistry and Physiology,* 87B(3): 507-512.

Li, S.W. and Yeung, K.C.: 2003, "Summary of Environmental Radiation Monitoring in Hong Kong". Hong Kong Observatory, technical Report No. 23.

Lough, J.M. and Barnes, D.J.: 2000, Environmental controls on growth of the massive coral *Porites. Journal of Experimental Marine Biology and Ecology,* 245: 225–243

Lowman, F.: 1959, Marine biological investigations at the Eniwetok test site. Proc. Conf. on Disposal of Radioactive Wastes, Vienna 2: 106.

Marchyulenene, D.P.: 1978, Migration of some radionuclides in freshwater bodies. *Journal of Hydrobiology* 14: 83-85.

Min, G.R; Edwards, R.L.; Taylor, F.W.; Recy, J.; Gaullup, C.D.; Beck, J.W.: 1995, Annual cycles of U/Ca in coral skeletons and U/Ca thermometry. *Geochim. Cosmochim Acta*, 59(10): 2025-2042.

Mistr, S. and Bercovici, D.: 2003, A theoretical model of pattern formation in coral reefs. *Ecosystems*, 6: 61-74.

Nakano, M. and Povinec, P.P.: 2003, Modelling the distribution of plutonium in the Pacific Ocean. *Journal of Environmental Radioactivity* 69: 85-106.

Noureddine, A.; Baggoura, B.; Hocint, N. and Boulahdid, M.: 1998, Uptake of radioactivity by marine surface sediments collected in Ghazaouet, West Coast of Algeria. *Applied Radiation and Isotopes,* 49(12): 1745-1748.

Povinec, P. P.; Aarkrog, A.; Buesseler, K. O.; Delfanti, R.; Hirose, K.; Hong, G. H.; Ito, T.; Livingston, H. D.; Nies, H.; Noshkin, V. E.; Shima, S. and Togawa, O.: 2005, ^{90}Sr, ^{137}Cs and $^{239,240}Pu$ concentration surface water time series in the Pacific and Indian Oceans - WOMARS results. *Journal of Environmental Radioactivity* 81: 63-87.

Ramos, A.A.; Inoue, Y. and Ohde, S.: 2004, Metal contents in Porites corals: Anthropogenic input of river run-off into a coral reef from an urbanized area, Okinawa. *Marine Pollution Bulletin*, 48: 281-294.

Russell, A. D.; Emerson, S.R.; Nelson, B.K.; Erez, J. and Lea, D.W.: 1994, Uranium in foraminiferal calcite as a recorder of seawater uranium concentration. *Geochemica et Cosmochimica Acta,* 58: 671-681.

Ryan R.P.; McMahon C.A. and Dowdall A.: 2003, Radioactivity monitoring of the Irish marine environment 2000 and 2001. The radiological Protection Institute of Ireland (RPII).

Sam, A.K.; Ahmed, M.M.; El Khangi, F.A.; El Nigumi, Y.O. and Holm, E.: 1998, Radioactivity levels in the Red Sea coastal environment of Sudan. *Marine Pollution Bulletin*, 36(1): 19-26.

Scott, P.J. and Davies, M.: 1997, Retroactive determination of industrial contaminants in tropical marine communities. *Marine Pollution Bulletin,* 34(11): 975-980.

Shen, G.T. and Dunbar, R.B.: 1995, Environmental controls on uranium in reef corals. *Geochimica, Cosmochimica Acta,* 59(10): 2009-2024.

Sheppard, C. R. and A. L. S. Sheppard: 1991, Corals and coral communities of Arabia. II. Fauna of Saudi Arabia 12: 170 p.

Swart, P.K. and Hubbard, A.E.: 1982, Uranium in Scleractinian coral skeletons. *Coral Reefs* (1): 13-19.

Yokoyama, Y. and Esat, T.M.: 2004, Long Term Variations of Uranium Isotopes and Radiocarbon in the Surface Seawater Recorded in Corals. *Global Environmental Change in the Ocean and on Land*, Eds., M. Shiyomi *et al*., pp. 279–309.

Valette-Silver, N.J., Lauenstein, G.G.: 1995, Radionuclide Concentrations in Bivalves Collected along the Coastal United States. *Marine Pollution Bulletin* 30, 320-331.

Veron, I.: 2000, Corals of the world. Australian Institute of Marine science, (3 Vols), 1400p.