

Levels of cesium-137 in seawater and fish from the Brazilian coast

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ABSTRACT

Considering environmental pollution problems and their impact on man, we have developed a research programme on environment monitoring. The aim of this work was to develop and to apply radiochemical methods for the analysis of cesium-137 in marine samples, such as seawater and fish. Cesium-137 levels in surface seawater from the coastal region of São Paulo State range from 1.7 to 1.9 Bq · m⁻³. Samples of the five species of fish most consumed by local population were taken for the analysis of cesium-137. Levels for fish varied from 0.1 to 0.3 Bq · kg⁻¹ of edible part. Data were used to calculate dose assessment.

Key words: cesium-137; seawater; fish; coastal waters; Brazil

INTRODUCTION

Nuclear weapons tests, discharges of effluents from nuclear reactors, dumping operations and nuclear accidents, have introduced artificial radionuclides into the environment. Among these are cesium-137 and strontium-90. The estimates of input of the fallout cesium into the oceans are of 6.4×10^8 TBq [1]. The inputs to the oceans in the southern hemisphere have been half of those in the northern hemisphere. The artificial radionuclides could affect marine organisms and their total activity is only a very rough guide to risks [2].

Radionuclides in the sea may contribute to the internal or external exposure of organisms, including man, through several pathways. The principal pathway leading to human exposure from the occurrence of radionuclides in the marine environment is due to the consumption of seafood. A large variety of seafood is eaten, but for the purposes of dose assessment fish is the most consumed in quantity.

In the present work a search was made in order to obtain data related to

catch of fish and consumption of fish by local populations. Levels of cesium-137 in seawater and fish samples from the coastal region of São Paulo State were determined. Data obtained were used to describe the radiological situation in the area studied as well as to obtain reference levels of cesium-137 to our country. Data were used to calculate the dose assessment.

EXPERIMENTAL

Seawater samples

A series of seawater samples were collected by the Oceanographic Institute of the University of São Paulo (USP). Surface seawater samples were collected from the Atlantic Ocean offshore of São Paulo State (45° Longitude, 23° Latitude). Samples were acidified to pH 1 and stored in polyethylene containers.

Radiochemical procedure for analysis of cesium-137 in seawater

To 50 l of seawater were added 10 mg of carrier cesium. Cesium was precipitated with ammonium phosphomolybdate (AMP). The AMP was added and the solution was stirred for 3 h. The precipitate was decanted overnight. The supernatant was siphoned to a polyethylene container to the lowest possible level so that the precipitate will not be disturbed. The supernatant was reserved for strontium analysis. The solution containing the precipitate was filtered, then dried for 2 h in the muffle furnace.

The analysis was made in two samples of seawater (50 l) and both precipitates obtained in each analysis were mixed. Cesium-137 was assayed by gamma counting. The sample was counted in a plastic pot placed directly over the detector. The counting time was over 3000 min. The efficiency curve was done employing standard samples.

RESULTS

Seawater samples were collected in two different points of the coastal region of São Paulo State. The mean values found at each local are shown in Table 1. Levels of cesium-137 in seawater range from 1.7 to 1.9 Bq · m⁻³. At these points of collecting there is no nuclear power plant and nuclear testing was not carried out directly in our country. The artificial radioactivity present is only due to atmospheric fallout from nuclear weapons tests or accidents such as Chernobyl which occurred in the North hemisphere.

For cesium-137 the variation according to the site of measurement varies to such an extent that it is impossible to give representative concentrations

TABLE 1

Cesium-137 levels in seawater

	Ubatuba	São Sebastião
Latitude	23,0° S	23°50' S
Longitude	44,5° W	45°25' W
Cs-137 (Bq · m ⁻³)	1.9	1.7

of this radionuclides in the various oceans. In deep ocean water the concentration of cesium-137 [3] is generally $< 2 \text{ Bq} \cdot \text{m}^{-3}$.

In a study area in the North Pacific, 900 km southeast of Tokyo, the cesium-137 concentrations range from 4.4 to 5.1 $\text{Bq} \cdot \text{m}^{-3}$.

In the Mediterranean, cesium-137 concentrations originating from nuclear weapons tests reach 5–10 $\text{Bq} \cdot \text{m}^{-3}$ at the surface. In some closed shallow brackish-water sea areas, such as the Baltic Sea, the concentration of cesium reached 20–40 $\text{Bq} \cdot \text{m}^{-3}$. In such an area the Chernobyl accident has changed the concentration values found for cesium-137, where concentrations in the surface layers of the Baltic Sea [4] were a few to some ten times higher than before the accident; concentrations in surface waters varied between 100 and 400 $\text{Bq} \cdot \text{m}^{-3}$.

The concentrations of cesium-137 are changing from region to region. In particular, the NE Atlantic is a special case, as its situation is dynamic due to the different sources of contamination namely the reprocessing facilities and the fallout from the Chernobyl accident.

Analysis of fish

Samples of fish were obtained by means of the Fishery Institute in the southern coastal region of the São Paulo (city of Santos, 23°,52'S, 45°,50'W). Samples of muscle and bone of the species of fish most consumed by local population were taken for the analysis of cesium-137.

Sardine and ballistes sp are the two main fish resources in the region of Santos. They are caught by local fishermen and sold in the markets. The fish were purchased directly from the fishermen that know the exact sampling site. Ballistes sp is a typical fish from South America, known as 'porquinho' (little pig). The other fish analysed were weak fish (goethe), corvine and dog fish.

Muscle from 2 kg of each fish was dried in a muffle oven at 110°C for 1

week. Later, the temperature was gradually increased to 450°C until ashed. The ashe was transferred to a plastic pot and counted in a Ge-Li detector. The level of cesium-137 is expressed in terms of $\text{Bq} \cdot \text{kg}^{-1}$ of the edible part.

The cesium-137 levels found in sardine, ballistes sp and weak fish were $0.1 \text{ Bq} \cdot \text{kg}^{-1}$. In the case of corvine and dog fish, values of $0.3 \text{ Bq} \cdot \text{kg}^{-1}$ were found. Typical values for cesium-137 in deep sea fish muscle [4] are around $0.1\text{--}0.5 \text{ Bq} \cdot \text{kg}^{-1}$. In the Baltic sea concentrations of such radionuclide in the muscle of fish vary from 1 to $4 \text{ Bq} \cdot \text{kg}^{-1}$ due to global fallout [5].

Estimating dose rates

In order to estimate the world's collective dose rate from cesium-137, it is necessary to carry out a series of regional assessments because cesium-137 concentration varies from one to another. For estimating dose rates, it was necessary to obtain data relative to fish catch, consumption of fish by the local population and the average cesium-137 concentration for fish caught in each area.

The quantity of sardine caught in the Santos region is 87 000 ton and 80% are consumed as fresh fish by a population of 18 million inhabitants which includes regions from Santos to Rio de Janeiro. In the case of ballistes sp, the total fish caught is 35 000 ton and 65% are consumed. The other part is used for the preparation of animal diets.

TABLE 2

The estimation of sea food habits

Fish	Level of cesium-137 ($\text{Bq} \cdot \text{kg}^{-1}$ edible part)	Quantity of fish caught (t)	Percentage of fish consumed	Consumption per person per year ($\text{kg} \cdot \text{man}^{-1} \cdot \text{a}^{-1}$)
Sardine (<i>Sardinella Brasiliences</i>)	0.1	87 000	80%	3.87
Ballistes sp.	0.1	35 000	65%	1.26
Weak-fish (<i>Cynoscion jamaicensis</i>)	0.1	33 000	85%	1.56
Corvine (<i>Micropogonia furnieri</i>)	0.3	17 000	70%	0.66
Dog fish	0.3	9 000	90%	0.45

The total catch of weak fish is of 33 000 ton and 85% are consumed. The quantity of corvine and dog fish caught are of 17 000 ton (70% of consumption) and 9000 ton (90% of consumption), respectively. Table 2 gives the estimates on sea food habits in the studied area. The average consumption of sea fish in the area is 7.8 kg per year, based on the statistics of the total population.

Based on the radioactivity level of cesium-137 and by taking into consideration the dose conversion factor recommended by ICRP [6], we estimate the annual effective dose equivalent as $0.013 \mu\text{Sv} \cdot \text{a}^{-1}$. This value shows that the dose via ocean pathways from cesium-137 is very low compared to the dose limit ($1 \text{ mSv} \cdot \text{a}^{-1}$) recommended by ICRP to protect members of the public. The above estimation gives a rough idea of the present exposure levels in the coastal region of the São Paulo State from cesium-137.

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