THE STUDY OF THE TRACE ELEMENT DISTRIBUTIONS IN BULGARIAN TOBACCO PLANTS BY X-RAY AND NUCLEAR ANALYTICAL METHODS

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Abstract

The distribution of trace elements and radionuclides in vegetative and generative parts of Krumgrad 90, Virginia, Burley tobacco plants varieties and soil have been studied. Tobacco plants were grown on the different soil substrates: 3 Bulgarian plantations, Moscow region's soil and on imitation model of soil for high uranium content. We discovered that the alkaline metals are accumulated in the flowers and roots, elements of second group of the periodic table – in leaves, elements with oxidation state +3 – in roots of tobacco plants. We found that the tobacco plant not absorb the thorium (≤0,3 ppm) and accumulate but not concentrate the uranium in roots. Dome effect may be the cause of accumulation lead-210 by leaves of tobacco plants.

Introduction

Tobacco plants *(Nicotiana)* is a genus of herbaceous plants and shrubs of the family Solanaceae. Mainly using of tobacco plants is tobacco industry. During vegetation microelements affect the biochemical processes in tobacco plants [1]. In addition they could effect on the quality of the dried tobacco. Soil characteristics may play important role in their mobility and availability to the plant, because soil is the main source of microelements [2]. Zaprjanova P. with colleges notice about correlations between pH, humus, mobile forms and total content of elements and its concentrations in biomass [3, 4]. Furthermore, the accumulation of trace elements by various tobacco sorts may be different [1, 5]. The purpose of this study is to determine the distribution of the trace element and U and Th natural radionuclide series in biological and soil samples from tobacco plantations using X-ray fluorescence analysis (XRF) and nuclear analytical methods: gamma spectroscopy, gamma activation analysis (GAA).

Experimental

Biological samples of vegetative and generative organs of tobacco sorts Virginia [B514], Krumgrad90 [KRUM], Burley [Б1317] grown at different soil substrates from 3 Bulgarian plantations, Moscow region [Dubna], imitation model of soil for high uranium content [U] were researched. All samples were dried at 105°C and milled for analyses.

Determination of soil aqueous extract pH was carried out by standard method [6] using pH-meter TESTO 206-pH1.

XRF analysis of biological and soil samples with mass 1-3 g was conducted at JINR FLNR by Canberra company standard spectrometer. Radioisotopes of ^{109}Cd (E=22.16 keV, $T_{1/2}$=453 d) and ^{241}Am (E=59.6 keV, $T_{1/2}$=458 y) were used for excitation of X-ray radiation. The characteristic X-ray radiation was detected by the Si(Li) semiconductor detector (30 mm^2 square and 3 mm thickness) with 25 µm thickness beryllium window and 145 eV resolution on the line of 5.9 keV (^{55}Fe). Measuring times were 15-30 min. For spectra processing and calculation of element concentrations in samples WinAxil Canberra software was used.

Natural activity of biological samples with mass 1-20 g and soil samples with mass to 200 g in the polyethylene cassettes were measured by the HP Ge-detector with a 1.5 keV resolution and 1% efficiency on the line of 1.33 MeV (^{60}Co) and GL0515R Ge-detector (15 mm thickness and 500 mm^2 square) with thin (15μm) beryllium window which has a 550 eV resolution and 7% efficiency on the 122 keV line. Measuring time was 24 h.

GAA was conducted at the MT-25 microtron, FLNR JINR. Samples and standards with mass 1-3g in the polyethylene cassettes, closed at the faces of a lavsan film thickness of 6 μm, were simultaneously irradiated by gamma-quanta with energy $E\gamma$ = 24 MeV and by electron current equal to 15 μA for 2-4 h. Uranium was determined by ^{237}U (E_γ=208keV) obtained by reaction $^{238}U(\gamma,n)^{237}U$, thorium was determined by ^{232}Th (E_γ=25,65keV) obtained by reaction $^{232}Th(\gamma,n)^{231}Th$. The gamma-spectrometric measurements of irradiated samples were performed using the HP Ge-detector and Si(Li) detector of XRFA installation. Measuring times were 15-60 min.

Periodical measurements of radon flux density were carried out by Department of Radiation Safety JINR using radiometer PPA-01M-03.

Results and discussion

One of the most important characteristic of the soil – actual pH – was determined. All soil substrates had near neutral pH from 6.20 to 7.84.

Distribution of 23 elements (K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, Rb, Sr, Zr, Nb, Mo, Cs, Ba, La, Ce, Nd, Pb) in biological and soil samples was determined. A typical X-ray spectrum obtained using the ^{109}Cd X-ray source is shown in the Fig. 1.

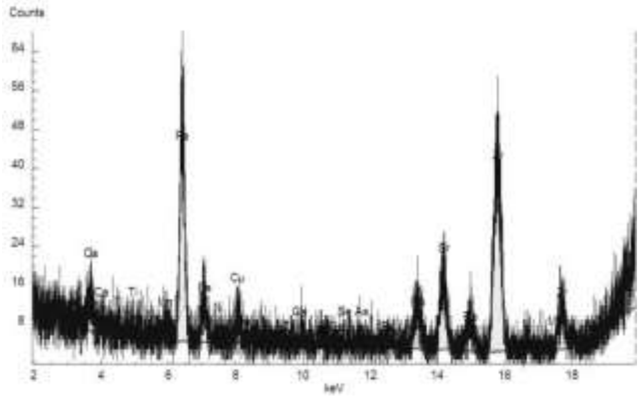

Fig.1. X-ray spectrum of the Bul_Б1317_root sample.

Elements of first group of the periodic table (K, Rb, Cs, including radioactive ^{137}Cs) were accumulated in flowers and roots of tobacco plants. This tendency was increased from K to Cs. The distribution of K, Rb and ^{137}Cs on tobacco plant is shown in the Fig.2. Cesium-137 was low concentrated in seeds: content of this radionuclide was 1,3±0,6 Bq/kg.

Second group elements of periodic table and cadmium were accumulated in tobacco leaves. This tendency was decreased from calcium to barium: Ba was distributed evenly on the vegetative tobacco organs. The distribution of Ca, Sr and Ba on tobacco plant parts is shown in the Fig.3.

The distribution of Fe on tobacco plant parts is shown in the Fig.4.

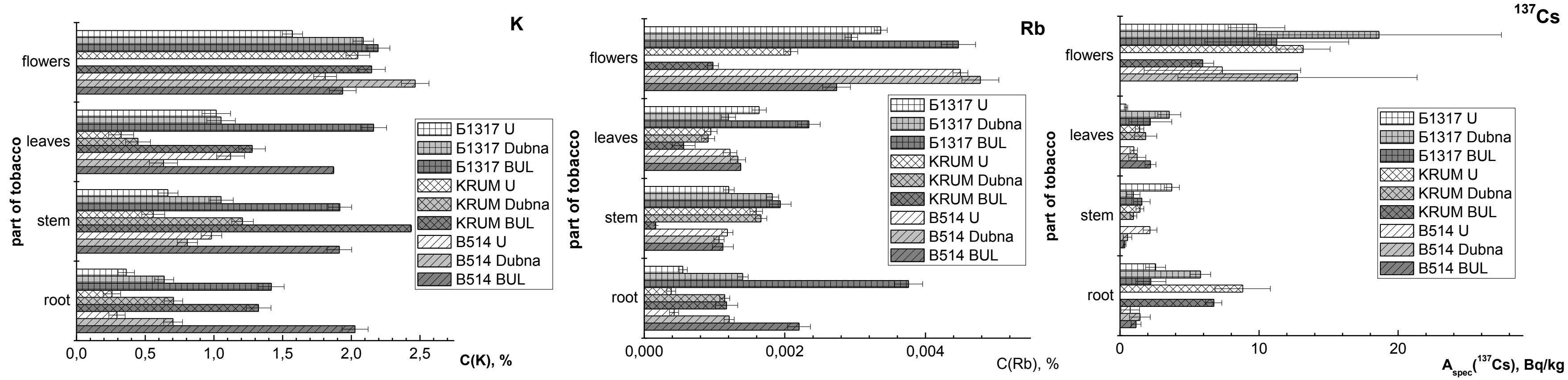

Fig.2. The distribution of K, Rb and ^{137}Cs on parts of tobacco B514, KRUM, Б1317 varieties grown at the various soil substrates.

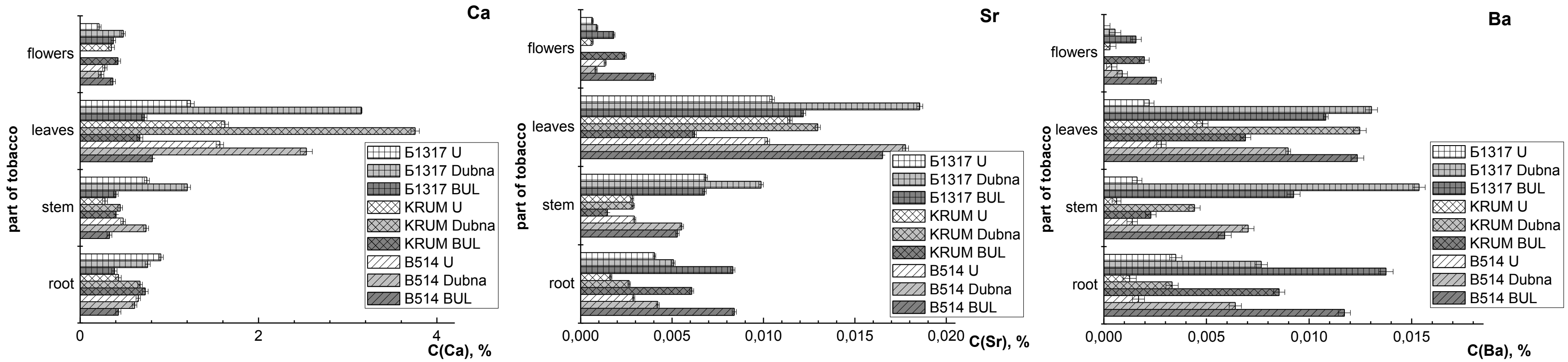

Fig.3. The distribution of Ca, Sr and Ba on parts of tobacco plant B514, KRUM, Б1317 varieties grown at the various soil substrates.

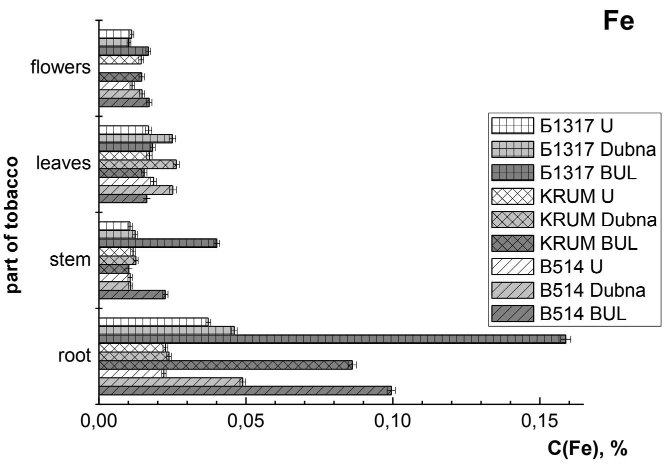

Fig.4. The distribution of Fe on parts of tobacco plant B514, KRUM, Б1317 varieties grown at the various soil substrates.

A higher content in root compared with other tobacco parts was typical for elements which prefer oxidation state +3 (Fe, La, Ce).

The distribution of the natural series radionuclides (^{238}U, ^{222}Rn, ^{210}Pb, ^{232}Th) at the biological and soil samples was explored. Thorium contents in soil were 0.9±0.5 ppm (Dubna) – 3.1±0.4 ppm (KRUM BUL) and ≤0.3 ppm in the tobacco samples. The distribution of U on tobacco plant is shown in the Fig.5.

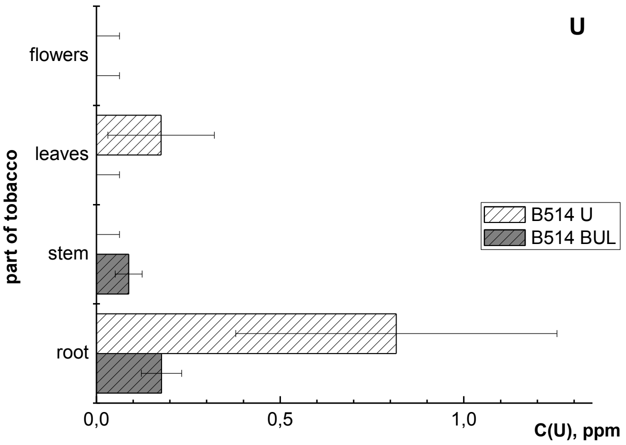

Fig.5. The uranium distribution on tobacco plant parts of B514 variety grown at the Bulgarian plantation ($C(U_{in\ soil})$=1.72±0.05 ppm) and at the soil with high uranium content ($C(U_{in\ soil})$=127±6 ppm).

Uranium was accumulated mostly in roots.

Difference in the intake of lead as natural isotope composition, which distributed evenly (XRF), and lead-210, which accumulated in leaves (γ-spectroscopy) was discovered. The distribution of the Pb and ^{210}Pb on tobacco plant is shown in the Fig.6.

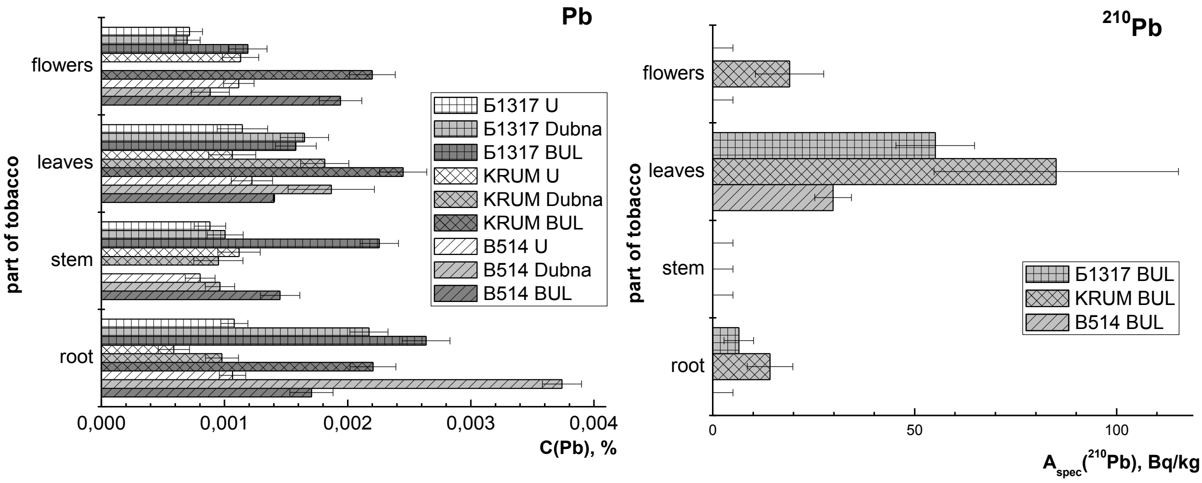

Fig.6. The distribution of Pb on parts of tobacco plant grown at various soil substrates and ^{210}Pb on parts of tobacco plant grown at the Bulgarian plantations (B514, KRUM, Б1317 varieties).

This difference could be linked with storage of ^{222}Rn under lower tobacco leaves formed domed effect. Hypothesis about probability of uptake radon decay products not for soil directly by plant roots was considered at [7].

Periodically measuring of radon flux density was conducted. It was 56±22 mBq/s·m^2 – 85±34 mBq/s·m^2 for Moscow region soil substrate and 124±49 mBq/s·m^2 – 186±74 mBq/s·m^2 for soil substrate with high uranium content. This value depends on season oscillations more than on uranium content in soil substrates.

We didn't detect notable affect of general microelement and radionuclide content in soil on its intake to tobacco plant from soil. Significant difference of contents in soil substrates was observed for Cs, Fe and U. Cesium-137 contents in the soil substrates were from 2.28±0.04 Bq/kg (Dubna) to 27.0±0.5 Bq/kg (KRUM, BUL); iron contents – from 0.027±0.007 % (B514, BUL) to 2.14±0.02 % (soil substrate with high U-content); uranium content – from 0.9±0.1 ppm (Dubna) to 127±6 ppm (soil substrate with high U-content). At the same time content of considered elements changed insignificant at each separate tobacco part. It agree with chemosystematization idea [8], which point that species-specific microelement profile of plant should reflect its systematic position as well as influence of general trace element content in soil on microelement profile of plant is small.

The contents obtained of K, Ca, Fe, Cd in tobacco parts were agreed with [1] results. However, we didn't find the good correlations with element content in soil and its content in tobacco part like at [3, 4].

Conclusions

Accumulating of microelements is species-specific and low depends on tobacco sort and microelement soil content. Alkaline metals have tendency to accumulate in the flowers and roots, bivalent elements – in leaves, elements with oxidation state +3 – in roots of tobacco plants. Thorium not absorbed by tobacco plant, uranium accumulated but not concentrated by tobacco roots. Dome effect may be cause of accumulation lead-210 by leaves of tobacco plant.

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