InterDosi-based assessment of S-values on a voxel-based crab phantom for Cs-137, Te-132 and Co-58

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Introduction

Most uses of nuclear energy produce harmful radioactive waste. In addition, low-level radioactive by-products and waste are discharged into the environment under strict radiation protection conditions. Once in the ocean, these radioactive elements can be dispersed and diluted through various physical and chemical processes.

Protection of the environment of non-human biota from ionizing radiation has attracted and continues to attract the interest of many scientific researchers as well as several global organisations

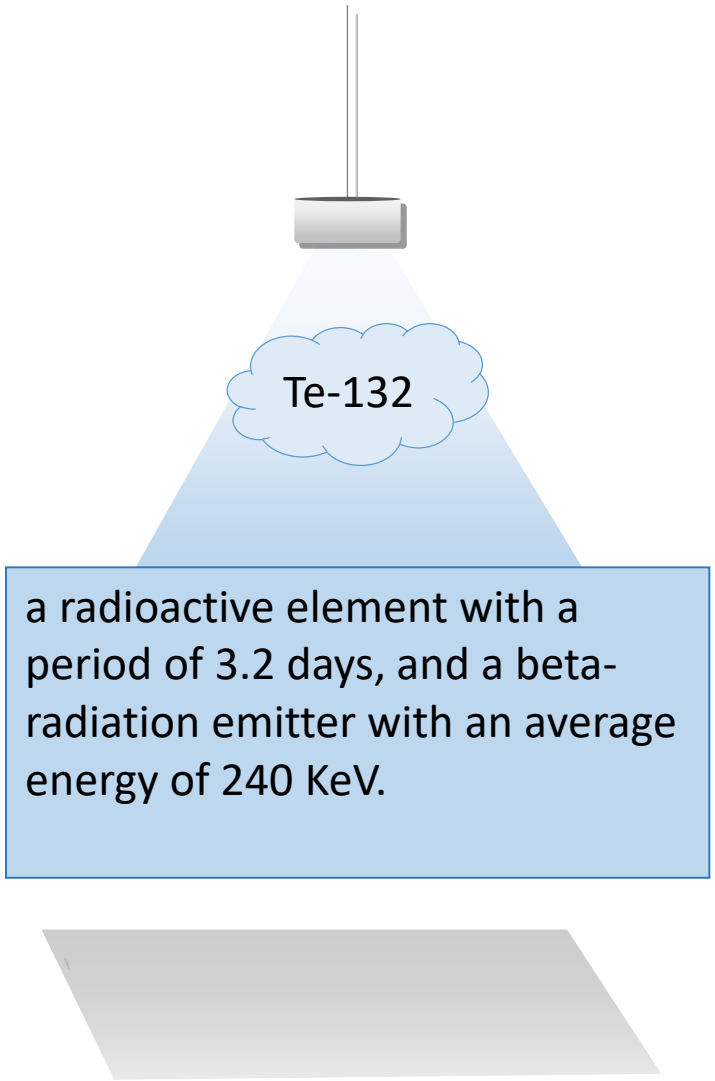
The accident at the Fukushima nuclear power plant in Japan leads to contamination of the marine environment and subsurface species, so fish may contain radioactive elements

After the accident, the immediate priority was the protection of populations rather than the protection of environmental species, for which it is not easy to control exposures.

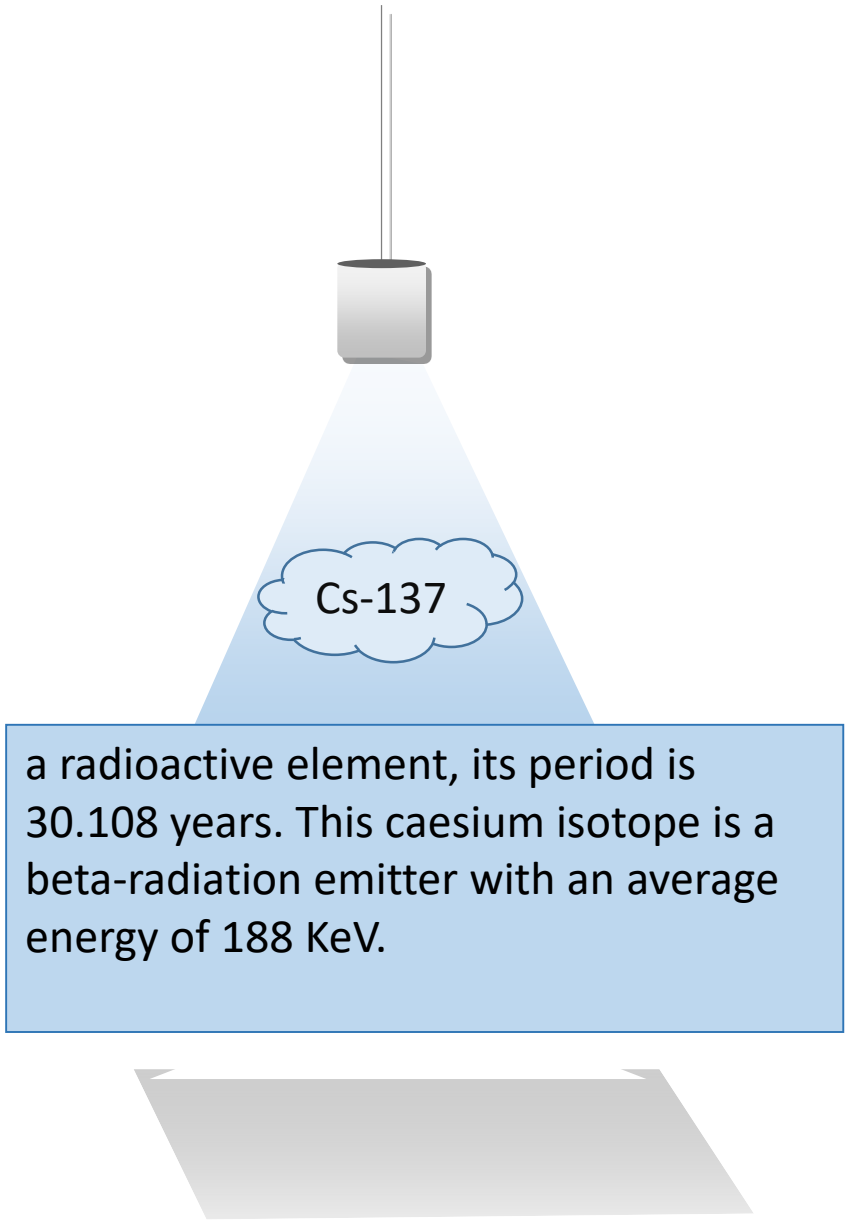
[1]

Objective

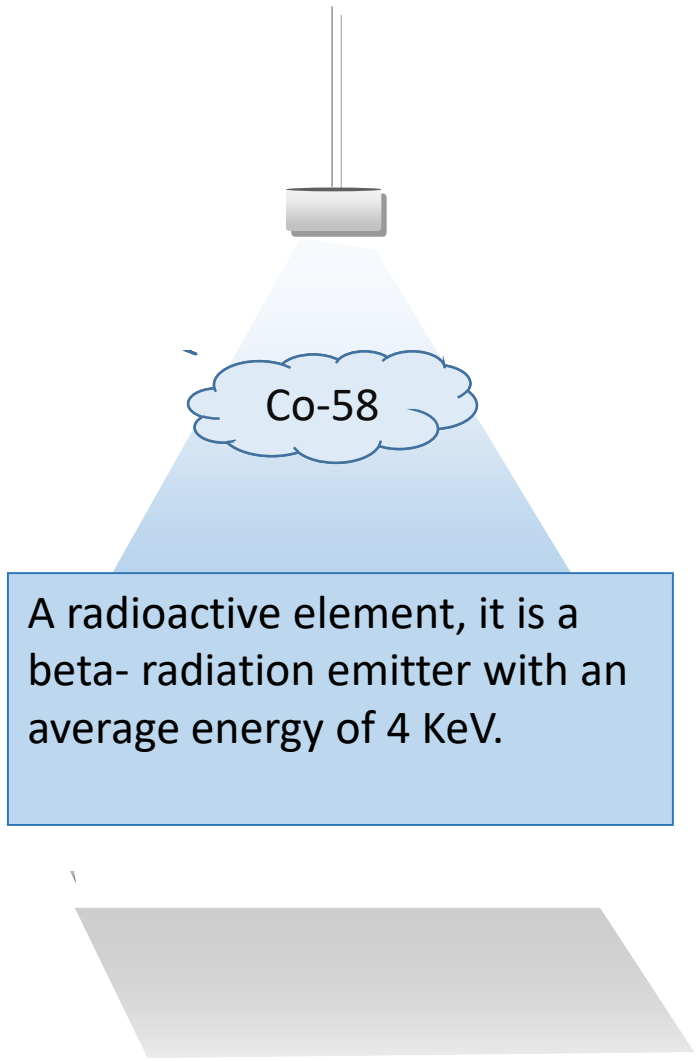
The objective of this research is to assess the radiological effects of ionizing radiation on crab identified as a biological indicator of radioactive pollution in the aquatic environment and to study the influence of radioactive waste on marine biodiversity. To do this, we conducted a study on the evaluation of S-values defined by the international organization MIRD as the key parameter for internal dose assessment. Indeed, using the Interdosi software, in the crab phantom for 3 radioisotopes Co-58, Te-132, and Cs-137 which are the main radionuclides measured in seawater, and which have been taken into account in the calculation of S values in the five main crab organs, namely: the heart, hepatopancreas, gills, gonads and carapace.



a radioactive element with a period of 3.2 days, and a beta-radiation emitter with an average energy of 240 KeV.



a radioactive element, its period is 30.108 years. This caesium isotope is a beta-radiation emitter with an average energy of 188 KeV.



A radioactive element, it is a beta- radiation emitter with an average energy of 4 KeV.

Main characteristics of radioisotopes

Internal dosimetry coefficients

Dosimetry is the quantitative determination of the dose absorbed by a biota, i.e. the energy received per unit mass after exposure to ionizing radiation.

Internal dosimetry is the calculation of absorbed dose deposited in target volumes by radiation emitted from source volumes over time as a result of accidental or medical administration of a radioactive substance

S Factor This is the mean absorbed dose DT in the target volume r T per unit of activity present in the source volume r S .
It depends on the geo-material of the volumes and physical characteristics specific to the radionuclide.

It is usually expressed in Gy. Bq-1. s -1

Internal dosimetry coefficients

$$D(\text{cible} \leftarrow \text{source}) = \tilde{A}(\text{source}) \times S\text{-value}(\text{cible} \leftarrow \text{source})$$

- $\tilde{A}$: Cumulative activity in a source (Bq.s)

01

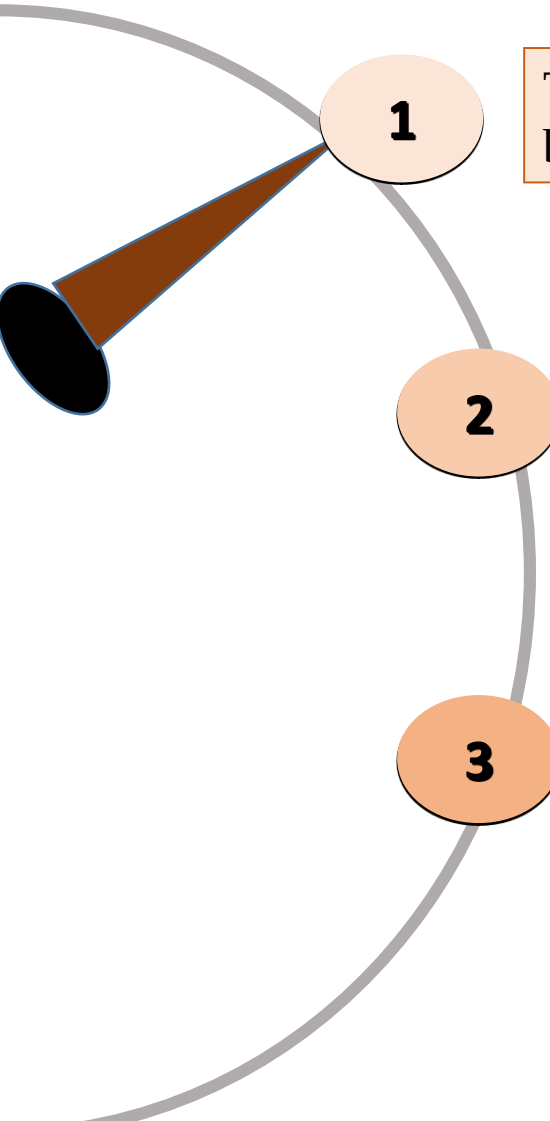
Corresponds to the number of disintegrations in the source organ during all irradiation
Biological parameter
Depends on the biokinetics of the radioisotope

02

- Calculation of the S-factor is done by Monte Carlo simulation on voxed models based on the MIRD voxel diagram.

03

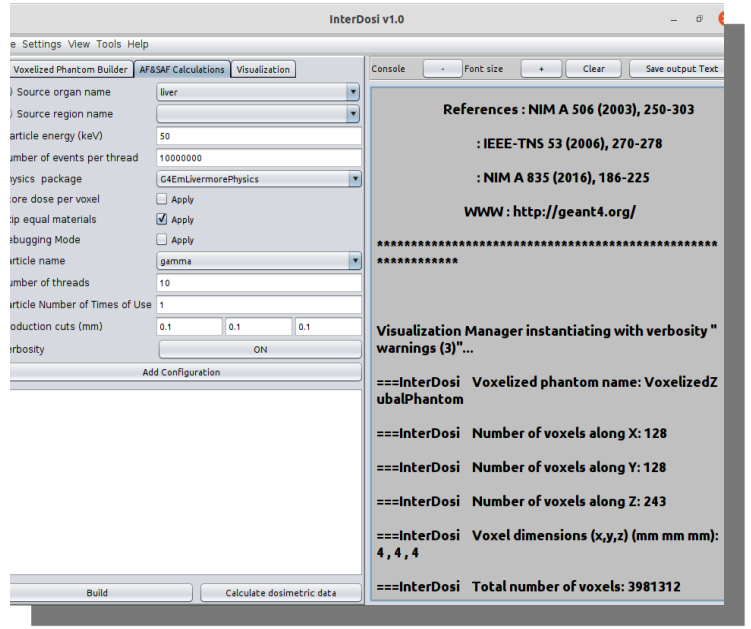
Methods and Materials



1. To estimate the S-values on a voxel-based crab phantom.

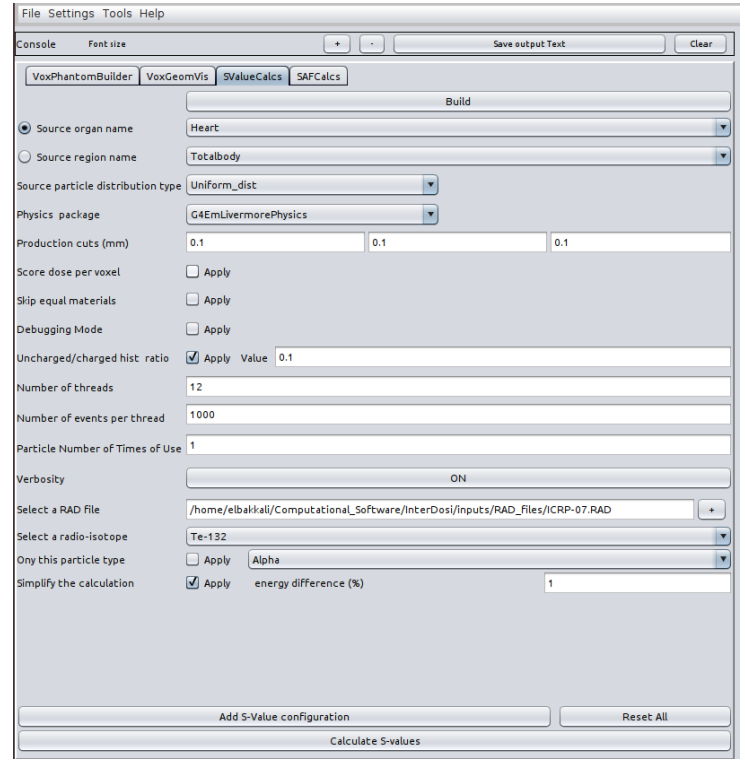
2. InterDosi code which is a Monte Carlo modeling tool specifically oriented to perform internal dosimetry studies on human phantoms and nonhuman biota based on voxels.

3. A user-friendly platform makes it possible to perform internal dosimetric studies on voxed phantoms in a simple way and in a very short time

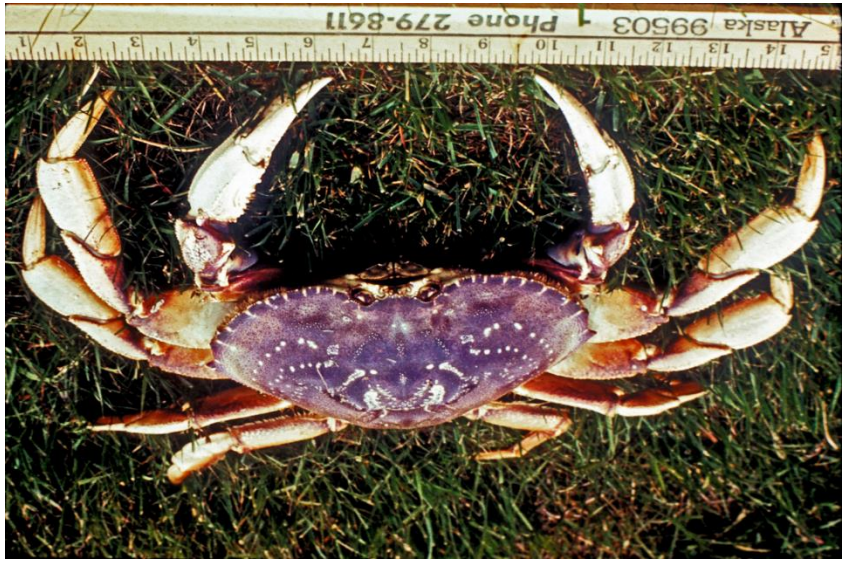


Methods and Materials

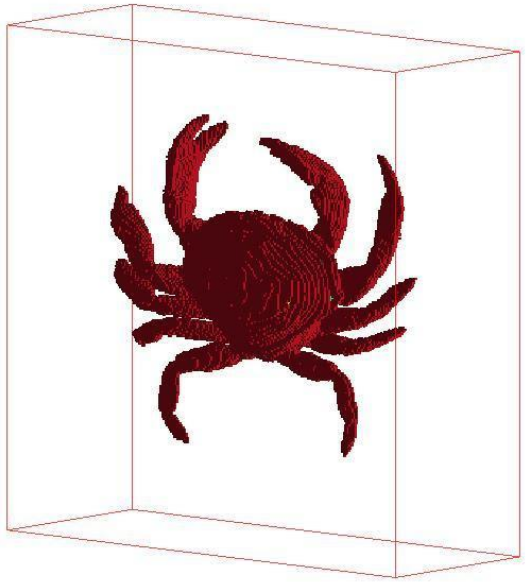
InterDosi simulations were run on 64 CPUs of the HPC-MARWAN-CNRST calculation grid. Each simulation is followed up with 10^8 for unloaded particles and 1/10 of this value for loaded particles. The calculation of the S-value has been simplified by not calculating the Absorbed Specific Fraction (FAS) for an energy if it was previously calculated for an energy that differs by less than 1%. This simplification was applied in order to accelerate the simulation



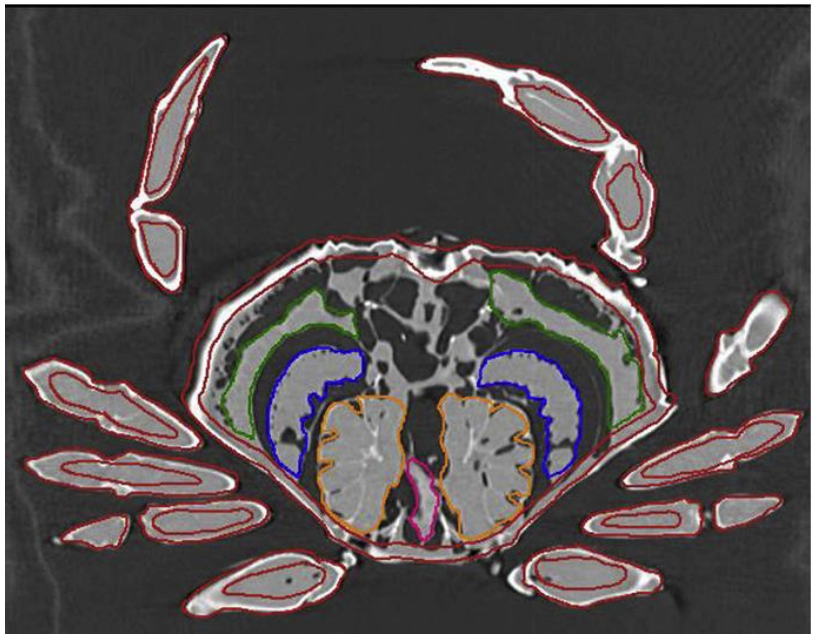
Methods and Materials



Reel Crab Image [2]



3D crab by InterDosi



scan image of crab [2]

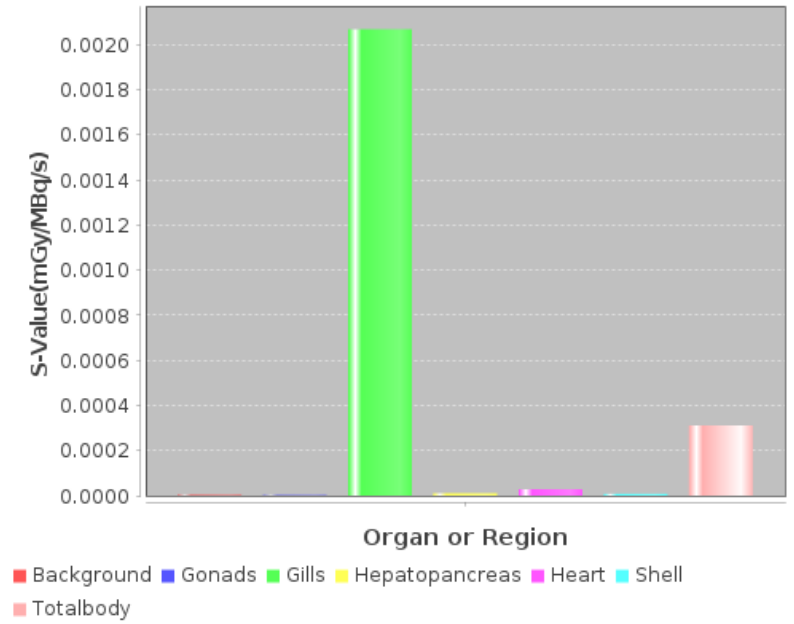
Results and discussions

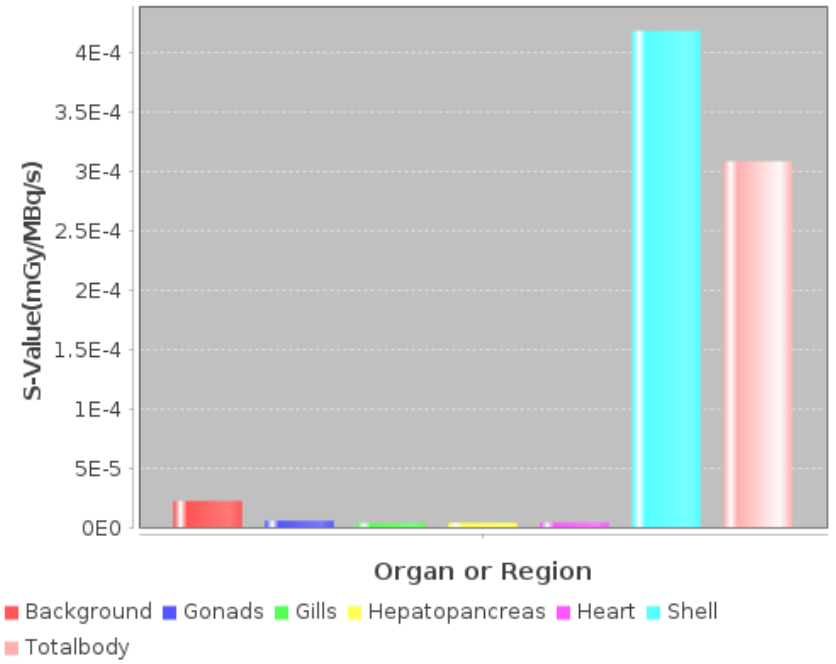
Irradiation is the deliberate or accidental exposure of an organism, substance or body to radiation. This term is particularly used when considering exposure to ionizing radiation .

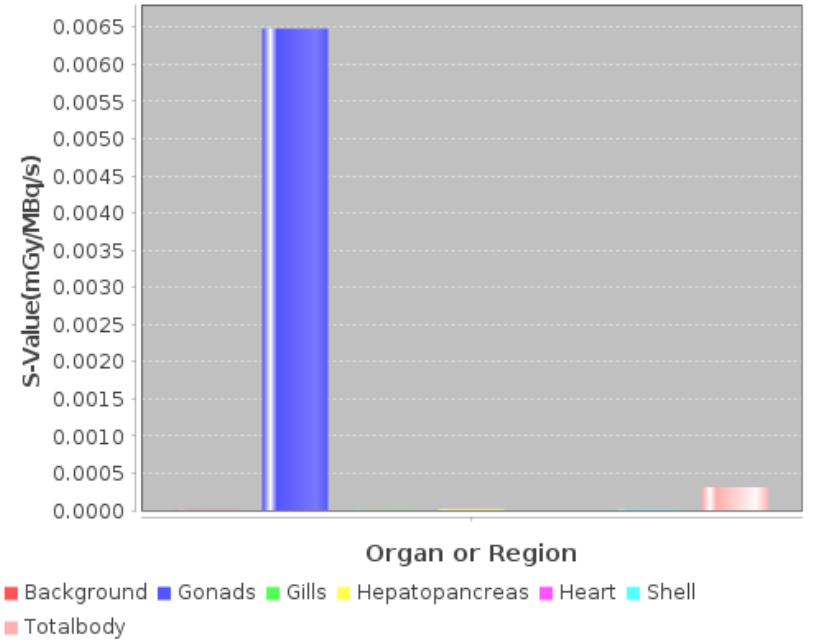
Self-irradiation

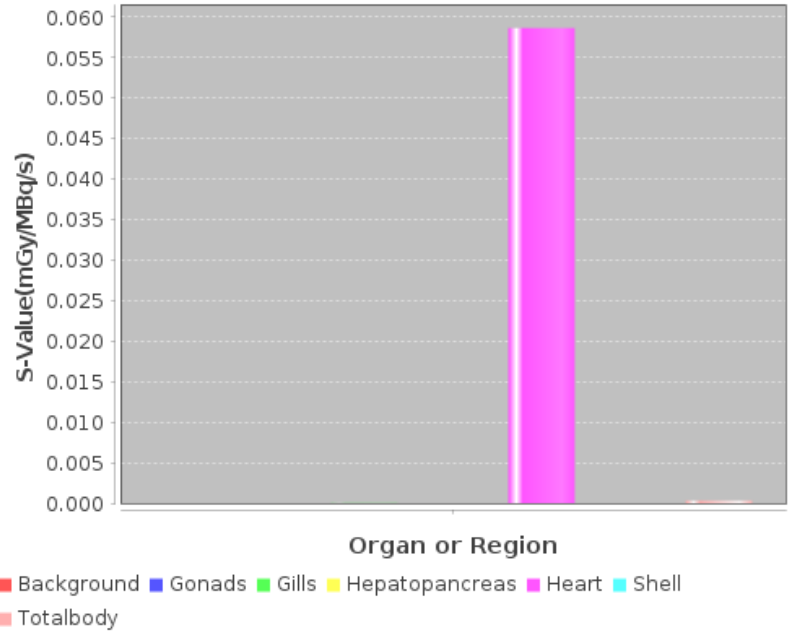
cross irradiation

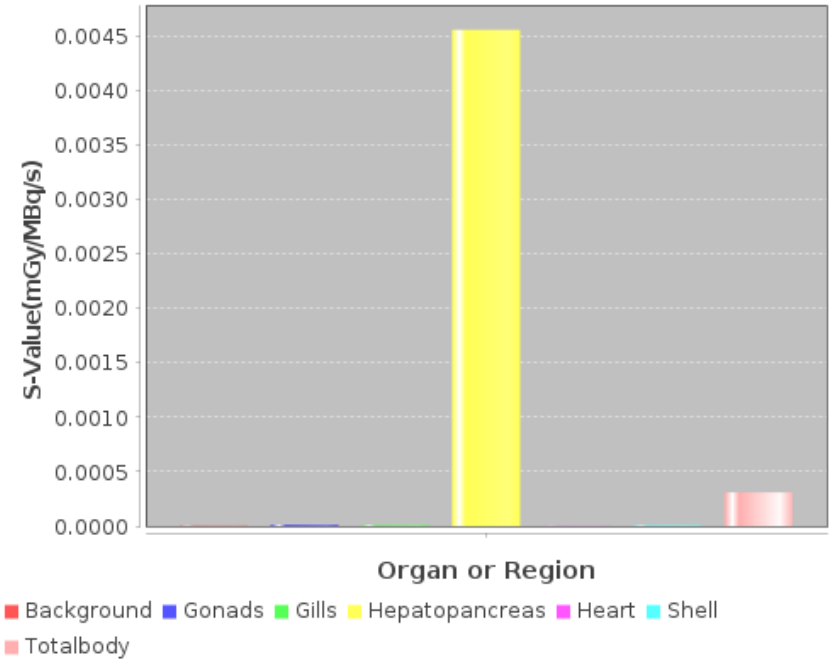
Results and discussions





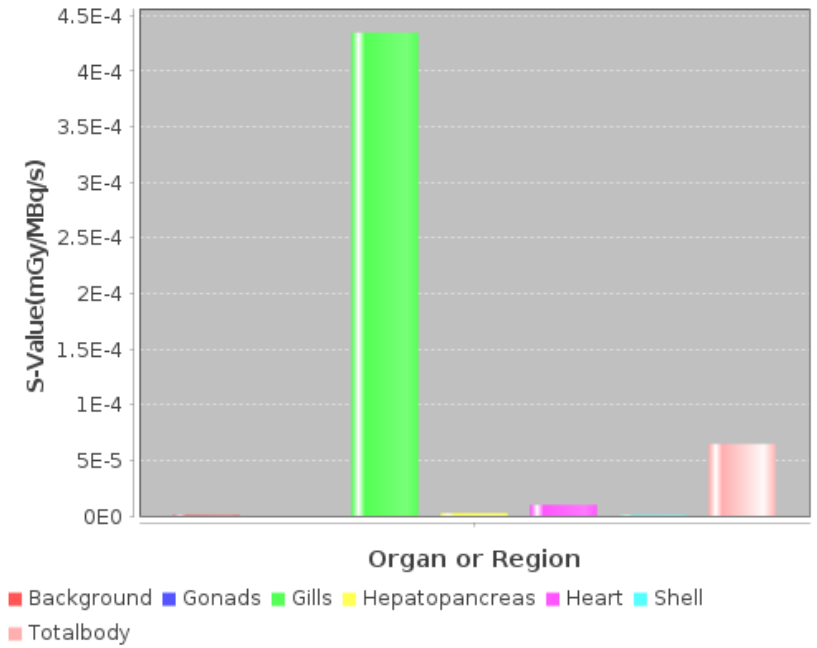


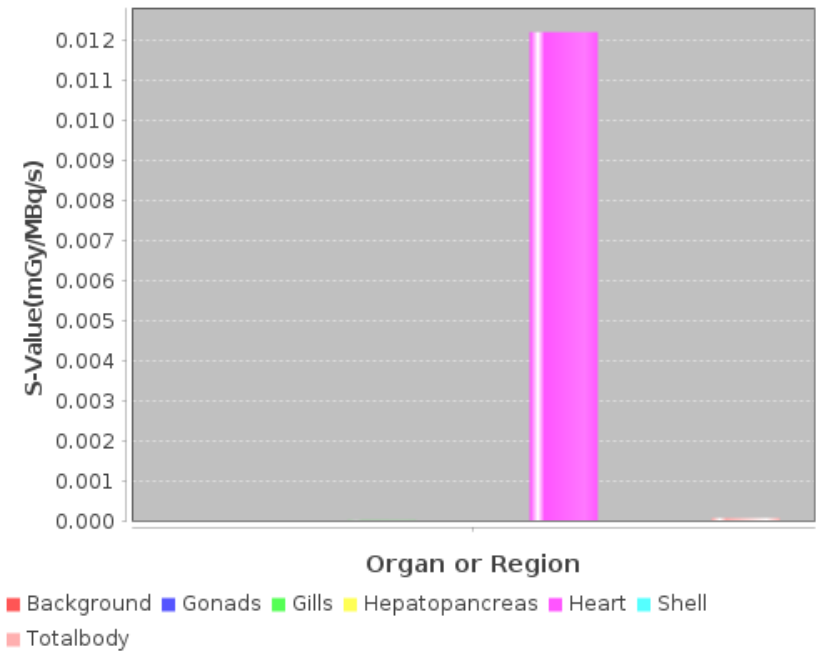


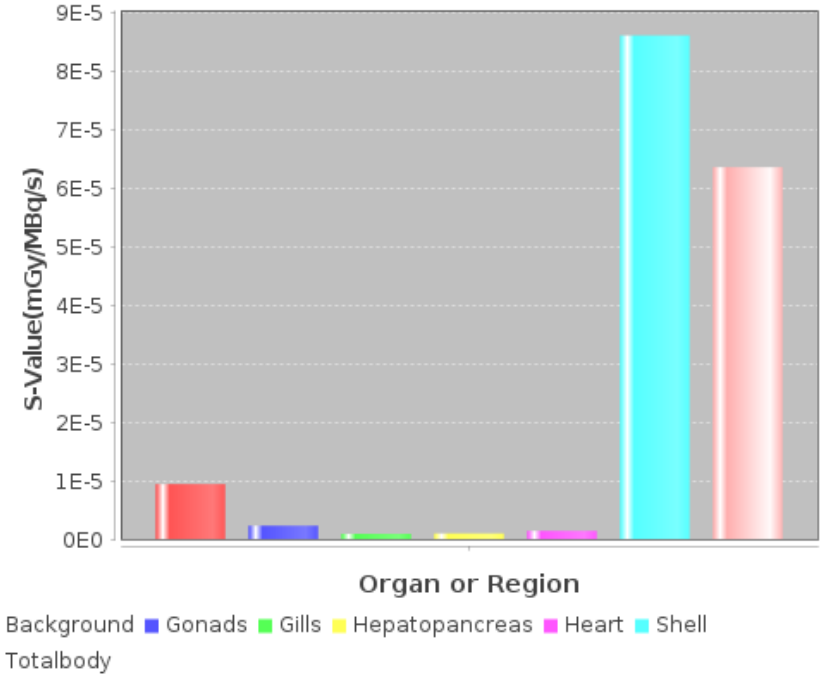


^{132}Te

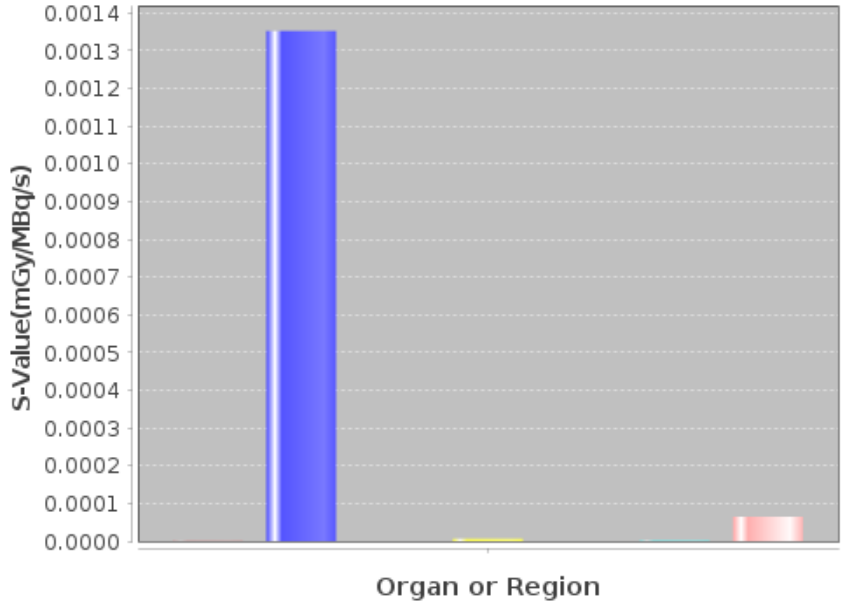
Results and discussions

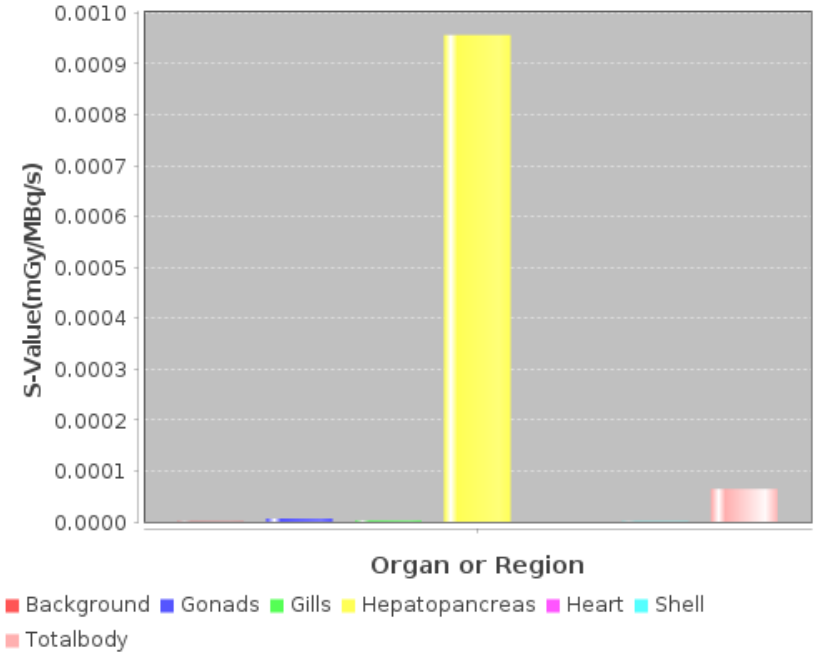




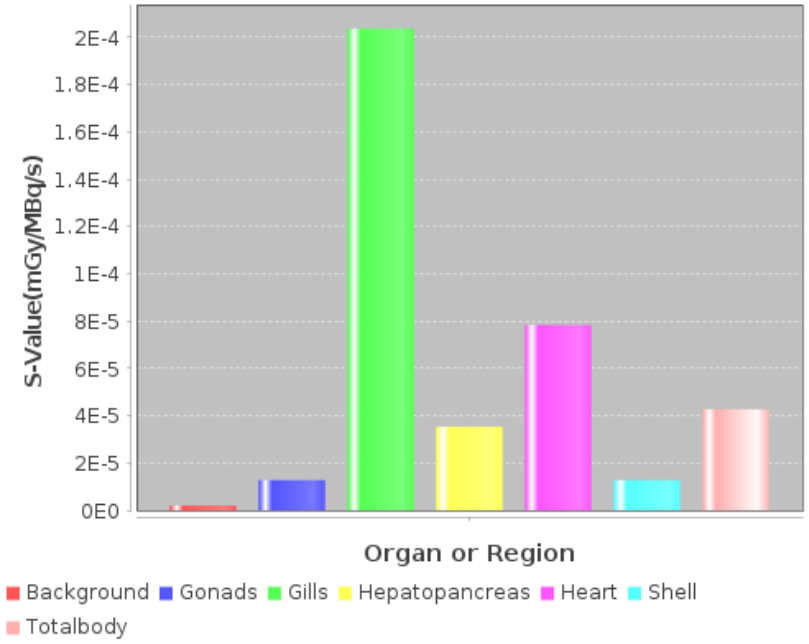


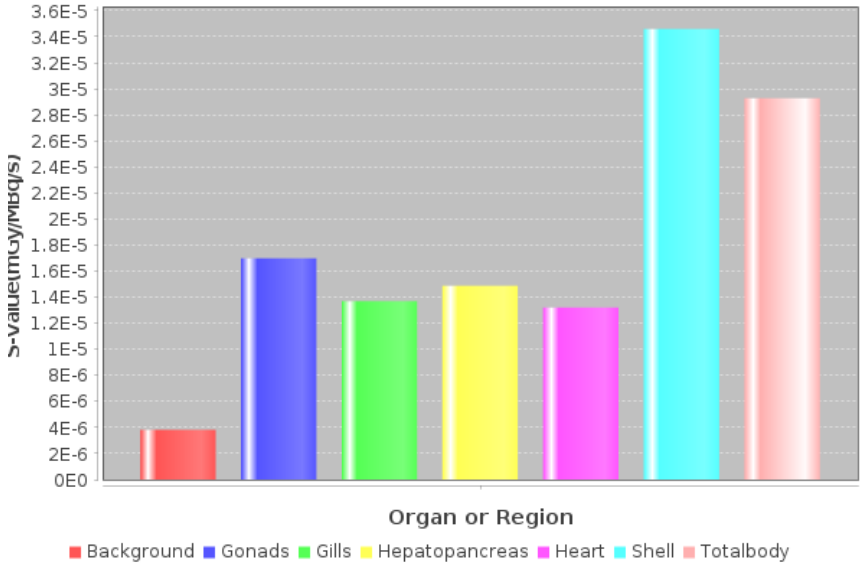
^{137}Cs

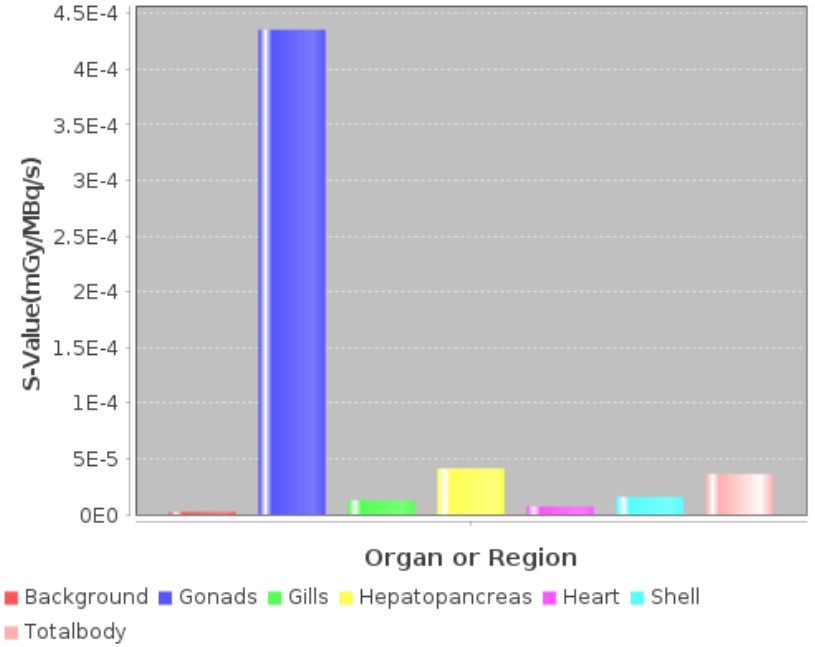


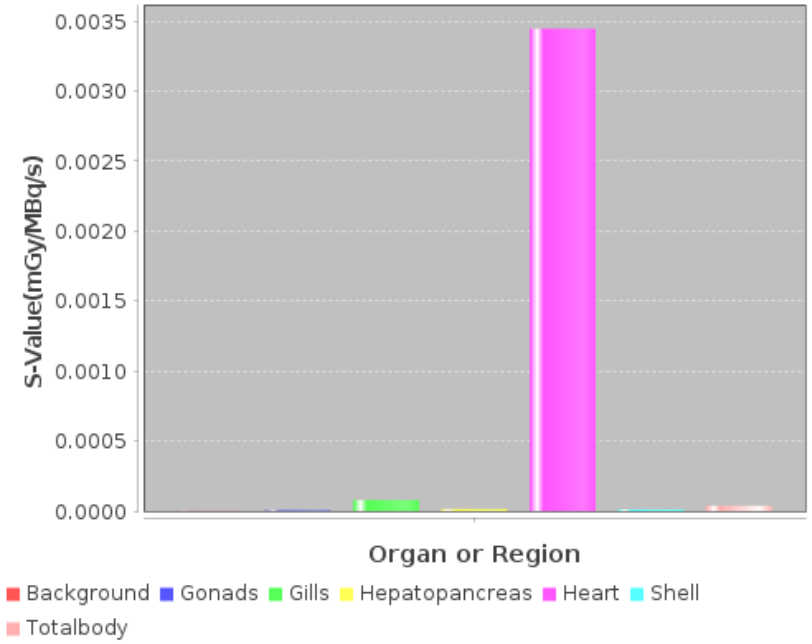


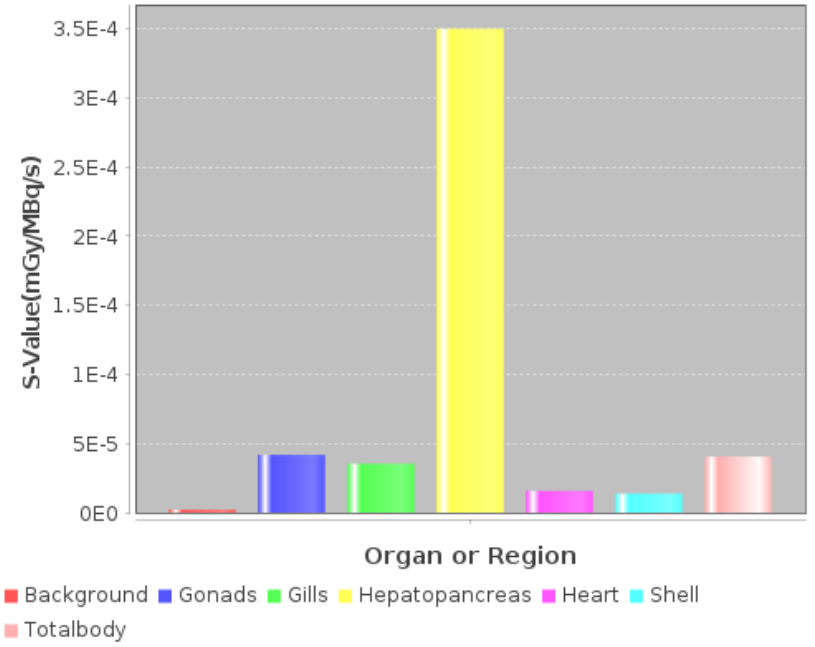
Results and discussions











^{58}Co

Results and discussions

The results showed that Te-132 produces the highest S-values on the various crab organs, followed by Cs-137 and Co-58 , this can be explained by the fact that Te-132 is the transmitter of the highest average energy beta radiation among the three radio-isotopes cited .

When the average energy of the beta radiation emitted by the radioisotope decreases, it is noted that the cross-average contribution of the S-factor increases

With regard to the biokinetics of the radioisotope based on literature:

The international scientific community agrees that cesium spreads homogeneously into muscle mass, and it may tend to concentrate in the heart muscle. The caesium is distributed in the muscles. Its biological period is 100 days, time after which it is eliminated from the body. This relatively rapid elimination reduces its harmfulness.

On the whole, the self contribution is greater in comparison with the average cross-contribution for the three radioisotopes mentioned. .

The total Monte Carlo simulation time expressed (min)

Radioisotop / Organ	^{58}Co	^{137}Cs	^{132}Te
Heart	60	49	68
Gills	60	50	69
Hepatopancrea	59	49	68
Carapace	58	44	63
Gonads	59	48	67

• total calculation time on a calculation grid having 64 CPUs. • NB: All these calculations require a huge amount of time, in fact it can reach the 40 days of continuous calculation on a single-core IT architecture.	**15h**

Results and discussions

	S-value (μGy. MBq $^{-1}$. s $^{-1}$)		
Radioisotops / organ	Te-132	Cs-137	Co-58
Heart	57	12	3,4
Gonads	6,4	1,35	0,425

Table 1: Self irradiation

Results and discussions

	S-value (μGy. MBq $^{-1}$. s $^{-1}$)		
Radioisotops / organ	Te-132	Cs-137	Co-58
Heart	58.66	12.1	3.4
Gonads	1.54	9.49×10^{-5}	7.21×10^{-3}

Table 2: Cross-irradiation of heart source

Results and discussions

Radioisotops / organ	S-value(μGy. MBq^{-1}. s^{-1})		
	Te-132	Cs-137	Co-58
Heart	**1.54**$\times 10^{-3}$	8.577×10^{-5}	7.188×10^{-4}
Gonads	6.4	1.35	430×10^{-3}

Table 3: Cross-irradiation source Gonads

conclusion

- After the calculation carried out, the results showed that Te-132 induces the highest S values on the various crab organs, followed by Cs-137 and Co-58 , this can be explained by the fact that Te-132 is the highest-energy beta transmitter of the three radioisotopes cited.
- So, this study led us to conclude that factor S depends on the characteristics of the organs, namely geometry and chemical compositions, on the other hand it depends on the physical characteristics of the radioisotope, namely the average energy of beta-radiation.
- We can conclude that in order to quantify the effects of radioisotopes in the marine environment, it is necessary to determine a value that takes into account the type of radiation and its average energy:

These efforts are devoted to the protection of the environment and to human development both in terms of environmental awareness and industrial capacity. After the accident, the immediate priority was the protection of populations rather than the protection of environmental species, for which it is not easy to control their exposures, these species directly or indirectly entering the human food chain, then, in a major concern for the radiation protection of human life, the aim of which is to prevent and limit the health risks caused by ionizing radiation whatever their origin, a limit of the activity threshold of each radioisotope must be respected.

Reference:

[1]https://www.google.com/search?q=dechet+radioactif+dans+le++milieu+marin&source=lnms&tbm=isch&sa=X&ved=2ahUKEwjcve7118fzAhUMRkEAHQM-DjMQ_AUoAXoECAEQAw&biw=1280&bih=609&dpr=1.5#imgrc=dN9eZQ5xiNutEM

[2]caffrey2013.pdf

[3] https://github.com/EL-Bakkali-Jaafar/InterDosi/blob/master/InterDosiUserManual.pdf

thank you for your attention