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Radioactive Contamination Factor (RCF) Obtained by Comparing Contaminant Radioactivity (^{137}Cs) with Natural Radioactivity (^{40}K) in Marine Sediments Taken up from Mexican Sea Waters

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Abstract

Radioactive contamination at planet scale started in 1945 when the first nuclear taste was performed in Alamo Gordo, New Mexico, followed by two war actions in Japan, a second test in Bikini, and more than 2000 tests were performed all over the world by different countries since then on. In this context, 10 main accidents in power and research nuclear reactors seem to be negligible in the general radioactive contamination at planet scale, which can be measured by comparing radioactivity of fission product ^{137}Cs with that of natural ^{40}K, both detected from marine sediments taken up at different places and depth. This paper shows 9 results obtained from Gulf of Mexico samples and one from Pacific North ocean, confirming the fact that this simple method works well enough to keep watching the process of radioactive contamination on earth, whatever may be the cause, to prove if it remains constant for a time, by equilibrium between contamination and decaying of ^{137}Cs, it is decreasing at same rate than ^{137}Cs radioactive decaying, or by the contrary, it is growing up and approaching at some extent the natural radioactivity from ^{40}K.

Keywords

Radioactive, Contamination, Factor, Sea, Sediments

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1. Introduction

This research work started 2 years ago, with a very limited number of 3 samples [1]-[3], as a consequence of a first work about radioactivity in sea water salts [4]. Since then, the general aim is to establish one radioactive contamination factor (RCF) in many places as possible from world's marine sediments; it has been increased to 10, all of them in Mexican coasts. The reason for this scarcity is of course always present difficulties in oceanography research, even when the results obtained are enough encouraging in the sense that today radioactive contamination, at least in Mexican waters, shows minimal values compared to natural radioactivity, but additionally and not less important, is the fact that we dispose now with one suitable indicator to evaluate some future radioactive contamination at planet scale, no matter what source might be. However, these results might acquire greater interest, only if they are compared with those obtained by other countries, in samples taken up from a large number of sites, as much as possible, and very well distributed all over the sea surface, which represents about 80% of that of entire planet.

2. Experimental

Samples of marine sediments were taken up along the Gulf of Mexico coasts, from north to southeast, about 60 - 150 km out of sea, at 50 - 2500 m depth (**Figure 1**). Situation of sampling were quoted, and samples were dried out in the laboratory by heating them on a flat recipient. They were ground in a glass mortar, conditioned in Marinelli containers and carefully weighed, in order to be detected by 12 - 24 hours in one low background semiconductor HPGe detector, coupled to a PC charged with Maestro program II of radioactive detection, in which background counts had been previously detected at same time span than samples. Radioactive contamination factor (RCF) has been obtained as percentage of contaminant radioactivity from ^{137}Cs (662 keV γ rays), related to that of natural radioactivity from ^{40}K (1462 keV γ rays), both expressed as Bq/g. In this way, RCF is established as follows: RCF = Bq ^{137}Cs × 100/Bq ^{40}K. In this equation ^{40}K radioactivity is the total one (11% EC γ rays ^{40}K-^{40}Ar + 89% β^- particles ^{40}K-^{40}Ca). So, counts obtained from γ spectra have been divided by 0.11.

3. Results

Table 1 shows the 10 more significant accidents happened till now in the whole history of nuclear reactors.

Figure 2 shows the background radioactivity in our HPGe detector.

Figure 3 shows the spectrum of ^{137}Cs and ^{60}Co known activities in an epoxy matrix conditioned in a Marinelli container, used to obtain the efficiency in our detection conditions for γ rays emitted by ^{137}Cs (0.45%).

Table 1. Ten more significant accidents in nuclear instalations.

Windscale, United Kingdom, October 1957. **Level 5. Fire in one from two nuclear reactors provokes radiation release. 518 square kilometers are contaminated. Crops and cattle must be sacrificed. 33 dead persons by cancer attributed to over dose radiation.**	Ural Mountains, URSS, October 1958. **Radioactive wastes explosion in a soviet nuclear weapons factory, near the city of Kyshtym. More than 10,000 persons are evacuated by authorities. No fatalities reported.**
Three Mile Island, USA, March 1979. **Level 7. Partial nuclear fusion in one from two reactors caused by overheating. Radioactive water and gases are released. 140,000 persons are evacuated by authorities. This is the worst nuclear accident in the country.**	**Chernobyl, Ukraine, April 1986.** Level 7. Explosion of a nuclear reactor caused by overheating. Fission products spread out in atmosphere. This is the worst nuclear accident in the country, and probably in the world. Estimated fatalities are 16,000 persons.
Tokaimura, Japan, March 1997. **Fire and explosion caused by a leak. At least 35 workers are contaminated.**	**Tokaimura, Japan, September 1999.** Level 5. Human mistake provokes out of control nuclear chain reaction in a processing uranium factory. Two fatalities reported and 50 persons received overdose radiation, while 300,000 plus residents were confined indoors.
Blayais, France, December 1999. **Level 2. Nuclear installation over flooded during one storm. Water excess interrupted automatically the operation of 4 reactors cooling water pumps. Partial melting of nuclear fuel. No fatalities reported.**	**Mihama, Japan, August 2004.** 4 fatalities and 7 burn injured workers by a leak in a nuclear plant.
Kashiwazaki, Japan, Jul 2007. **Earthquake 6.8° Richter provokes fire, water and radioactive gases release. No fatalities reported. However, the plant is closed to verify security systems.**	**Fukushima, Japan, Mar 2011.** Level 6. Earthquake followed by tsunami provokes failure in cooling water pumps of reactors. Radioactive water and gas are released to atmosphere. Residents around 32 square kilometers are evacuated. No fatalities by radiation overdose reported.

Figure 1. Map of sites where marine sediments samples where taken up.

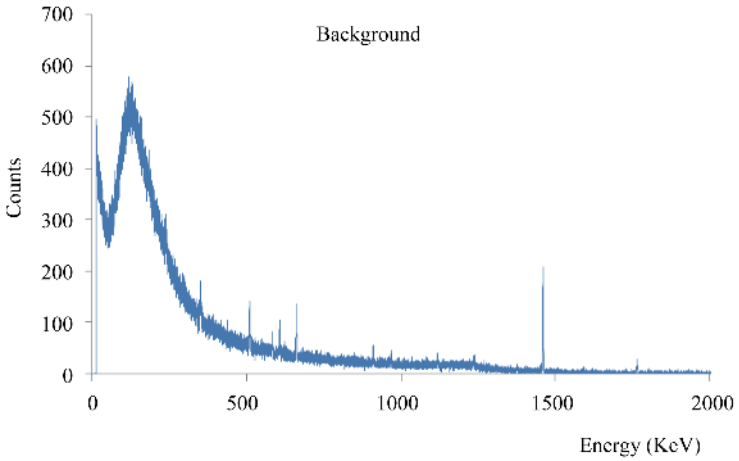

Figure 2. Background spectrum in HPGe detector.

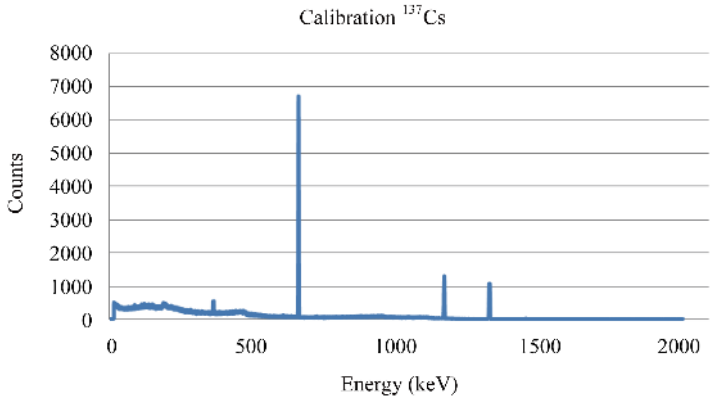

Figure 3. Calibration spectrum with standard sample (^{137}Cs + ^{60}Co).

Figure 4 shows the spectrum of ^{40}K known activity in a weighed sample of KCl conditioned in a Marinelli container, used to obtain the efficiency in our detection conditions for γ rays emitted by ^{40}K-^{40}Ar (0.22%).

Figure 5 shows the superimposed spectra of 7 sediment samples taken up during the last campaign.

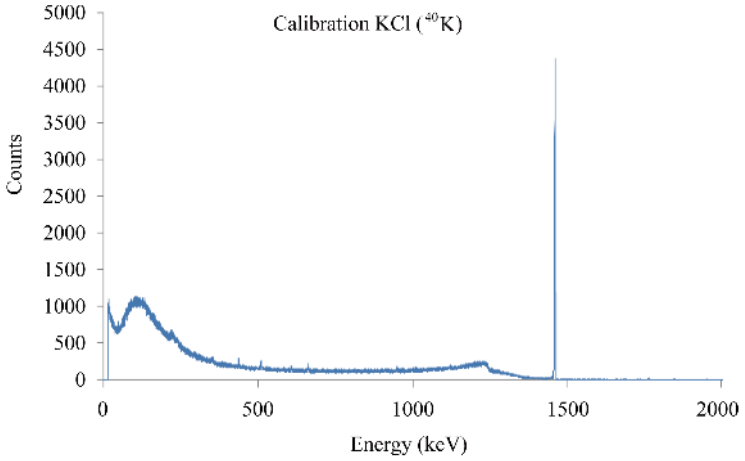

Figure 4. Calibration spectrum with a KCl sample (^{40}K).

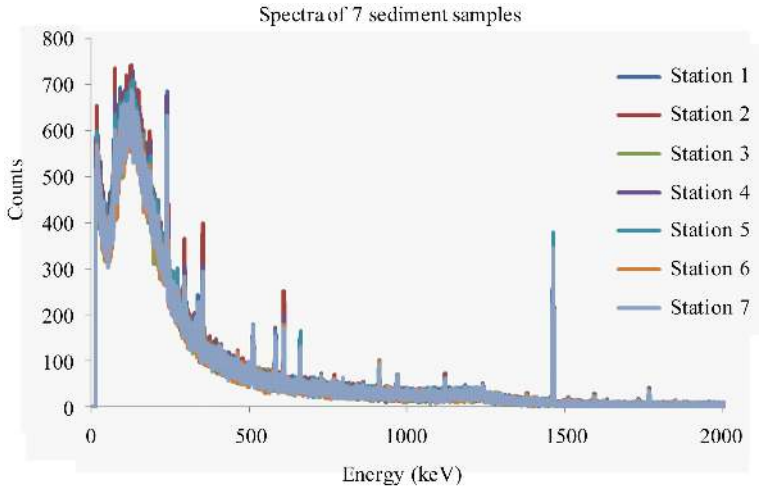

Figure 5. Superimposed spectra of 7 sediment samples.

Table 2 shows RCF values for ten samples treated till now (7 in last campaign and 3 in previous one).

4. Discussion and Conclusions

In our samples we found one very small peak of ^{208}Tl, (2614 keV, half life 3.1 m), and some other small peaks of radioactive heavy metals, members of the radioactive chain of ^{232}Th (half life 1.4×10^{10} years), which is evidence of the presence of ^{228}Ac (1459 keV, half life 6.1 hours). So, peaks of ^{40}K and ^{228}Ac should not be distinguishable [5]. However, counts from ^{40}K have always been 10 - 15 times larger, and then in the ratio of contaminant vs. natural radioactivity, this tiny contribution goes into the ^{40}K natural one. Therefore, it seems that marine sediments represent the most suitable type of sample to measure the radioactive contamination at planet scale, by means of RCF, since the sea occupies the greatest portion of earth surface. One sediment taken up from Mexican lake (Avandaro) has been treated also at same conditions with marine ones, but has not been found in neither ^{40}K nor ^{137}Cs [3]. Therefore, it also seems that marine sediments are contaminated at present by more than 2000 nuclear tests performed in the world since 1945, while 10 significant nuclear reactors accidents happened in the last 50 years represent just a negligible contribution to radioactive contamination at planet scale. Moreover, these accidents happened till now confirmed the statistical results obtained by Rasmussen report in 1976 [6], which predicts that danger imposed by nuclear research and power reactors is definitely smaller than those caused by a lot of human activities, such as cars and airplanes circulation, fires, high voltage, dams, and of course air and water contamination, as well as natural disasters, such as earthquakes, rays, tsunamis and floods.

Table 2. RCF values for ten sediment samples in Mexican sea waters.

	Location	Latitude N	Longitude W	% RCF
Station 1	Northern Gulf of Mexico	25˚51'06"	96˚12'00"	0.73
Station 2	Northern Gulf of Mexico	25˚51'06"	95˚49'00"	1.17
Station 3	Northern Gulf of Mexico	25˚51'06"	95˚25'00"	1.21
Station 4	Northern Gulf of Mexico	25˚19'48"	96˚20'00"	0.79
Station 5	Northern Gulf of Mexico	25˚19'48"	96˚59'00"	1.09
Station 6	Northern Gulf of Mexico	24˚56'54"	96˚32'18"	0.58
Station 7	Northern Gulf of Mexico	24˚28'30"	95˚56'00"	0.68
Station 8*	South Eastern Gulf of Mexico	No data	No data	0.89
Station 9*	Northern Pacific Ocean	No data	No data	0.58
Station 10*	North Eastern Gulf of Mexico	No data	No data	0.93

*Three first samples.

So, it seems quite reasonable to continue this research, by taking up samples as many as possible all over the world, in order to measure the conditions of radioactive contamination at optimum scale, avoiding panic with the comprehensive fact that nuclear power installations are not an uncontrollable danger, now that nuclear energy represents the most promissory means to continue the mankind evolution. Also, the proposed high number of RCF results should lead to some suitable average, with small positive or negative variations, by no means unreliable, since everyone should be always different, due to marine currents (studied by limnology), as well as chosen depth to take up the samples.

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