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Contents of macro-, microelements and long-lived radionuclides in the medicinal plants belonging to the wetland community of Siberian region, Russia

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ABSTRACT

Studied contents of macro-, microelements and long-lived radionuclides in the following medicinal plants belonging to the wetland community of Siberian region, Russia: *Sphagnum fuscum* (Schimp.) Klinggr., *Sphagnum balticum* (Russ.) Russ. ex C. Jens., *Polytrichum strictum* Brid., *Pinus sylvestris* L., *Pinus sibirica* Du Tour, *Betula pubescens* Ehrh., *Andromeda polifolia* L., *Ledum palustre* L., *Oxycoccus palustris* Pers., *Rubus chamaemorus* L., *Vaccinium uliginosum* L., *Comarum palustre* L., *Chamaedaphne calyculata* (L.) Moench. Samples were collected in the sphagnum wetlands of Tomsk region and Khanty-Mansi Autonomous Okrug. For the purpose of research, we used roots, shoots and bark of the plants in the Pinophyta and Magnoliophyta species and turf of the Bryophyta species. The content of macro-, microelements in the plants was determined by an atomic emission spectrometer with inductively coupled plasma “iCAP 6300 Duo” of the “Thermo Scientific” company. The specific activities of the long-lived radionuclides Th-232, K-40, Ra-226, Cs-137 were measured by a gamma-ray spectrometric complex with a high purity germanium semiconductor detector by “ORTEC” (AMETEK) and a digital analyser “ORTEC DSPEC LF”. The obtained results of the element content are useful when selecting a medicinal plant species (or part thereof) which may be used in preparation of new medicinal drugs.

1. Introduction

Drugs based on medicinal plant raw have long and thoroughly entered the curative practice, because they usually have a soft and wide therapeutic effect, are not toxic, practically have no side effects and are affordable. A wide range of their action is explained by the multi-component composition of biologically active substances of various nature. At the present time, every third medical preparation is prepared on the basis of raw materials (Potselueva, 2012). According to WHO, up to 80% of the world’s population prefer to be treated by means of natural plant origin (Voznesenskaya, 2006). Creation of new medicinal drugs requires systematic data on the amounts of organic and mineral substances contained in medicinal plants. When conducting research in this field, major focus is made on the study of organic compounds (e.g. see (Kaškoniene and Stankevičius, (2015); Prota et al., 2014; Li and Gao, (2014); Li and Gao, 2015; Verma et al., 2015; Fahmy et al., 2015; Dong et al., 2013)). However, treatment of many diseases requires medications containing certain macro- and micronutrients. It is well known that the physiological effect of different elements depends on their dose (Skalniy and Rudakov, 2004), and an increased content of long-lived radionuclides can be dangerous to human health. Despite the increasing use of plant raw materials in the production of medicinal drugs, the available data on the content of chemical elements in medicinal plants is extremely insufficient (Tripathy et al., 2015; Yuan et al., 2011, 2009; Chen, 2009; Naidu et al., 1999; Kan, 2011; Kan et al., 2011; Nischwitz et al., 2017; Filipiak-Szok et al., 2015; Jin et al., 2016; Aziz and Adnan, 2016; Chizzola et al., 2003; Karabagias et al., 2017; Volpe et al., 2015; Rashid et al., 2016; Stef and Gergen, 2012; Ebrahim et al., 2012; Ražić et al., 2008; Majid et al., 1995; Sarmani et al., 1999; Nedjimi and Beladel, 2015; Jia et al., 2011; Babeshina et al., 2016; Birch and Padgham, 1994; Babeshina, 2011; De Britto Pereira and Felcman, 1998).

The content of chemical elements in plants is known to depend on climatic conditions of their habitat (Borisenko et al., 2014). The same is evidenced by the findings of our research published in the works of multiple international conferences. This research involves samples of the medicinal plants collected in the wetland communities of Khanty-Mansi Autonomous Okrug and Tomsk region. These territories are

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Table 1
Research items, dates and areas of sampling.

Division	Family	Species	Part of the plant	Areas and dates (dd/mm/yyyy) of sampling
Bryophyta	*Polytrichaceae*	*Polytrichum strictum*	turf	KMAO Chistoye Marshes 06/08/03
	Sphagnaceae	*Sphagnum balticum*	turf	KMAO Chistoye Marshes 06/08/03
		Sphagnum fuscum	turf	Tomsk region Chaginskoye Marshes 28/08/08
		Sphagnum fuscum	turf	Tomsk region Chaginskoye Marshes 27/05/08
		Sphagnum fuscum	turf	Tomsk region Bakcharskoye Swamp 15/07/09
Pinophyta	*Pináceae*	*Pinus sylvestris*	shoots, bark	KMAO, Shapsha village Chistoye Marshes 07/08/03
		Pinus sibirica	shoots, bark, roots	KMAO, Shapsha village Chistoye Marshes 07/08/03
Magnoliophyta	*Betulaceae*	*Bétula pubéscens*	shoots, bark, roots	KMAO, Shapsha village Chistoye Marshes 07/08/03
	Ericaceae	*Ledum palustre*	shoots	KMAO, Shapsha village Chistoye Marshes 07/08/03
		Vaccinium uliginosum	branches, roots, leaves	KMAO, Shapsha village Chistoye Marshes 07/08/03
		Oxycoccus palustris	shoots	KMAO, Shapsha village Chistoye Marshes 07/08/03
		Andrómeda polifolia	shoots	KMAO, Shapsha village Chistoye Marshes 07/08/03
		Chamaedaphne calyculata	shoots	KMAO, Shapsha village Chistoye Marshes 07/08/03
	Rosaceae	*Cómarum palústre*	shoots	KMAO, Shapsha village Chistoye Marshes 07/08/03
		Rubus chamaemorus	shoots	KMAO, Shapsha village Chistoye Marshes 07/08/03

sparsely populated, therefore environmentally clean, and may be used for collecting medicinal raw materials.

The studied plants are representatives of three divisions of medicinal plants belonging to the wetland community (Table 1). For the purpose of this research, in gymnosperms and angiosperms species, different parts were used: the roots, shoots, bark, in mossy species – the turf.

There is abundant evidence that the above referenced plants are widely used in traditional medicine of different countries (Elina, 1993). For example, the use of sphagnum mosses is based on the bactericidal, wound-healing, haemostatic properties and high hygroscopicity of these plants (Jia et al., 2011; Birch and Padgham, 1994; Dmitruk et al., 2011; Babeshina et al., 2016, 2015; Babeshina, 2011). *Polytrichum species* are used in Oriental medicine as antipyretic and diuretic, also to dissolve stones in kidneys and gall bladder. In medical practice, they commonly use anti-inflammatory, antiscorbutic, disinfectant, expectorant and diuretic properties of the drugs made from *Pinus sylvestris*. Extracts of *Ledum palustre* shoots have antiseptic, expectorant, analgesic, wound-healing and diuretic effect. Used externally, Ledum makes a good remedy for gout, rheumatism, neuralgia, scrofula, and skin diseases. Diuretic, choleretic, bactericidal, anti-inflammatory and wound-healing effect of extracts of *Betula pubescens* leaves and *Comarum palustre* shoots are widely known; *Rubus chamaemorus*, *Vaccinium uliginosum*, *Oxycoccus palustris* are used to treat many diseases, including cardiovascular and gastrointestinal diseases (Elina, 1993; Pavlova and Karadjova, 2013).

2. Experiment

The plants were gathered in the sphagnum wetlands of Tomsk region and Khanty-Mansi Autonomous Okrug (KMAO), the Russian Federation. The plants were collected under field conditions; to obtain representative samples of the plants weighing 0.5–1.0 kg of natural humidity, at least 8–10 spot samples were collected. The roots were dug out, the aboveground part of the plant was cut with a sharp knife (bark) or scissors (shoots) at a height of 15–50 cm above the soil surface, the Bryophyta species were collected manually. All samples were dried up to constant weight in the shade at room temperature in a well-ventilated area and stacked in a plastic film or kraft paper. It should be noted that the roots were thoroughly washed with distilled water before drying.

The study included 13 species of the wetland medicinal plants. Table 1 presents plant species and their parts as well as areas and dates of sampling; the total number of samples collected is 22.

Prior to taking measurements, the samples were dried and comminuted in a porcelain mortar; for statistical processing of the results, three parallel specimens were made from each sample. The measurements were performed in the scientific and analytical centre of the Tomsk Polytechnic University (Russian Federation) on an atomic emission spectrometer with an inductively coupled plasma "iCAP 6300 Duo" of the "Thermo Scientific". Contents of the following chemical elements were determined: Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Si, Sn, Sr, Te, Ti, V, W, Zn. Based on the measurement results, we calculated relative standard deviation $\delta = \frac{\sigma}{\bar{c}}\cdot 100\%$ ($\bar{c}$ – concentration averaged by parallel specimens, σ – standard deviation); for the vast majority of chemical elements δ did not exceed a few percent.

Prior to measurement, preparation of moss samples was carried out in accordance with the procedure of Ryzhakova et al. (2014) (RF patent No. 2,463,584, 2012). In order to reduce any potential errors, two parallel samples were prepared. Using atomic emission spectrometry, Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Si, Sr, Ti, V, and Zn concentrations were determined in the samples. Depending on the chemical element, the measurement error ranged from 20 to 50%.

A reliability check of the analysis results was carried out using the frame of reference $q = \frac{\bar{c} - c_{at}}{c_{at} \cdot \delta}$, where $\bar{C}$ is the average measured chemical concentration in two parallel samples of a reference sample, c_{at} is the certified concentration of the chemical element in the same reference sample, and δ is the error when determining the concentration of the chemical element.

To validate the reliability of the results of the AES analysis, a reference "birch leaf" sample was measured, for which the certified content of the following elements was known: Al, Ba, Co, Cu, Fe, Li, Mn, Na, Sr, Ti, and V. From the data obtained, we can consider the results for Ti as reliable with an accuracy of 50%; those for Na and Co as reliable with an accuracy of 40%; those for Ba, Mn, Sr, and Fe as reliable with an accuracy of 30%; those for Al and V as reliable with an accuracy of 25%, and those for Cu as reliable with an accuracy of 20%.

In the studies conducted, the content of the long-lived radionuclides Th-232, K-40, Ra-226, Cs-137 was measured by means of a semiconductor gamma-ray spectrometer equipped with a germanium-based detector, DGDK-100V type. The detector was placed in a low-background chamber, which is a combined protection in the form of a sequential set of layers of lead (100 mm), steel (10 mm) and aluminium (10 mm). For measurements, 0.22 l plastic containers were used; depending on the plant species and its part, the mass of the samples was 5…12 g. The spectrometric data processing was administered via AnGamma 3.24 program having photopeaks at energies 295, 352, 609 keV for determining Ra^{226}; 583, 911 keV for determining Th^{232}; 661 (Cs^{137}); 1460 keV (K^{40}). In order to obtain results with an error not exceeding 10...15%, the measurement time was two-three days. Before the measurements, the efficiency of the spectrometer was carried out using a calibration source.