Technogenic migration of cesium-137 in cities

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Abstract: Pollution from caesium 137 in territories of Moscow is caused by radioactive losses as a result of nuclear tests, and failure on the Chernobyl atomic power station. Dropping out of an atmosphere, caesium 137 is strongly adsorbed in a soil layer. In natural ecosystems such as in soils, concentration of caesium 137 annually decreases due to radioactive disintegration and migration caesium 137 in mineral layers. Speed of migration and depth of penetration in a mineral layer are small (from 5 up to 25 cm for 15 years). Naturally caesium 137 is also inactive in its concentration within a soil layer. This is reflected by the intensity of atmospheric losses in the given territory.

In City ecosystems technogenic migration of caesium 137, connected with destruction and moving of a soil layer containing caesium 137 is very active. Distribution of caesium 137 concentrations in City soils is determined by a category of economic land tenure. In forest parks and the agricultural grounds soil layer distribution of caesium 137 is close to natural background levels. Within the limits of industrial zones and abandoned lands (a dump etc.) caesium 137 is absent, because the soil cover containing dropped out atmospheric caesium 137 has been removed or mixed. In territories of a residential zone the distribution of caesium 137 is the most complex. Here the soil layer containing caesium 137, as a whole is kept; however it constantly is cut off, moves from place to place and is partially destroyed by building and excavation works. Besides in a residential zone the creation of artificial lawns using mixed and imported soils are constantly undertaken. Chernozems from areas with high levels of pollution of caesium 137 as a result of Chernobyl accident are often imported and cause special alarm. In the territory of Moscow imported chernozems in which the contents of caesium 137 reaches 300 Bq/kg have been revealed characteristic for soils in Moscow, these approximately exceed pollution levels by 50 times. Thus, distribution of caesium 137 in soils of Moscow is caused, first of all, by its technogenic migration with moved soils.

Résumé: Pollution par ^{137} s du territoire de Moscou est conditionnée par les précipitations radioactives causées par les essais nucléaires ainsi que par l'accident à la Centrale électronucléaire de Tchernobyl. Dans les écosystèmes urbains se manifeste activement la migration technogène de ^{137} s relative à la destruction et au déplacement de la couverture du sol qui contient de ^{137} s. Sur le territoire des zones industrielles urbaines il n y a pas de ^{137} s puisque là les sols sont le plus souvent détruits. Dans la zone résidentielle la couverture du sol contenant de ^{137}Cs est conservée mais elle est coupée et déplacée continuellement en cours de la construction et l'aménagement des espaces verts. Avec cela, on apporte à Moscou les terres noires des régions ayant un haut niveau de pollution par ^{137}Cs à la suite de l'accident de Tchernobyl. De ce fait, sur le territoire de Moscou on trouve les sols où le contenu de ^{137}Cs dépasse de 50 fois le niveau ambiant régional.

Keywords: ecology, environmental protection, laboratory studies, laboratory tests, radioactive waste, risk assessment

INTRODUCTION

Pollution with ^{137} s of the central part of European Russia, including the Moscow territory, is caused by global nuclear fall-outs as a result of atmospheric nuclear weapons testing, and also by ^{137} s that fell out after the accident on the Chernobyl nuclear power station. Mass atmospheric tests of nuclear weapons launched in the mid-50s, and finished generally in the early 60-es have brought about an atmospheric emission of a great deal of radioactive nuclides that penetrated the stratosphere and then diffused quickly along the whole hemisphere. Further radioactive nuclides passed from the stratosphere into the troposphere and fell out onto the earth surface due to being washed out by atmospheric precipitates, and dry-deposited. The stratospheric or global fall-outs are a source of pollution with relatively long-living radioactive nuclides – ^{137}Cs, ^{90}Sr, ^{14}C, ^{3}H and others (Anon, 1986; Anon, 1999). The accumulation maximum was registered in 1965 during most intensive testing. When the USSR and the USA ceased mass atmospheric nuclear testing the quantity of ^{137}Cs in the atmosphere has been constantly decreasing due to the radioactive decay (Table 1). The average global soil pollution with ^{137}Cs in latitudes 50-60 North just before the Chernobyl accident was about 2.2 kBq/m^2 (0,059 Ci/km^2). The total quantity of global cesium fell out as a result of nuclear weapons testing is estimated for the territory of Europe as 20 PBq (0.54 MCi) (ANON, 2001).

The accident at the Chernobyl nuclear power station has led to vast radiation pollution covering part of Ukraine, Byelorussia, Russia and some European countries. Because of him accident a large quantity of fission and activation products was released into the atmosphere to a considerable height. In some Central Russia regions there fell fine relatively volatile radioactive nuclides – ^{137}Cs, ^{134}Cs, ^{132}Te, ^{125}Sb, ^{106}Ru ^{131}J and others (ANON, 2001; ANON, 1999, Ignatov & Lihin 1998). Most of the above listed nuclides are relatively short-living and by now have completely decayed, except for ^{137}Cs and ^{90}Sr, half-life of which is respectively 29.9 and 28.7 years.

Table 1. The dynamics of Summary deposit ^{137}Cs in soils of northern hemisphere (ANON, 1986).

Years	Summary deposit ^{137}Cs, Bq/km^2
1960	1.0
1965	2.7
1980	2.31
1981	2.27
1982	2.23
1983	2.18
1984	2.13
1985	2.08

The Bryansk, Kaluga and Tula regions have suffered the severest pollution (over 40 kBq/m^2). At the west of the Bryansk region the fallout levels of ^{137} s by early May, 1986 exceeded 1000 kBq/m^2 (in the central spot up to 40000 kBq/m^2 or about 1000 Ci/km^2), which is even higher than the pollution level in the 60-km area around the reactor (The Atlas… 2001). In the other regions pollutions level were in 10-100 times bellow pollutions level in the west of the Bryansk region. For example, in Tula region the levels of pollution with caesium are as high 10 to 185 kBq/m^2. The total quantity of ^{137}Cs fell out on the territory of Europe following the Chernobyl accident is estimated at 64 PBq (1.7 Ci). The Chernobyl fallouts are characterized by spotty inhomogeneous pollution; a close connection between cesium distribution and the quantity of atmospheric rain precipitates was often revealed on the radioactive cloud track (ANON, 1999).

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Moscow was literally bypassed by the radioactive cloud from the south and southwest. At the most territory of the Moscow region the integral reserve of ^{137}Cs in soil from the amount of global and Chernobyl fallouts as of May 10, 1986 did not exceed 4 kBq/m^2. As of 1991 the reserve of ^{137}Cs within the region under consideration averaged to 2.4 kBq/m^2 (0.065 Ci/km^2), where the portion of the Chernobyl fallouts amounted to approximately 23 % (ANON, 1992), which corresponds to the ^{137}Cs specific activity in soil of about 8 Bq/kg (Petrova et al. 2004). At present it seems impossible to differentiate the Chernobyl cesium and the global cesium in Moscow soils, as the content of ^{134}Cs (which is a reference point of the Chernobyl fallouts) now is below the equipment detection limit.

Despite the fact that the cesium pollution of various natural landscapes is thoroughly studied and described in numerous publications, especially after the Chernobyl nuclear power station accident, the principles of ^{137}Cs distribution in urban ecosystems are insufficiently studied. Meanwhile, the principles of cesium pollution of natural and urban ecosystems differ greatly.

Under natural conditions when ^{137}Cs penetrates into the soil layer about 90-98 % of its quantity gets bound quickly in the top 5 cm of the layer, less often – in the layer of 0 – 20 cm, and migrates very slowly (Gusev & Belyaev 1991; ANON, 1999). According to the results presented in Table 2 it is clear that most part of ^{137}Cs lays in the surface bedding, and at the depth of 10-20 cm cesium is virtually absent, that complying with literary data (ANON, 1999; ANON, 1992; ANON, 1991). That is the speed of cesium migration into the mineral layer is 10-15 cm per 20 years. Cesium lateral migration in soils under natural conditions is also extremely small. So the content of ^{137}Cs in soils of natural ecosystems reflects the rate of atmospheric precipitates within the territory.

Table 2. Distribution of specific activity ^{137}Cs in soil profile

Depth, cm	Specific activity ^{137}Cs, Bq/kg
0-5	22.0±1.8
5-10	10.7±1.2
10-15	1.9±0.7
15-20	-

On the urban territory according to our research the cesium specific activity in urban soils is not linked directly to the intensity of atmospheric precipitates, but is determined by man-caused factors. The most important factor influencing the displacement of ^{137}Cs in cities is man-caused (technogenic) migration with relocating soils. In cities the prolific soil layer during ground works gets moved and transported away, digged over or covered with ground (Gerasimova et al. 2003). Within the urban area there are also constantly underway works of planting trees and biological restoration, during which a humus layer is placed on the surface of the reclamated soil. And the soil material to produce the humus layer is being brought to cities from other regions. So urban soils are moved constantly from area to area and are extremely inhomogeneous and variable environment, the attributes of which change all the time, this affecting distribution of ^{137}Cs.

In Figure 1 the distribution of the caesium specific activity in Moscow soils is shown. The distribution of ^{137}Cs in Moscow soils is complicated – three modes can be distinguished. The distribution, close to the logarithmically normal one, and typical of most pollutants, with maximum of 4-5 Bq/kg is overlaid by a "burst" of about <1 Bq/kg (the specific activity of ^{137}Cs is below the instrument detection limit) and an ill-defined maximum within 9-10 Bq/kg. Moreover according to our research the caesium distribution in soil is connected with the nature of economic land use, which determines peculiarities of urban soil formation.

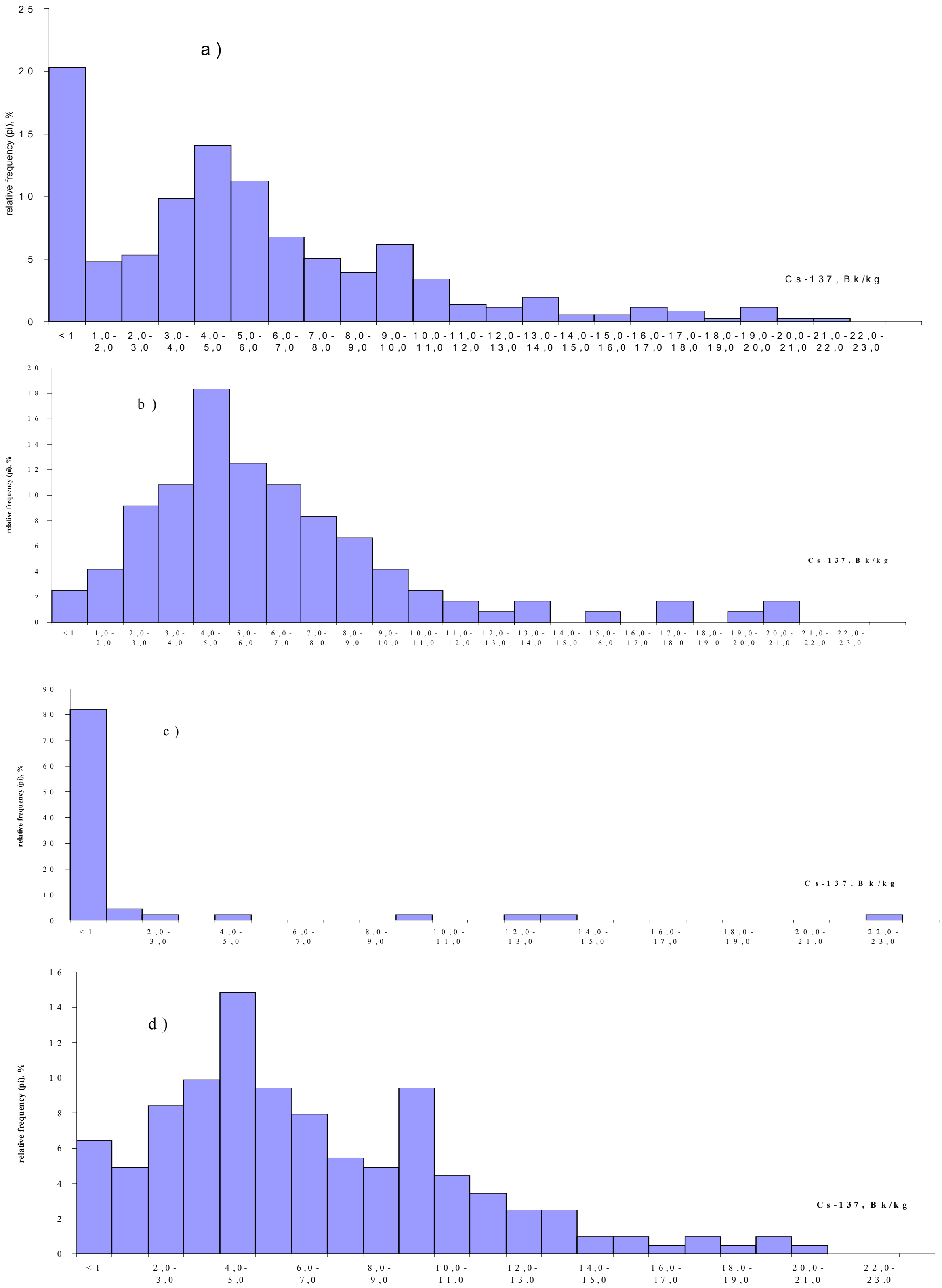

Figure 1. Distribution of specific activity ^{137}Cs in soil of Moscow: a) in City soils as a whole; b) on the agricultural lands and forest parks; c) in industrial zones and abandoned lands; d) in territories of a residential zone.

The distribution of caesium within the territories belonging to different categories of land use is shown in Figure 1b, c, and d.

On urban lands for agricultural use (gardens, vegetable gardens, and tillage), and also in forest parks (Figure 1b), i.e. on the territories less prone to man-caused affect the distribution of ^{137}Cs in soil has a right asymmetry with one apparent maximum of about 4-5 Bq/kg. This cesium distribution is typical of natural landscapes. That is here there is no man-caused caesium migration.

For industrial areas and reserve lands – territories of plants, warehouses, dump, and waste areas – there is typical caesium absence in the soil layer (Figure 1c). In 80 % of samples the caesium specific activity is below the gamma spectrometer detection limit. On these territories the soil layer has suffered most intensive man's impact. The upper layer of soil formerly containing the Chernobyl and global ^{137}Cs is mostly destroyed – trampled down, taken away, digged over or covered with root or imported ground. The territories form the zone of man-caused caesium removal from soils.

On territories of urban site development (dwelling zone) bimodal distribution of the ^{137}Cs specific activity in soils is being observed. The "natural" distribution of the Chernobyl and global caesium is overlaid by an additional mode corresponding to the ^{137}Cs specific activity in soils of 9-10 Bq/kg. The emergence of a maximum of about 9-10 Bq/kg is linked to works on improvement (lawns creation and repair). The process of lawn creation envisages formation of a quite large fertile horizon of planted subsoil to create favourable conditions for grass roots development. As a result peat (marsh) soils and alluvial (floodplain) soils are often imported to the Moscow area. The largest areas of alluvial soils are along river floodplains. Alluvial sediments forming such soils are brought by floodwater from the Tula region, where the River Oka flows amid the zone of Chernobyl pollution with ^{137}Cs, this determining a strong possibility of alluvial sediments pollution. Moreover all the above stated soil types are more than other soils of the area under consideration characterized by higher potential possibility of pollution due to their formation conditions and landscape location. Their confinement to depressions and subordinate relief elements makes these soils accumulate excellently pollutants, including ^{137}Cs.

The delivery to Moscow of true chernozem for planting is particularly alarming. The point is that the closest to Moscow chernozem is located in the Tula region (Dobrovolskyi & Urusevskaya 1984), where the levels of pollution with caesium are as high 10 to 185 kBq/m^2 (Plavskoye spot) (ANON, 2001). There have been precedents. For example, to plant greenery on the territory of a Moscow high school there has been imported the Tula chernozems, which contained ^{137}Cs up to 300 Bq/kg (10-20 kBq/m^2); this is approximately 50 times higher than the pollution levels typical of Moscow soils. So dwelling areas are zones of man-caused accumulation of caesium in soils and surface formations, which results from importing soil from southern regions, which has a much higher levels of caesium pollution.

So in cities there happen processes of man-caused (technogenic) migration of ^{137}Cs that have no prototypes in the natural environment. Therefore cesium, being in nature a slow-moving element, is transported in urban conditions in huge lumps for large distances (dozens of kilometres). As a result, within urban ecosystems the cesium distribution in soil has nothing to do with the atmospheric precipitates rate, but is predetermined by man-caused processes resulting in removal of ^{137}Cs from surface soil formations, as well as in caesium entering urban areas together with imported soil mixtures. The latter process requires particular attention as it aggravates the risk of radioactive pollution areas creation in densely populated urban districts.

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REFERENCES

ANON. 1986. Background pollution of an environment in territory of the USSR by technogenic radioactive products in 1985. Edited by Mahanko K.P., IEM, Obninsk, 212 p. (in Russian).

ANON. 1991. Research of distribution and migration of radionuclidEs in ground and water ecosystems. *Proceedings of Institute of applied geophysics.* Moscow. (in Russian).

ANON. 1992. Radiation conditions in territory of Russia and the adjacent states in 1991. YB Edited by smb. Mahanko K.P., Research-and-production Association "Tayfun", Obninsk, 324 p. (in Russian)

ANON. 1999. Radioecology after Chernobyl. BIOGEOCHEMICAL PATHWAYS OF ARTIFICIAL RADIONUCLIDES. Edited by Warner F. & Harrison R., Mir, Moscow, 393 p. (in Russian).

ANON. 2001. The atlas of pollution 137Cs of the Europe after Chernobyl failure. European Communities, 2001, EC/EGCE Roshydromet/Minchernobyl (UA)/Belhydromet (in Russian).

DOBROVOLSKYI, G.V. & URUSEVSKAYA, I.S. 1984. *Geography of soils*. Publishers of MSU, Moscow, 415 p. (in Russian).

GERASIMOVA, M.I., STROGANOVA, M.N., MOGAROVA, N.V. & PROKOFYEVA, T.V. 2003. *Anthropogenic soils: genesis, geography, revegetation.* Edited by smb. Dobrovolskii G.V., Oykumena, Smolensk, 268 p. (in Russian).

GUSEV, N.G. & BELYAEV, V.A. 1991. *Radioactive deposits in biosphere.* Reference book, Energoatomizdat, Moscow, 215 p. (in Russian).

IGNATOV, P.A. & LIHIN, A.G. 1998. Radioenvironmental problems of the central areas of Russia. *News of the Russian Academy of Natural Science,* **1**, 75-85 (in Russian).

PETROVA, T.B., MIKLYAEV, P.S., VLASOV, V.K., OHRIMENKO, S.E. & SEMENYUK, O.V. 2004. Background concentration of 137Cs in soils of Moscow. *News of radiation measurements,* **3** , 35-41 (in Russian).