Iranica Journal of Energy & Environment

Journal Homepage: www.ijee.net

IJEE an official peer review journal of Babol Noshirvani University of Technology, ISSN:2079-2115

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Research Note

Radiological Risk Assessment to Marine Biota Along Manora Channel Karachi Coast Pakistan

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P A P E R I N F O

Paper history:
Received 6 March 2015
Accepted in revised form 3 May 2015

Keywords:
Radionuclides
Radiological risk assessment
ERICA tool
Cs-137
Ra-228
Marine biota

A B S T R A C T

Sources of radioactivity in the aquatic environment include naturally occurring radionuclides, fallout from the atmospheric and radioactive effluent from nuclear facilities that was released either accidentally or routinely. Depending upon the element and the chemical form, radionuclides may accumulate in bottom sediment or remain in the water column in the dissolved state. Marine organisms receive external radiation exposure from radionuclides in water and sediment. Radiological risk assessment was made for marine fish that are exposed to ^{137}Cs, ^{226}Ra, ^{228}Ra and ^{40}K along Manora channel Karachi coast of Pakistan using ERICA tool software. The ERICA tool is a software system that has a structure based upon the tiered ERICA integrated approach to assessing the radiological risk to terrestrial, freshwater and marine biota. The results were calculated using Tier 1 and Tier II assessments which are based on media concentration and use pre-calculated environmental media concentration limits to estimate risk quotients. If the sum of the risk quotients is <1, then it can be assured that there is a very low probability that the assessment dose rate to any organism exceeds the incremental screening dose rate and therefore the risk to non-human biota can be considered negligible. Risk quotient in this study is far below 1 which reveals that there is no evidence of deleterious effect of radionuclide for marine biota of the area under study.

***doi**: 10.5829/idosi.ijee.2015.06.03.09*

INTRODUCTION

According to their origin, radioactive materials are classified into two general types: i) naturally occurring radioactive materials and ii) artificially produced radioactive materials. Naturally occurring radioactive elements have always present in the human environment having specific distribution levels. Artificial radionuclides are anthropogenic in nature and are the result of human endeavors [1]. Natural radioactivity is present in the environment in soil, rocks, plants, water and air. Terrestrial gamma radiation from Earth's crust materials is the major contributor to the average annual external gamma dose received in soft tissues by humans [2]. Natural radionuclides are present in sediments, where they tend to accumulate mainly through weathering, erosion and depositional processes of various geological materials showing generally increasing concentrations when grain size decreases [3]. Besides, several anthropogenic activities can alter natural radioactivity levels, such as oil and gas processing, coal power plants, metal scrap recycling and smelting [4-6].

Radionuclides that enter the aquatic environment originate from natural as well as artificial sources. Naturally occurring nuclides (radioactive forms of elements) are derived from weathering of minerals in the Earth's crust and from cosmic rays, while artificial radionuclides are released to the marine environment from a variety of past and present human activities associated with the nuclear industry and military uses. These include the operation of nuclear power plants and nuclear fuel reprocessing plants, atmospheric nuclear weapons testing and fallout from accidents. Human activities have led to elevated levels of naturally

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Please cite this article as: S. Saleem, A. Mashiatullah, M. Asma, N. Yaqoob, M. Sarwar Khan, 2015. Radiological Risk Assessment to Marine Biota Along Manora Channel Karachi Coast-Pakistan, Iranica Journal of Energy and Environment 6 (3): 212-216.

occurring radionuclides [1]. In general, three distinct environmental processes have been mentioned by most investigators as being responsible for the entry of radioactive elements into marine organisms. These are adsorption, absorption and ingestion. These mechanisms operate to various degrees both individually and collectively. A considerable accumulation of radioelements may occur through the food chain. This is particularly the case with filter feeders (e.g.: Mussels), which ingest detritus material with a high degree of radionuclide association, and so mussels, the filter feeding bivalve mollusks, have been recognized internationally as first-order biological indicators of radioactive pollution [1] which has become a most important subject to environmental scientists as well as to governments throughout the world [7-9].

Recently, there has been growing international interest in the assessment of doses and risks to biota resulting from exposure to radionuclides from anthropogenic sources [10-12]. Several models are now available that enable the assessment of radiological risk to biota [13, 14]. One of these is the ERICA Tool [15], which implements the ERICA Integrated Approach [10] developed within the EC 6th Framework Programme. The ERICA Tool allows the estimation of dose rates to biota for terrestrial, freshwater and marine ecosystems for a set of default reference organisms or user defined organisms. The Tool includes databases on radionuclide transfer [16] and dose conversion coefficients [17] enabling dose calculation to be performed from input data on radionuclide concentrations in biota and/or media such as soil or water.

MATERIALS AND METHODS

Study area

Manora is a small headland of 2.5km^2 located near the Port of Karachi. Manora Channel is linked to the inland by a walkway that is called Sandspit. Manora and its adjacent islands makes a shielding blockade to the south between Karachi harbor and the Arabian Sea. The western side of the port comprises threatened mangrove forests that borders the Island of Manora (Figure 1).

Radiological risk assessment

The available data was used to calculate the radiological risk assessment in marine biota through ERICA Tool.

ERICA tool

The 'Environmental Risks from Ionizing Contaminants: Assessment and Management' (ERICA Tool) is a software system that has a structure based upon the tiered ERICA integrated approach to assess the radiological risk to terrestrial, freshwater and marine biota. The Tool has simple transport models embedded to enable conservative estimates of media activity concentrations from discharge data. The ERICA assessment tool was used for estimating dose rates to marine biota. The ERICA tool provides a tiered approach allowing the input of site-specific measured activity concentrations in biota and media at Tiers 1, 2

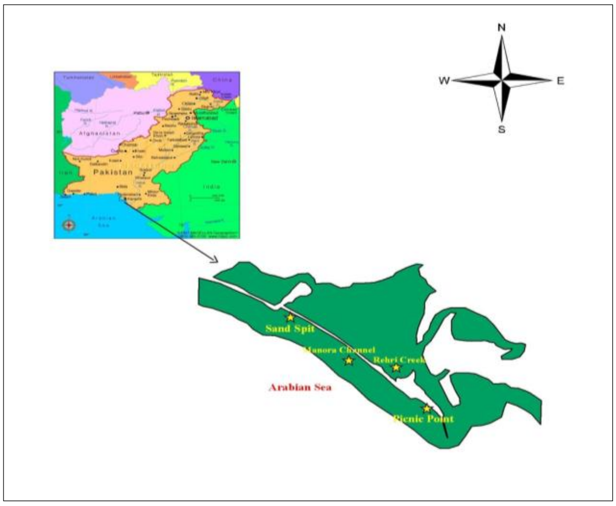

Figure 1. Map of Manora Channel

and 3 [15]. The assessment was carried out using Tier 2. Best estimate values of measured activity concentrations in biota, water and/or sediment were used as inputs at Tier 2, as recommended by Brown et al.,. For the geometries and dimensions of the biota, default reference organisms were used in the model calculations (Table 1).

TABLE 1. Reference organisms were used in the model calculations

Sample	Reference organism selected in the ERICA Tool
Croaker - *Nibea* Spp.	Benthic Fish
Queen fish - *Scomberoides* spp.	Pelagic Fish
Black sea bream – *Spondyliosomacantharus*	Pelagic Fish
Silvery Grunter - *P. argyreus*	Pelagic Fish
Acrocalanus spp.	Zooplankton

RESULT AND DISCUSSION

Dose rate is the amount of radiation absorbed per unit of time. Dose rates to the marine biota are calculated taking into account their quantitative analysis and ecological characteristics, as a sum of internal and external exposure (from water and bottom sediments). Dose rates from the incorporated γ-emitting radionuclides in marine biota are calculated through ERICA Tool. ERICA (Environmental Risk from Ionizing Contaminants: Assessment and Management) is an integrated approach to scientific, managerial and societal issues concerned with the environmental effects of contaminants emitting ionizing radiation, with emphasis on biota.

If the sum of the risk quotients is <1, then it can be assured that there is a very low probability that the assessment dose rate to any organism exceeds the incremental screening dose rate and therefore the risk to non-human biota can be considered negligible. Risk Quotient in this study is far below 1 which reveals that there is no evidence of deleterious effect of radionuclide for marine life of the area under study.

Dose rates are calculated through average concentrations of radionuclides in seawater and sediments that are given in the given Table 2.

TABLE 2. Average activity concentration of radionuclides in sea water and sediments

Radionuclide	Average activity concentration in sea water (Bq/L)	Average activity concentration in sediment (Bq/kgd)
K-40	14.43	539.36
Ra-226	0.4	23.98
Ra-228	0.51	21.21
Cs-137	0.03	1.3

Radiological risk assessment for fish at manora channel

Radiological risk assessment in croaker (*Nibea* spp.)

Croaker (*Nibea* spp.) is a ray-finned fish of family *Sciaenidae*. The name croaker are expressive of the noise that the fish makes by vibrating strong muscles against the swim bladder, that acts like a hollow chamber like a drum. They are benthopelagic fish of shallow waters and evade brackish conditions. They have traditionally been used for food.

Total gamma dose to Croaker *(Nibea* spp) as calculated through ERICA tool at Tier-II presented in Table 3 due to ^{137}Cs, ^{40}K, ^{226}Ra and ^{228}Ra come out to be 0.0002, 0.0582, 1.1158 and 0.0070μGy h^{-1} respectively. Total Dose rate due to all these radionuclide is 1.1811μGy h^{-1}or 0.0011811 mGy h^{-1}. Risk Quotient to *Nibea Spp.* is 0.1181 that is less than the recommended value 1 showing no poisonous effects of radioactivity for this fish.

Radiological risk assessment in black sea bream (*Spondyliosoma cantharus*)

Black Sea bream (Spondyliosoma cantharus) of family Sparidae. They are identified by oval compressed body and jaws containing 4-6 rows ofslender teeth. They are silver in color with blue and pink dashes and broken longitudinal gold lines.

TABLE 3. Gamma dose rate for *Nibea Spp.*

Isotope	External dose rate [μGy h^{-1}]	Internal dose rate [μGy h^{-1}]	Total dose rate [μGy h^{-1}]	Total dose rate per organism [μGy h^{-1}]	Risk quotient
Cs-137	0.0002	1.19E^{-05}	0.0002	1.18	0.118
K-40	0.0264	0.0318	0.0582		
Ra-226	0.0118	1.1040	1.1158		
Ra-228	0.00564	0.0014	0.0070		

Total gamma dose to Black Sea Bream *(Spondyliosoma cantharus)* as calculated through Erica tool at Tier-II due to ^{137}Cs, ^{40}K, ^{226}Ra and ^{228}Ra is 2.13 x 10^{-05}, 0.0251, 1.0941 and 0.0017 μGy h^{-1}, respectively. Total Dose rate due to all these radionuclide is 1.1208 μGy h^{-1} or 0.00112 mGy h^{-1} presented in Table 4. Risk Quotient to *Spondyliosoma cantharus* is 0.1121 i.e. below 1 signifying no harmful effects of radioactivity for this fish.

TABLE 4. Gamma dose rate to *Spondyliosoma cantharus*

Isotope	External dose rate [μGy h^{-1}]	Internal dose rate [μGy h^{-1}]	Total dose rate [μGy h^{-1}]	Total dose rate per organism [μGy h^{-1}]	Risk quotient
Cs-137	8.7E^{-06}	1.26E^{-05}	2.13E^{-05}	1.1208	0.1121
K-40	0.0013	0.0238	0.0251		
Ra-226	0.0004	1.0936	1.0941		
Ra-228	0.0002	0.0013	0.0017		

Radiological risk assessment in queen fish *Scomberoides lysan*

Queen fish *(Scomberoides lysan)* is a game fish. It is benthic fish ranges present in Indian, Pacific Oceans and Arabian Sea. They are silver in color, with dark coloration on the dorsal and caudal fins. Queen fish eat small crustaceans, crabs, and fishes.

Total gamma dose to queen fish (*Scomberoides lysan*) as calculated through ERICA tool at Tier-II due to ^{137}Cs, ^{40}K, ^{226}Ra and ^{228}Ra is 2.13 × 10^{-05}, 0.0267, 1.0941 and 0.0017 μGy h^{-1}, respectively (Table 5). Total Dose rate due to all these radionuclide is 1.1225 μGy h^{-1}or 0.00112 mGy h^{-1}. Risk quotient to *Scomberoides lysan* calculated through ERICA tool is 0.1122 which is below 1 that shows there is no deleterious effect of radioactivity for this fish.

TABLE 5. Gamma dose rate to *Scomberoides lysan*

Isotope	External dose rate [μGy h^{-1}]	Internal dose rate [μGy h^{-1}]	Total dose rate [μGy h^{-1}]	Total dose rate per organism [μGy h^{-1}]	Risk quotient
Cs-137	8.7E^{-06}	1.26E^{-05}	2.13E^{-05}	1.1225	0.1122
K-40	0.0013	0.0254	0.0267		
Ra-226	0.0004	1.0937	1.0940		
Ra-228	0.0003	0.0013	0.0016		

Radiological risk assessment in silvery grunter *Pomadasys argyreus*

Silvery grunter (*Pomadasys argyreus*) is found in the Indian ocean and western pacific, where they live in brine, salty and freshwater habitats. This has large eyes, a flat ventral profile and a large caudal fin. These are is silver in color.

Total gamma dose to silvery grunter *(Pomadasys argyreus)* as calculated through ERICA tool at Tier-II due to ^{137}Cs, ^{40}K, ^{226}Ra and ^{228}Ra come out to be 2.13 x 10^{-05}, 0.0300, 1.0941 and 0.0017 µGy $h^{-1,}$ respectively (Table 6). Total Dose rate due to all these radionuclide is 1.1257 µGy h^{-1}or 0.0011257 mGy h^{-1}. Risk quotient to *Pomadasys argyreus* is 0.1126 which is far below 1 which reveals that there is no evidence of deleterious effect of radioactivity for this fish.

Table 6. Gamma dose rate to *Pomadasys argyreus*

Isotope	External dose rate [µGy h^{-1}]	Internal dose rate [µGy h^{-1}]	Total dose rate [µGy h^{-1}]	Total dose rate per organism [µGy h^{-1}]	Risk quotient
Cs-137	8.7E^{-06}	1.26E^{-05}	2.13E^{-05}		
K-40	0.0013	0.0286	0.0300		
Ra-226	0.0004	1.0937	1.0940	1.1257	0.1126
Ra-228	0.0003	0.0014	0.0017		

Radiological risk assessment for zooplanktons

Radiological risk assessment in acrocalanus spp.

Zooplankton are heterotrophic planktons. Zooplanktons is usually microscopic, but some are larger and visible. Although zooplanktons are primarily transported by water currents, many of them have locomotion that is used to avoid predators or to increase prey encounter rate.

Total gamma dose to zooplanktons as calculated through Erica tool at Tier-II due to 137Cs, 40K, 226Ra and 228Ra come out to be 0.000427, 0.035594, 1.183004 and 0.006869 respectively (Table 7). Total Dose rate due to all these radionuclide is 1.226 µGy h-1 or 0.001226 mGy h-1. Risk Quotient to zooplanktons calculated in Erica tool is 0.1226 which is lesser than 1 that indicates insignificant effect of radioactivity for zooplanktons.

Comparison of risk quotients due to radionuclides to different fish spp. and zooplanktons of Manora Channel is shown in Figure 1.

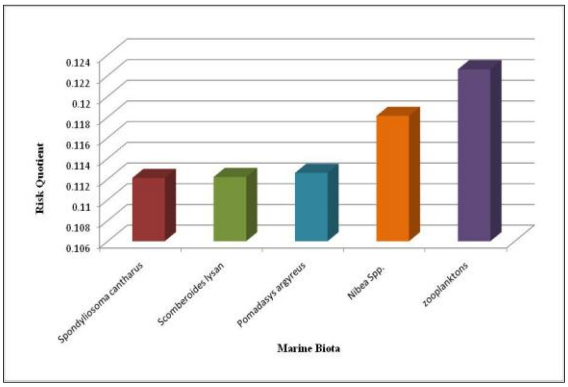

Figure 1. Risk quotient to marine biota of Manora Channel

Table 7. Gamma dose rate to *Acrocalanus spp.*

Isotope	External dose rate [µGy h^{-1}]	Internal dose rate [µGy h^{-1}]	Total dose rate [µGy h^{-1}]	Total dose rate per organism [µGy h^{-1}]	Risk quotient
Cs-137	1.05E^{-05}	0.0002	0.0001		
K-40	0.0032	0.0120	0.0151		
Ra-226	0.0004	1.1143	1.1148	1.1313	0.1131
Ra-228	0.0003	0.0009	0.0011		

CONCLUSION

The present study was focused on baseline data for radiological risks assessment and calculation of total dose to marine biota along Manora Channel Karachi coast. The dose rates to species studied were clearly below the screening level of 10 mGy h^{-1}, indicating no significant impact of the radionuclides on these species. According to the Tier 2 assessment, there is less than a 5% probability that the absorbed dose rate to any organism, in this assessment, exceeds the screening dose rate. Since this first of its kind systematic study of coastal areas of Pakistan, it appears appropriate to extend such work to measure the radiological risk assessment of radionuclides to marine biota of entire coastal zone of Pakistan in order to assess the suitability of the resources for use by human being.

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Persian Abstract

DOI: 10.5829/idosi.ijee.2015.06.03.09

چکیده

منابع رادیواکتیو در محیط های آبی شامل رخداد رادیونوکلیدهای طبیعی، ذرات پرتوزا از جو و پساب رادیو اکتیوی که از تاسیسات هسته ای به طور تصادفی یا به طور معمول آزاد می شوند، می باشند. بسته به عنصر و فرم شیمیایی اش، پرتوزا ممکن است در رسوبات قسمت پایین ستون آب انباشته شوند و یا در آن بصورت محلول باقی بمانند. موجودات زنده ی دریایی در معرض تابش های خارجی از رادیونوکلیدها در آب و رسوب قرار دارند. خطر رادیولوژی برای ماهی های دریایی که در معرض ^{137}Cs، ^{226}Ra، ^{228}Ra، ^{40}K در امتداد کانال Manora ساحل کراچی پاکستان قرار دارند با استفاده از نرم افزار اریکا ارزیابی شده است. ابزار اریکا یک سیستم نرم افزاری است که دارای یک ساختار بر اساس رویکرد یکپارچگی اریکا می باشد که برای ارزیابی خطر رادیولوژی زمینی، آب شیرین و زندگی گیاهی و جانوری دریایی است. نتایج رابطه ی ۱ و رابطه ی۲ که براساس غلظت محیط کشت و با استفاده از محدوده غلظت محیط کشت زیست محیطی پیش محاسبه شده می باشند که به منظور برآورد بهره خطر محاسبه شدند. اگر مجموع بهره کمتر از یک باشد میتوان مطمئن بود که احتمال خطر خیلی پایین است که میزان دوز به هر موجود زنده بیشتر از میزان دوز های افزایشی غربالگری ارزیابی شده است و در نتیجه خطر برای موجودات زنده غیر انسانی را می توان قابل اغماض در نظر گرفت. بهره ی خطر در این پژوهش بسیار کمتر از ۱ می باشد که نشان دهنده این است هیچ شواهدی از اثر مضر رادیونوکلئید برای موجودات زنده ی دریایی در منطقه مورد مطالعه وجود ندارد.