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Radiocarbon in Vegetation of coastal Zone of Finnish Bay (Russia)

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Abstract

Radiocarbon is a radioactive isotope of carbon, which is forming in the nature constantly by interaction of cosmic fast neutrons and nitrogen nuclei at the low atmospheric layers. Another source of radiocarbon in the environment is pollution in processes of Nuclear Power Plant exploitation. The expanding construction of nuclear industrial plants and nuclear power stations on the shores of the Baltic Sea is creating a real possibility for the introduction of radioactive wastes into environment of Finnish Bay basin. The activity of radiocarbon in the plant of coastal zone was determined by a system of Sample Oxidizer 307 and low-level liquid scintillation system Quantulus 1220 (Wallace, Turku, Finland) The Radiocarbon analysis is a sensitive tool for the registration of pollution. The variations of radiocarbon concentration in the one-years grasses can be used as an indicator of carbon dioxide pollution of the urban environment. The variation of radiocarbon in tree-rings reflects the local and global radioactive contaminations.

Keywords: Radioactive pollution, Finnish Bay, Radiocarbon, Tree rings, Quantulus1220, Scintillation Counter, Sample Oxidizer 307

1. Introduction

The concentration of radiocarbon is at high level in the environment after nuclear tests of 1950-1960 years till now. In the nature a radioisotope 14C is forming constantly by interaction of cosmic fast neutrons and nitrogen nuclei at the low atmospheric layers. The most of technogenic radiocarbon is emitted in result of processing of fuel elements, in which radioisotope is concentrated in result of neutron

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activation of fuel admixture and heat-transfer material in the Nuclear Power Plant [1]. The vegetation assimilates the radiocarbon in process of photosynthesis in the environment and afterward the radiocarbon is assimilating by animals and human. The radiation damage of albumen molecules and DNA bounds take place when the radiocarbon isotopes decay with β-emission and in result of chemical transformation carbon atom to nitrogen atom. The most part of DNA damage in result of decay 14C nuclei lead to genetic mutations [2, 3]. In period of 1945-1980 years in result of the nuclear tests about $2,2 \cdot 10^{17}$ Bq ^{14}C was emitted in the atmosphere. It is in 1,6 time higher than the natural radiocarbon equilibrium activity in the troposphere. According to modern tests [4, 5], the average content of radiocarbon in water and biota near Irish coastal zone is at the level of 247,6±1 Bq/kg. The Nuclear Power Plants have the differences in the fulfilled products. In the BWR Nuclear Power Plants the radiocarbon enters to the environment as compounds of hydrocarbonates and CO_2, CO – 2,5%. [6]. In the PWR 80 Nuclear Power Plants the radiocarbon has compounds of CH_4 and C_2H_6, 5 % — CO_2 and CO. The emission from graphite-moderated nuclear reactors is assessed at 10^{11} Bq/(MW·g). The most high emission registered for HWR reactors is at $(1,0\text{-}1,7) \cdot 10^{13}$ Bq/(GW · g.). The lowest emission is characteristic of reactors of PWR and BWR types and they are at $(2,5) \cdot 10^{11}$ Bq/(GW · g.). The one-year vegetation is sensitive to changes of radioecological situation in the zone of Nuclear Power Plants. The measurements of radiocarbon concentration in the grasses allow us to determine the seasonal variations of radiocarbon. The study of radiocarbon distribution in the wood tree-rings is important for retrospective estimates of radiocarbon pollution for long time periods. The investigations of radiocarbon pollution of vegetation have been conducted in the coastal area of Finnish Bay near St.Petersburg City (Russia).

2. The investigations and results

2.1. The region under study

The ecosystem of Finnish Bay as part of Baltic Sea basin is the zone in which the large industrial complexes of different European countries are concentrated. The exploiting of Nuclear Power Plants increases the risk of nuclear waste of this region. Monitoring of distribution of long-life radioisotopes was carried out by Helsinki commission of preservation of the marine environment of Baltic Sea (HELCOM). The Baltic Sea is shallow and has isolation from Atlantic Ocean. It is the reason of low capability for purification and the time of whole water exchanging come to 27 years [8]. On the data of HELCOM [8] there are twelve Swedish, four Finnish and nineteen Germany power(-generating) units in force in the Baltic Sea zone. In Finnish Bay the Leningrad (Sosnovy Bor) Nuclear Power Plant is situated. At the area of Nuclear Power Plants the depositories of radioactive waste is located. The atomic submarines and ships are repairing on the coastal parts. Today the potentially dangerous sources of man-caused radioactive nuclides in the environment of Baltic Sea amass at Leningrad Nuclear Power Plant, at Kola Nuclear Power Plant, at Ignalinskaya Nuclear Power Plant (Lithuania). The numerous radiation-dangerous objects are concentrated within the St.Petersburg city and around one. This is the objects of medicine, shipbuilding, scientific investigations and others. The Chernobyl accident had impact on the ecology of Baltic Sea basin too. Leningrad Nuclear Power Plant are located in the Sosnovy Bor City of Leningrad district, on the Southern coast of Finnish Bay, in about 80 km to western from Central part of St.Petersburg City. The building of Leningrad Nuclear Power Plant was begun at September of 1967 year. The first power block was put into operation at 1973 year, the forth – in 1981 year. At the Leningrad Nuclear Power Plant installed water-graphite reactors of the RBMC-1000 (high-energy reactor channel) channel-type reactor on the thermal neutrons [9]. The first series of reactors of RBMC-1000 in service at the Plant in Sosnovy Bor have not reliable security systems. Later they were modernized and many deficiencies have been corrected. Today the acceptable level of safety of RBMC was confirmed by the national and international expertise. However, the radioactive decay products, including long-lived, radioactive isotope of carbon, which is a half-life 5730 years enter in the environment as a result of Nuclear Power Plants work. Therefore, the monitoring of radiocarbon distribution should be conducted in the environment of this region.

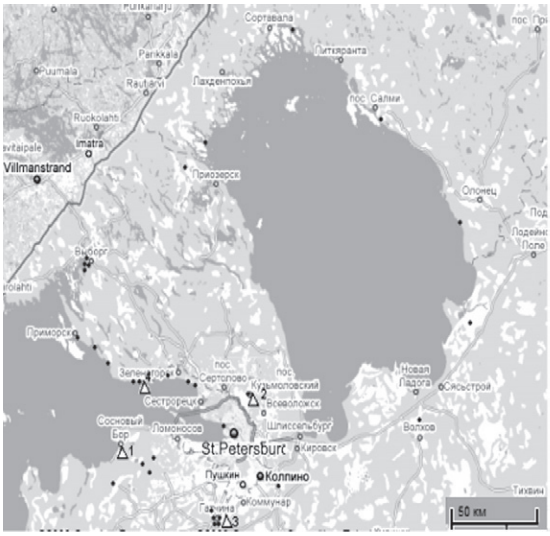

Fig. 1: Map of coastal zone of Finnish Bay

2.2. The methods of investigation

The sampling of grass and trees was carried out in July 2010. The samples were collected on the territory of St.Petersburg City and Sosnovy Bor City. The samples of grass were dried at a temperature 105^{o}C in an oven. A sample of wood core was collected in March 2011 by manually wood core from spruce tree, which grows near the Nuclear Power Plant, the coordinates of the point N 59.87916^{o}, E 29.10790^{o}. The width of tree rings was measured with a laboratory optical measuring tree cores CORMI Maxi. The Samples of tree-rings and grass have been prepared with the help of automatic system Sample Oxidizer 307 with using of absorbent CARBO-SORB ® E (6 ml) and the scintillate PERMAFLUOR ® E + (11 ml) [7, 10]. The Liquid Scintillation Spectrometer Quantulus 1220 was used for the counting.

2.3. Radiocarbon concentration in vegetation

The radiocarbon activity was determined in the tree-rings of spruce (Picea abies L.) (Figure.2), that is growing near Nuclear Power Plant of Sosnovy Bor city. The age of spruce consists of 115 years. Until 1955 year the radiocarbon activity did not exceed background. In some years, for example, in 1923, there is a significant decrease in the radiocarbon activity. It should be associated with a local burning of fossil fuels (eg coal). Significant increasing in the radiocarbon content almost twice observed in 1955-1965 years, the maximum occurred at 1963 year [18]. This was connected with the nuclear tests which were in this period in the northern hemisphere. After 1965 year, the concentration of radiocarbon in the atmosphere begins to decline. The next peak of ^{14}C activity to 400pMC% was in 1974-1975. The high level radiocarbon concentration records in the tree rings of this time. According to published data [19] of Non-governmental Environmental organization “Greenworld” which is the member of International

Socio-Ecological Union the first serious accident on the Nuclear Power Plant in Sosnovy Bor City occurred at January 7, 1974 year. It was two weeks after the start of the first unit on the Leningrad Nuclear Power Plant. At November 28 - December 30 of 1975 year the next accident of 3 level on a scale of INES was occurred. On the graph it is a maximum of radiocarbon concentration in tree-ring of this year. After this incident, the level of radiocarbon in the following period begins to fall. The next rise of radiocarbon activity to 350% pMC is observed in the tree-rings of 1986-1987 years. During this period, the pollution from Chernobyl accident was emitted to atmosphere. However, the radiocarbon concentration in the tree-rings of these years is quite high, which also shows on local pollution effect. In 1987 year in result of unauthorized increasing of the reactor power the emission of radioactive substances into the environment of Sosnovy Bor City took place. The increasing of radiocarbon concentration to 270 pMC% was recorded in the tree-rings of 2000-2001 years. The emergency situation on the Nuclear Power Plant was registered at May 8 of 2000 year. In 2001 year one of the reactors was stopped. The accident was 1 level on the scale of INES. During last years the radiocarbon content in the tree-rings is at the level of background and poses no threat to the environment.

The distribution of radiocarbon in the grass is shown on the map (Figure.3). The Nuclear Power Plant pollution has low influencing on the radiocarbon concentration in grass. In St. Petersburg City the most high radiocarbon activity at 115-124 pMC% was recorded in the Central part of City with dense traffic activity. In the areas of parks and gardens beyond of City the radiocarbon activity does not exceed 90 pMC%. The high level of radiocarbon activity about 113-130 pMC% was registered in the gardens located near auto and rail way stations. In general, the radiocarbon average activity in the grass cover of the Central part of City is higher than in the vegetation of parks beyond of City (Figure 3). According to Lichtfouse et al. [11] the changes of radiocarbon activity in the grass of cities is the sensitive indicator of CO_2 variations in results of industrial processes. Therefore the radiocarbon can be used for the assessment of air pollution factors. Some authors [12, 13] consider the decreasing of radiocarbon concentration in the atmosphere of industrials regions as result of dissolving of “dead radiocarbon” named “Suess effect” [14]. It is process of emitting to atmosphere the CO_2 of burning of fossil fuel (coal, oil, natural gas). This process was considered with middle 19 century with beginning of the Industrial revolution. After the nuclear test of 1950-1960's prohibition, when the maximum concentration of radiocarbon in the atmosphere was in two times than background natural level the content of radiocarbon began to decline due to the exchange of CO_2 between the atmosphere and ocean carbon reservoir and as a result of increasing of "dead" radiocarbon. At present the content of 14C in atmospheric CO_2 dropped to 115 pMC [15]. So the inflow of large amount of CO_2 to atmosphere emitted in result of urban transport activity reduces the concentration of radiocarbon in annual grasses. The sources of local increasing of radiocarbon in the grass could be the burning of organic debris, the increasing of CO_2 in result of high people density, the quick regeneration of plant biomass and the intensive metabolic processes. [16] The last reaction influences on the autonomic capability of vegetation. According to Pataki et al. [17] the biogenic respiration is one of the possible causes of radiocarbon increasing in the grasses. Especially it is significantly for the regions with high populate density.

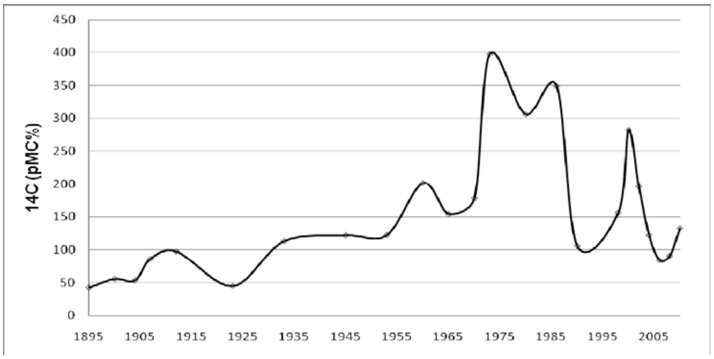

Fig. 2: The distribution of radiocarbon (%pMC) in the tree-rings.

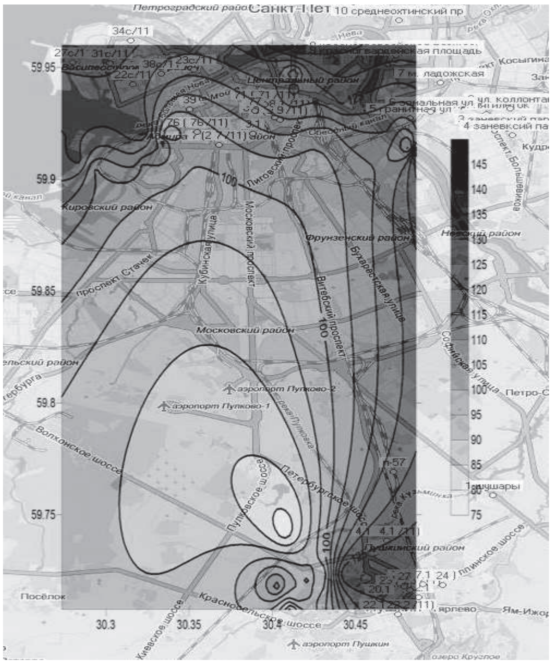

Fig. 3: Map of distribution of radiocarbon (%pMC) in the grass of St.Petersburg City.

2.4. Summary

The variations of radiocarbon activity in the vegetation depend on the different factors. It is radioactive pollutions during Nuclear Power Plant exploitation, the burning of fossil fuels, the changing of carbon dioxide balance due biogeochemical processes. These factors influence both on an increase and decrease of radiocarbon concentration in the environment.

The variations of radiocarbon concentration in the one-year grasses of the city can be used as an indicator of carbon dioxide pollution of the urban environment. In some cases, the carbon dioxide emissions from burning of fossil fuels reduce the concentration of radiocarbon in the environment. In other cases, the carbon dioxide from burning of modern organic debris and different biological processes increase the content of radioactive carbon. These questions require further researches.

The Radiocarbon analysis is a sensitive tool for the registration of radioactive contamination, especially near the Nuclear Power plants. These processes can be registered by the radiocarbon analysis of tree rings. The radiocarbon activity in tree-rings reflects the levels of local and global radioactive contamination which can be considered in the different periods of life of the tree.

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