Hydric resources radioactive contamination in the central region of Cuba as a consequence of fallout after the atmospheric nuclear bombs tests

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Introduction

With the birth of the nuclear era a new group of contaminants have been introduced into the atmosphere, they are the artificial radionuclides. From 1945 up to 1980, with the high scale nuclear bombs tests, more than 960 PBq of ^{137}Cs has been released into the atmosphere in 545 Mt predicted released power (UNSCEAR, 1983). Besides, the nuclear fuel cycle (mainly as a result of nuclear power plant accidents) has promoted radioactivity releases become another important source of artificial radionuclides contaminating our atmosphere.

Not all radionuclides releases in the atmosphere remain for indefinite time, their presence in the atmosphere depend upon physical-chemical properties in relation with their interaction capacity in this media. For these reasons the radioactivity releases have caused one of the greatest changes of all times in the atmosphere composition, and have brought about the contamination of almost every environmental component, not only in the testing or power plant sites, but also all around the world because of the Global Fallout.

The Cuban water masses, as well as the rest of the natural components of our ecosystems, are not free of this source of global contamination. Although the contamination coming from this source is not an imminent danger to the populations using these water, it has been seen as an increase in the radiological background of the main hydrological resources of the country. These resources are used for direct consumption, food production and irrigation of crops. Furthermore, it is perceivable the presence of artificial radionuclides in the underground waters, despite their different self-cleaning mechanisms and the slow speed of the contamination processes characterizing these water masses (CRESL, 1993; CRESL, 1994; CRESL, 1995a2,3,4,5).

The use of radioactive tracers implies the implementation and evaluation of every measurement methodology. It permits us to determine their distributions in the environment and to understand the dynamic processes that control their behavior in the environment. The *Radiological and Environmental Surveillance Laboratory* have developed a monitoring program for some environmental variables, among which the ^{137}Cs concentration in several environmental samples such as soil, grass, milk, foods, surface and underground waters and air, are measured. Therefore the natural cycle of these radionuclides has been studied thoroughly. This article main goal is to present the ^{137}Cs activity level determined in atmospheric and hydric samples, as well as some considerations about transference processes of these radionuclides throughout some environmental components.

Methods

The studied zone, was located around the Juraguá Nuclear Power Plant (Central-South region of the country, Cienfuegos province) and it was 10 000 km^2 wide. We fixed six sampling places distributed as follow: three sampling places for surface waters in the most important dams (Hanabanilla Dam, Abreus Dam and Avilés Dam), two samples places in the Juraguá water bearing for underground waters, and one place for continuous air monitoring in our laboratory.

The period of study was five years long (1994-1998). The air samples were collected weekly. Aerosol samples were collected by PRIMUS, an air pump designed in our laboratory (CRESL, 1995b). It has a 800-1400 mμ.h^{-1} air flux, a collecting area 0.65m^2 and uses a Petrianov filter (FPP-15-1.5) able to retain the particles with dimensions greater than 3mm (99%) and avoid the resuspension in dry season. Each filter was exposed for 168 hours (1200 mμ.h^{-1} air flux average), after that each samples was dry ashed and measured by gamma spectrometry. Fallout samples were collected in try covered with the same Petrianov filter. Each filter was exposed during 30 days, after that each sample was dry ashed (350 °C). Due to ^{137}Cs low level, each quarter samples xere unified and measured by gamma spectrometry.

The waters were sampled after three months and were collected in 50 l cleaned bottles (CPHR, 1990a; CPHR, 1990b; EML, 1990). To determine ^{137}Cs, 20 l samples were filtered trough a qualitative filter paper and nitric acid or hydrochloric acid up to 1.5 pH was added. To determine ^{137}Cs in water, AMP was used to concentrate it and then it was measured by gamma spectrometry. A germanium detector was used for comparative measurements: HPGe detector having 11.1% relative efficiency, geometry Hole P-Type, and energy Resolution FWHM of 2.26 keV on 1.33 MeV photopeak of ^{60}Co, (CPHR, 1990a; CPHR, 1990c; CRESL, 1995c). The pulses were analyzed with a multichannel buffer, Silena Spectrometer

System. The background contribution was reduced by surrounding the detector with 1 mm thickness copper, 5 cm thickness lead, and 15 cm thickness iron castle.

Results and discussion

Aerosols samples

Let's begin our analysis with aerosols samples, because they are the first indicator of all kind of atmospheric contamination. The ^{137}Cs and ^{7}Be concentration behavior in aerosol samples during the period of study is very regular, (Figure 1). The ^{137}Cs averaged concentration

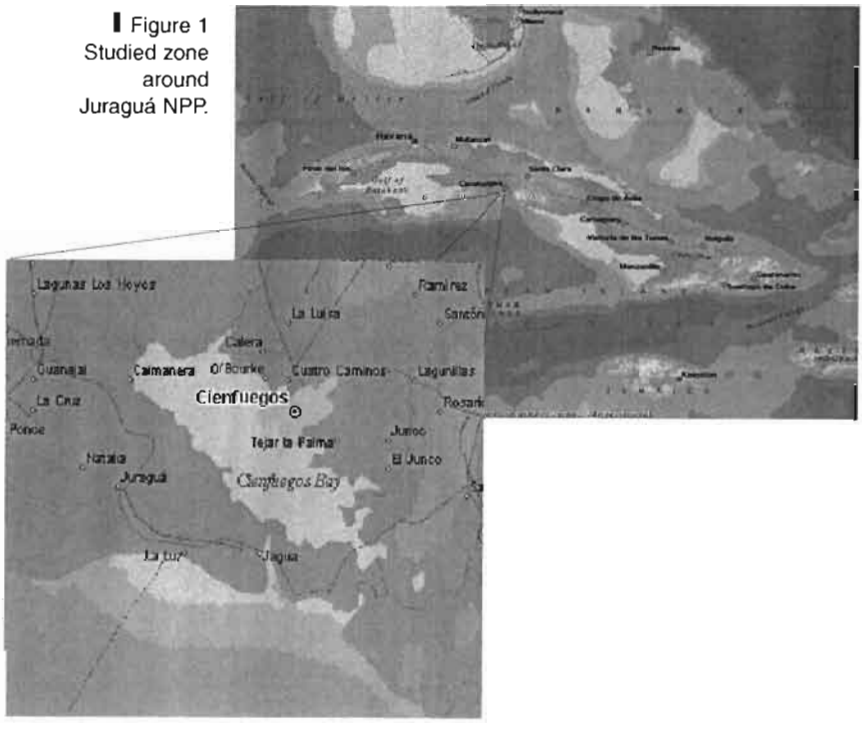

Figure 1
Studied zone around Juraguá NPP.

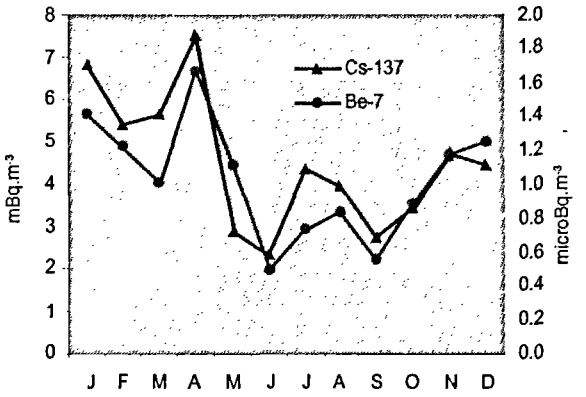

Figure 2
^{137}Cs and ^{7}Be concentration behavior in aerosol samples.

is 1 $\mu Bq.m^{-3}$, this value is representative of normal radiological regions, affected by global fallout only. It is observed that both radionuclides have the same behavior, implying that they are both affected by the same vertical transport processes. A correlation coefficient between these two series is 0.8. The results obtained are coincident with others authors like Feely *et al.* (1988), who reported a correlation coefficient of 0.79 for the same variables in Miami city.

^{7}Be seasonal behavior depends upon several factors not studied completely yet, but the transference processes in the tropopause and the regional climatic conditions are the most important ones (Marenco & Fontan, 1974; Feely *et al.*, 1988). Figure 3 shows the monthly behavior for ^{7}Be versus rain quantity in the study period. The 73.9% of ^{7}Be levels could be predicted by the rain variations, while the no correlation probability is less than 0.2%. These behaviors and r^2 and r values are similar to those reported by Feely *et al.* (1988) for tropical zones from 08° to 25° north latitude.

The results obtained for Cienfuegos have the same temporal behavior that other measurements in cities of the Caribbean region, have like Panama, Miami and San Juan cities, where the maximum ^{7}Be levels are reached in the first quarter of the year coinciding with the minimum levels of precipitation reported for the region (Kendrew,

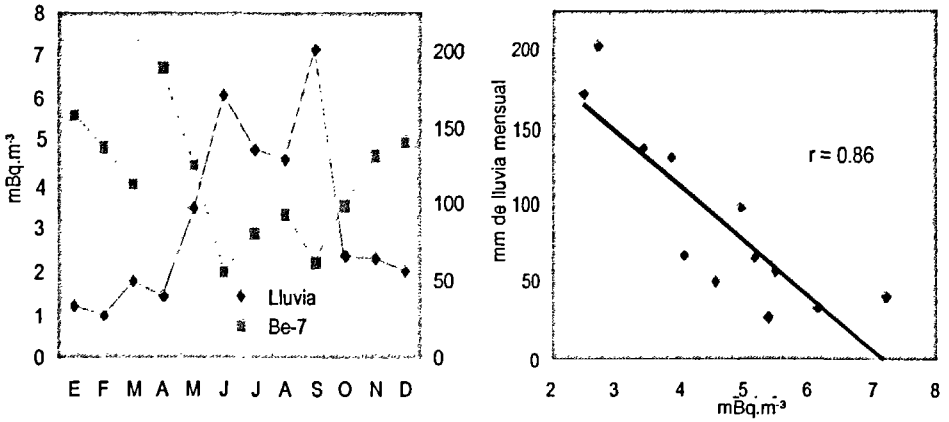

Figure 3
Monthly behavior for ^{7}Be versus rain quantity in the study period.

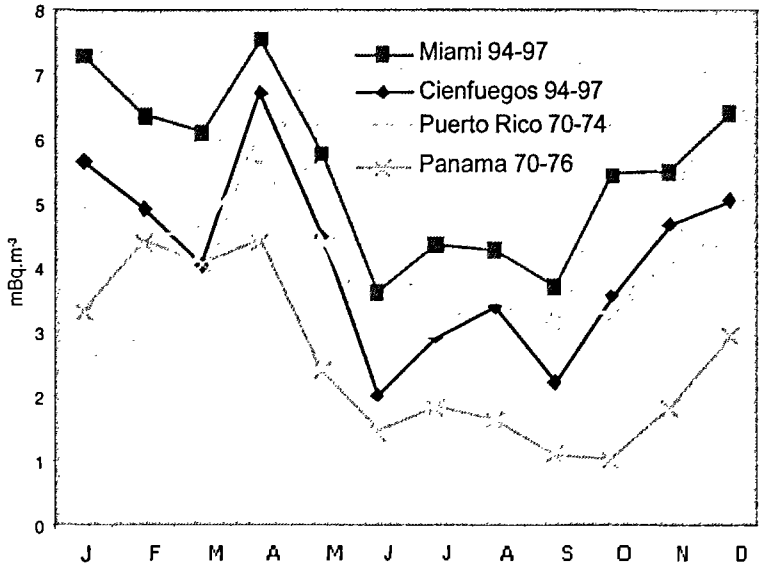

Figure 4
^{7}Be aerosols monthly behavior for the period in Cienfuegos, Miami, Puerto Rico and Panama cities.

1963). The increase observed in April has been explained by Aegerter *et al.* (1966) and Feely *et al.* (1988), due to breaking of tropopause at the end of the winter season when the vertical transport from the stratosphere to tropopause is higher.

The $^{137}Cs/^{7}Be$ ratio for Miami and Cienfuegos has a correlation coefficient of 0.93, see Figure 5. Using the linear equation fit and systematizing by monthly ratio $^{7}Be_{Cienf}/^{7}Be_{Miami}$, the ^{137}Cs in aerosols for Cienfuegos could be expressed by :

$$^{137}Cs_{Cienf}=0.729\,^{137}Cs_{Miami}.R \quad [1]$$

The ^{137}Cs levels in aerosols obtained by the expression [1] coincide with those reported by (SASP, 1998) for Puerto Rico (1970-1974), Bahamas (1968-1972), Panama (1965-1967) and Hawaii (1970-1994). The maximum level was 4.7 $mBq.m^{-3}$, calculated for the year 1963 when higher numbers of atmospheric nuclear weapons were tested (UNSCEAR, 1982). But the most relevant component of this study was that the Chernobyl accident signal in our country was

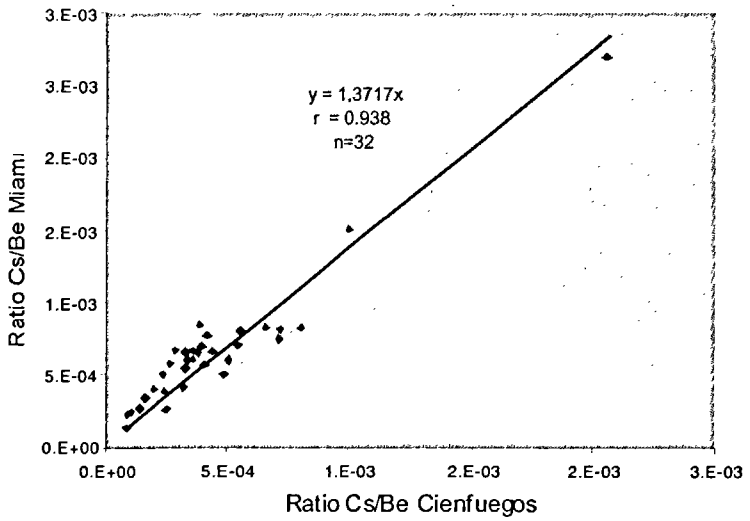

Figure 5
$^{137}Cs/^{7}Be$ ratio for Miami and Cienfuegos.

observed. It was predicted for May, 1986, 0.74 mBq.m^{-3} of ^{137}Cs, two orders higher than the average level for the region in the period of this study. This result is concordant with observations made by Feely *et al.* (1988, 1988a) and Larsen *et al.* (1986) for the east coast of the United State from Maine (47°N,68°W) to Miami (26°N,80°W) in May, 1986. The presence in our latitude of Chernobyl radionuclides has been explained by Larsen *et al.* (1989), Pearson *et al.* (1987) and Roy *et al.* (1988) where the global transport processes transferred the initial plume forward northeast of Canada, after that part of the plume was associated with a quasistacionary low pressure in the northeast of the Atlantic ocean which promoted the descent of contaminated air around all of the north American east coast.

Fallout

In the studied period the ^{137}Cs was detected by gamma spectrometry, the ^{137}Cs averaged concentration was 0.12 Bq.m^{-3}.month^{-1} and range 0.015 and 0.207 Bq.m^{-3}.month^{-1}. Figure 6 shows the temporal

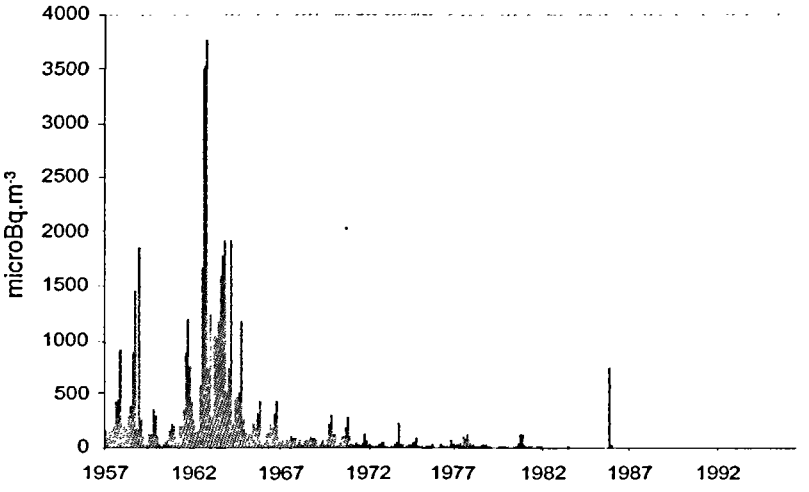

Figure 6
Retrospective ^{137}Cs predicted values in aerosols for Cienfuegos in the period July 57 - May 94.

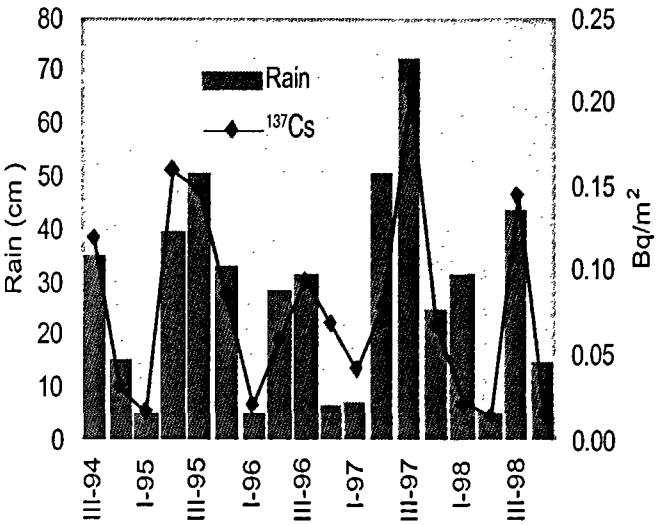

Figure 7
^{137}Cs total fallout and precipitation
for period June 94 – December 98 in Cienfuegos.

behavior of fallout deposition. A good correlation with precipitation levels in the period was observed, where the higher values are in wet season (May-October) and diminish rapidly in the dry season. A correlation analysis indicates that the 71% ^{137}Cs fluctuations are explained by the fluctuations in precipitation regime. This variable is the principal in the vertical transport processes of ^{137}Cs from low troposphere to the surface ground and agrees with observations made by Feely *et al.* (1988) in the 1970-1985 period for Miami city.

Waters

The ^{137}Cs radionuclide was detected by gamma spectrometry in surfaces and underground waters after radiochemical extraction. The concentrations range determined in surface waters was 0.34 – 9.04 $mBq.l^{-1}$, averaging 7.9 $mBq.l^{-1}$ Underground waters have a 2.73 $mBq.l^{-1}$ average concentration and a 1.38 – 5.28 $mBq.l^{-1}$ range.

There are no significative differences between the results obtained for the different sampling places in both media. It is observed that underground waters have a ^{137}Cs concentration lower than surface waters. This shows that the speed of the contamination processes is slow and that their self-cleaning mechanisms characterize these water masses.

Averaged concentration ^{137}Cs [mBq.l^{-1}]		
Control Media	Period	Activity levels
Underground waters	88-97	2.83 ± 1.86
	1998	1.68 ± 0.30
	1999	3.88 ± 1.40
Surface waters	88-97	6.46 ± 2.58
	1998	3.75 ± 1.54
	1999	0.84 ± 0.50

Table 1
^{137}Cs range and averaged concentration in underground and surface waters.

The ^{137}Cs in aquatic fish and aquatic vegetation is *0.18 ± 0.1* and *0.18 ± 0.06 10 Bq.kg^{-1} wet weight* respectively. Those values are representative of zones affected by Global Fallout only.

Conclusions

The results drawn by our studies show the presence of ^{137}Cs nuclear fission product in all the studied areas, and it having an activity above the detection limits of our measurement systems.

The ^{137}Cs concentration in aerosols samples show a good correlation with the behavior of local atmospheric perturbations, which

are more frequent in the summer season (May-September). This behavior has been associated with a greater transport in the precipitation processes from the atmosphere to earth. The increase observed in April has been explained by Aegerter *et al.* (1966) and Feely *et al.* (1988), due to breaking of tropopause at the end of the winter season when the vertical transport from the stratosphere to tropopause is higher.

It is perceivable that the presence of ^{137}Cs in the underground waters and in aquatic biognosis, despite their different self-cleaning mechanisms, is due to the slow speed of the contamination processes that characterize these water masses.

We conclude that our hydrological resources have been contaminated by the ^{137}Cs nuclear fission product coming from the past nuclear weapons tests by means of Global Fallout. The level of specific activity of this radionuclide is very similar with those reported in the scientific literature for zones affected by Global Fallout only (UNSCEAR, 1983; UNSCEAR, 1993).

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