AES BIOFLUX
Advances in Environmental Sciences - International Journal of the Bioflux Society

New data for Cesium from soil in Cluj-Napoca town after Cernobyl accident

Dan C. Niţă, Constantin Cosma, and Robert C. Begy

Babes-Bolyai University, Faculty of Environmental Science, Cluj-Napoca, Romania.
Corresponding author: D. C. Nita, dan.nita@ubbcluj.ro

Abstract. Cesium 137 deposits are due to serious nuclear disaster (such as Chernobyl) and nuclear weapons tests. Due to the wide range of uses in environmental studies is important to know that radionuclide concentrations in environment. Soil samples were measured, in which 137 Cs activities varies between 4.3 and 114.3 Bq / kg. The highest concentrations were found in the top layers of the soil. From the soil depth profiles it can be observed the 137 Cs migration. Horizontal and vertical migration depends mainly on water runoff and the concentration of radionuclides, hydrological regime and the type of soil. It is important to know the amount of radionuclides in the soil because there are already developed models which describe the radionuclides migration in different environments. One of the most studied radionuclide Cs-137 is due to its abundance and relatively long half-life. If the concentration of the radionuclides exceeds a certain value, it might be a threat to human health.
Key Words: Caesium, Cesium, Chernobyl, gamma spectrometry, soil profile.

Introduction. The 137 Cs depositions are due to the nuclear weapon testing and accidents of nuclear reactors. The main period of nuclear weapons testing in the open atmosphere occurred between 1958 and 1963, with a minor Cs deposition on the Earth's surface, from 1971 to 1974 (Al-Masri 2005; Ritchie & McHenry 1990).

The most serious nuclear disaster is considered the Chernobyl accident (1986), from the beginning of the nuclear energetics. The deposition of radionuclide strongly depends on meteorological conditions, so the radioactive cloud was directed to the north-west of the former Soviet Union, towards Europe and also reached the North America.

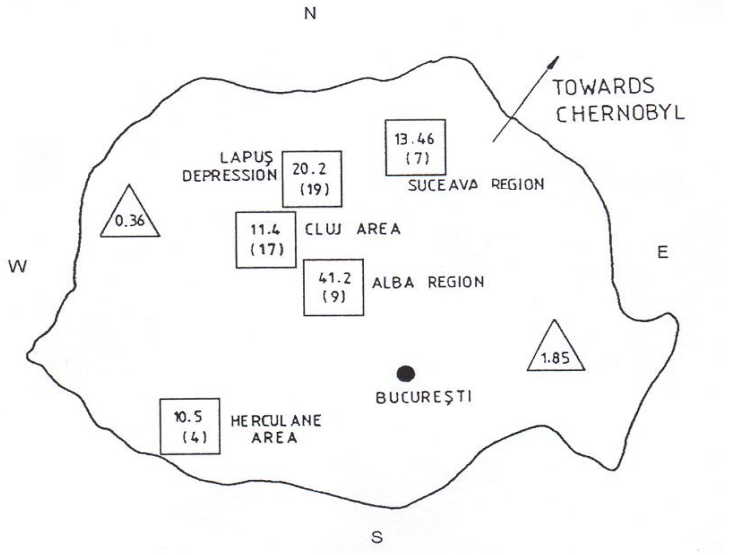


Fig. 1. ^{137}Cs deposits in Romania after Chernobyl accident (Cosma 2002).

It is estimated that 6 t of fragmented fuel was emitted from Chernobyl Nuclear Power Plant (NEA 2002).

Romanian territory was exposed to the contamination with radioactive products, as shown in Figure 1, the deposition of ^{137}Cs (Cosma 2000, 2002).

Cesium-137 (137Cs) is an artificial radionuclide with a half-life of 30.2 years. It decays by beta emission to Ba 137m. Ba-137m has a half-life of about 2.55 minutes, and it decays by gamma emission with an energy of 662 keV.

Cesium-137 measurements are very important in environmental studies, for dating marine and lake sediments, it is used as a tracer to study transport of pollutants and to estimate rates of soil erosion and transport (Arapis & Karandinos 2004; Zapata & Garcia-Agudo 2000; Walling & He 2001).

Many factors influence the extent to which radionuclides are transferred through terrestrial pathways. Because Cesium is a radionuclide with environmentally mobile and transfer readily properties under certain conditions, it can reach to foodstuffs. The main routes for the cycling of radionuclides and the possible pathways to humans are shown in Fig. 2 (IAEA 2006).

Cesium undergoes vertical and horizontal migration. Horizontal migration depends mainly on water runoff and the concentration of radionuclides. The vertical migration depends mainly on the hydrological regime and the type of soil (Arapis & Karandinos 2004; Al-Masri 2005).

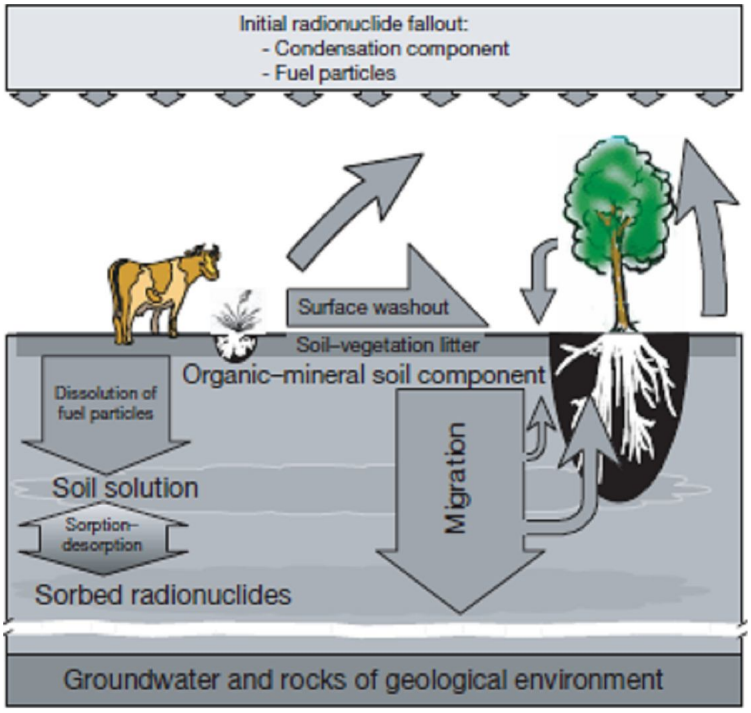


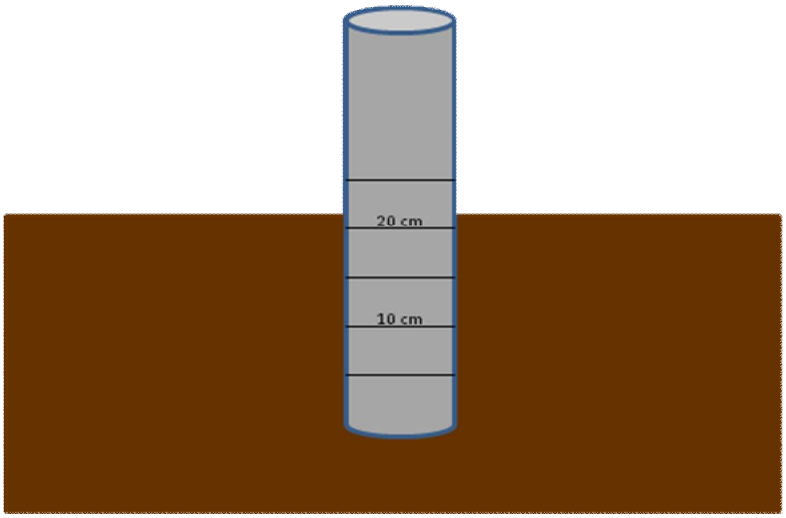
Fig.2. Main transfer pathways of radionuclides in the terrestrial environment (IAEA 2006)

The speed of Cesium migration varies, according to the parameters, and is estimated between 0.4 and 1.2 cm/year^{-1} that corresponds to 6 and 18 cm in depth for the period of 15 years. 80% of the Cesium-137 from Chernobyl is located within the upper 15 cm of soils (Graham & Simon 1996; Zhiyanski et al 2008).

The aim of this work was to determinate the Cs 137 concentrations from soil and the Cs 137 soil migration from the studied area.

Material and Method. There were collected six soil samples from the college garden, from a depth of 4-6 cm, using a metal cylinder with a diameter of 5.5 cm. Also, to observe the vertical migration of cesium 137, soil samples were taken in the vertical profile using the same metal cylinder (Fig. 3).

Measurements were made using a spectrometer with multichannel ORTEC Digidart detector type with GMX HPGe (gamma-X) semiconductor type with a beryllium window. The detector energy field is between 10 and 1500 keV and has a 1.92 keV resolution at the 1.33 MeV line Co-60 and a relative efficiency of 34.2%.



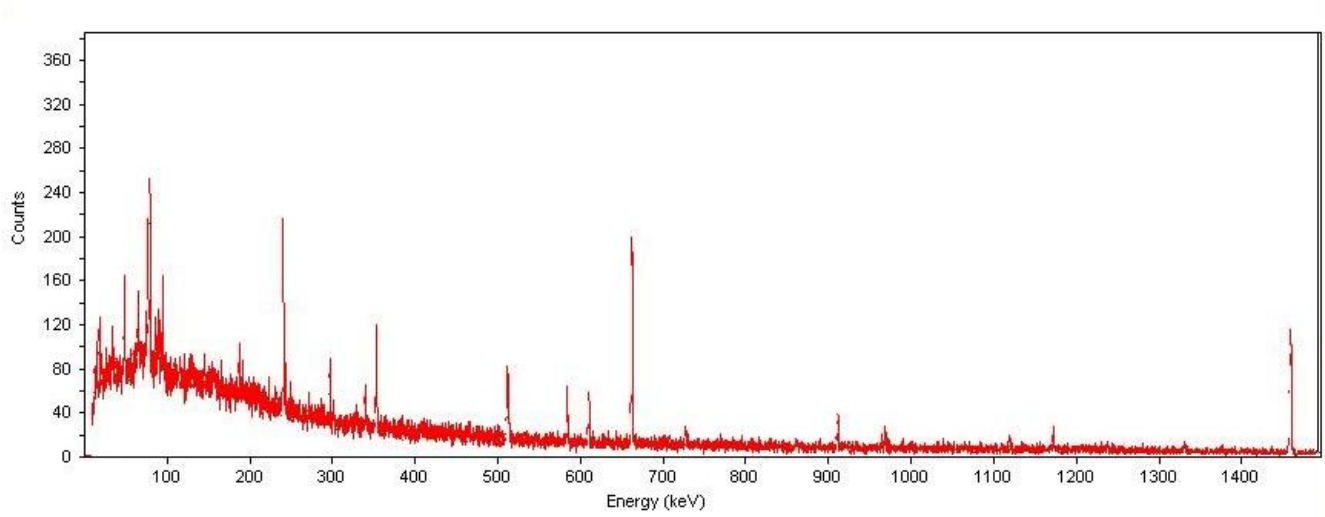


Fig. 3. Method of soil sampling scheme.

Fig. 4. Gamma-spectrum of a soil sample collected from Cluj-Napoca in 2010.

The detector has a lead shielding with a thickness of 5 cm. Inside the lead shielding is a Cu layer of 3 mm. The shielding is very important especially in the case of environmental samples where the sample activity isn't bigger than the background activity. The used geometry is the "sarpagan" type, a cylindrical box.

The concentration of radionuclides in the sample was calculated using the IAEA-375 standard, from the spectra, like the one above (see Figure 4).

Results and Discussion. In Table 1 are shown the results of the measurements of surface soil samples and the deposit calculated for 2010 and for 1986, considering only the half-life in the calculus.

Table 1

Six points of measurement in Cluj-Napoca area (2010)

Sample no.	*A(Bq/Kg)*	*±A(Bq/Kg)*	*Deposit 2010 (Bq/m²)*	*Deposit calculated for 1986 (Bq/m²)*
1	83.77	9.15	5363.66	9462
2	105.56	10.27		
3	103.30	10.16		
4	99.85	9.99		
5	93.38	9.66		
6	104.11	10.20		

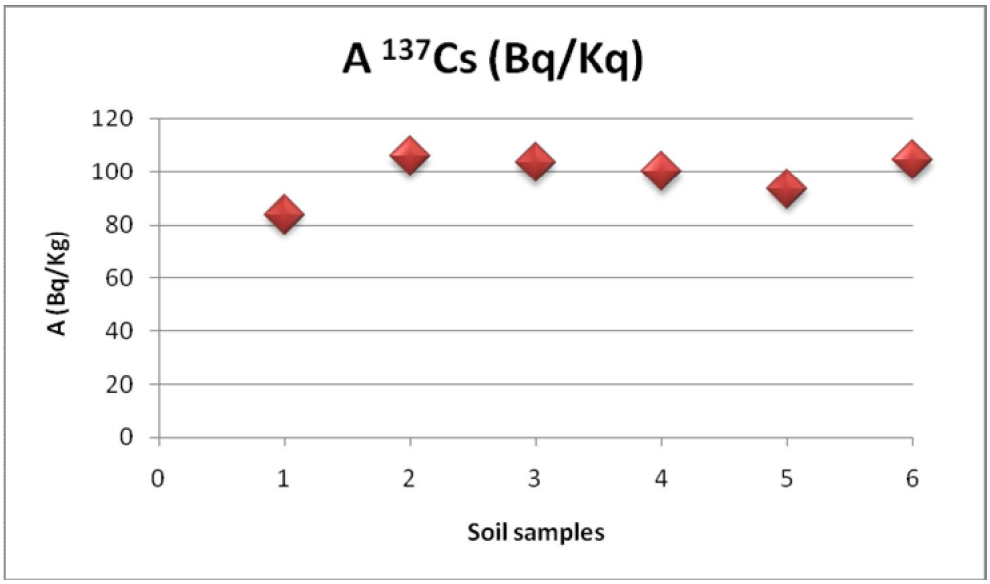


Figure 5. Cs 137 soil activity samples (2010)

Table 2

Romanian soil samples (Cosma 2002)

Nuclide	*Half-life*	*Specific activity (Bq/kg ± 15 % dry weight)*	*Deposit (Bq/m²)*
^{144}Ce	286 days	380 000	
^{125}Sb	2.75 years	56 000	1 500
^{106}Ru	367 days	410 000	10 900
^{134}Cs	2.06 years	187 000	6 300
^{137}Cs	30.1 years	482 000	12 800
^{110m}Ag	250 days	7500	200

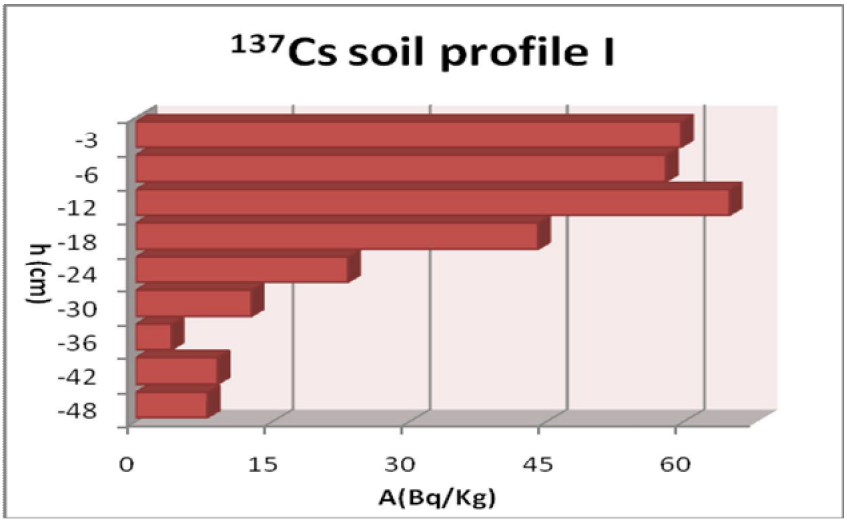


Figure 6. Soil in depth profile activity for profile I.

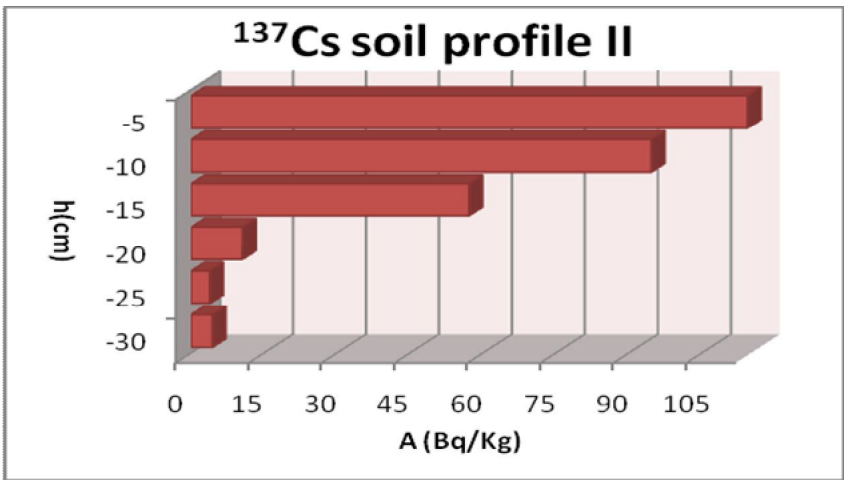


Figure 7. Soil in depth profile activity for profile II.

The highest ^{137}Cs concentrations were found at the top 0-5 cm soil layers of the profile I and decreases exponentially with depth. This relation suggests that there is no runoff and no soil redistribution effect on ^{137}Cs concentrations with depth and most of the ^{137}Cs activity was transferred vertically.

In profile II, 137Cs concentrations were found to extend further down into the profile, the maximum concentration being at a depth of 16 cm, indicating good vertical transport of 137Cs.

Although the two profiles were taken from the same area, being a short distance between sites (3-5 m) and the soil type is about the same, we can observe a remarkable difference between the two profiles. The explanation may consist in the fact that next site I is a small ditch which fills with water during rain, this site being irrigated more than the site II, and cesium transport being stronger.

In literature, the rate of migration of Cesium in depth is approximated from 0.4 cm per year to 1.2 cm per year (Graham & Simon 1996; Zhiyanski et al 2008). This means that the largest quantity of cesium should be at a depth between 9.6 cm and 28.8 cm. This does not always apply, because the implications of many variable parameters that cannot be approximated, as it is apparent from our depth profiles (Fig. 6 and Fig. 7).

Table 3

137 Cs deposit for 2010 and calculated for 1986
from the two in depth profiles

Profile	*Total deposit 2010 Bq/m^2*	*Total deposit calculated for 1986 Bq/m^2*
I	9172.5	16065
II	8269.5	14484

Calculus of the deposition for 1986 (Table 3) was made considering only the half-life of Cesium 137. Comparing the results with those of Cosma (2002, 2010) (Table 2, Fig. 6 and Fig. 7), it is apparent that they are in good correlation.

Conclusions. Most of the Cesium concentration is still found in the upper layers of soil. Vertical distribution of 137Cs in most of the undisturbed soil cores (0-16 cm) is highly related to to rainfall and decreases with the depth.

Comparing the results of initial deposit (1986) of the soil samples collected from the surface profile with the ones from the depth profile, it can be seen the horizontal and and especially the vertical transport of Cesium in the soil.

The relatively high concentrations of up to 114.34 Bq/kg, are demonstrating once again how great was the catastrophe of Chernobyl, but on the other hand we can still use Cs 137 as a tool for environmental research.

Acknowledgements. This paper was realized with the support of EURODOC „Doctoral Scholarships for research performance at European level" project, financed by the European Social Fund and Romanian Government.

References

Al-Masri M. S., 2005 Vertical distribution and inventories of 137Cs in the Syrian soils of the eastern Mediterranean region. Journal of Environmental Radioactivity **86**:187-198.

Arapis G. D., Karandinos M. G., 2004 Migration of 137Cs in the soil of sloping semi-natural ecosystems in northern Greece. Journal of Environmental Radioactivity **77**:133-142.

Cosma C., 2000 Strontium-90 measurement without chemical separation in samples after Chernobyl accident. Spectrochimica Acta, Part B, **55**:1165-1171.

Cosma C., 2002 Some aspects of radioactive contamination after Chernobyl accident in Romania. Journal of Radioanalytical and Nuclear Chemistry **251**:221-226.

Cosma C., 2010 Old and new aspects of the post Chernobyl contamination in Romania and Austria. PROCEEDINGS OF THE „2th Terrestrial Radioisotopes in Environment International Conference on Environmental Protection"/ University of Pannonia, Veszprem /12 Mai 2010 /Veszprem/Ungaria CONFERENCE, in press.

Graham J. C., Simon S. L., 1996 A study of 137Cs in soil profiles from the Marshall Islands. Science of the Total Environment **183**(3):255–268.

IAEA, 2006 Environmental consequences of the Chernobyl accident and their remediation: twenty years of experience / report of the Chernobyl Forum Expert Group 'Environment'. — Vienna: International Atomic Energy Agency, 2006.

NEA, 2002 Nuclear Energy Agency, Chernobyl - Assessment of Radiological and Health Impacts 2002 Update of Chernobyl: Ten Years On.

Ritchie J. C., McHenry J. R., 1990 Application of radioactive fallout cesium-137 for measuring soil erosion and sediment accumulation rates and patterns: a review. Journal of Environmental Quality **19**:215-233.

Walling D. E., He Q., 2001 Models for converting 137Cs measurements to estimates of soil redistribution rates on cultivated and uncultivated soils, and estimating bomb-derived 137Cs reference inventories (including software for model implementation). A Contribution to the International Atomic Energy Agency Coordinated Research Programmes on Soil Erosion (D1.50.05) and Sedimentation (F3.10.01). Department of Geography Exeter, U.K.

Zapata F., Garcia-Agudo E., 2000 Future prospects for the 137Cs technique for estimating soil erosion and sediment rates. Acta Geologica Hispanica **35**:197-205.

Zhiyanski M., Bech J., Sokolovska M., Lucot E., Bech J., Badot P.-M., 2008 Cs-137 distribution in forest floor and surface soil layers from two mountainous regions in Bulgaria. Journal of Geochemical Exploration **96**:256–266.

Received: 22 June 2011. Accepted: 25 August 2011. Published online: 27 August 2011.
Authors:
Dan C. Niţă, Babes-Bolyai University, Faculty of Environmental Science, Fântânele Street, No. 30, Cluj-Napoca, Romania; e-mail: dan.nita@ubbcluj.ro
Constantin Cosma, Babes-Bolyai University, Faculty of Environmental Science, Fântânele Street, No. 30, Cluj-Napoca, Romania; e-mail: constantin.cosma@ubbcluj.ro
Robert C. Begy - Babes-Bolyai University, Faculty of Environmental Science, Fântânele Street, No. 30, Cluj-Napoca, Romania; e-mail: robert.begy@ubbcluj.ro
How to cite this article:
Niţă D. C., Cosma C., Begy R. C., 2011 New data for Cesium from soil in Cluj-Napoca town after Cernobyl accident. AES Bioflux **3**(2):229-235.