Trace elements in peat bogs of Tomsk region (South Siberia, Russia)

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(Received 11 August 2012; accepted 16 February 2013)

Abstract
16 peat bogs of Tomsk region (in Siberia) were used to study trace elements concentrations in ombrotrophic peat. The calculations of concentration coefficient in relation to the sedimentary rocks allowed us to determine some elements which tend to accumulate in ombrotrophic peat of Tomsk region. They are Au, Br, Sr, Ba, Fe, and Cr. For selective trace elements we considered spacial variability of their mean contents in the ombrotrophic peat of Tomsk region. Together with the study of vertical distribution of trace elements in the studied peat bogs we outlined factors influencing their accumulation in peat. Lithological and mineral composition of surrounding territories plays role in the accumulation of Cr, Sc, Br, Au, and lanthanides, climatic conditions and necessity for living plants cause Ca variations. Cr, Sc, lanthanides and U are also actively accumulated in the peat near industrial cities in the south of Tomsk region.

Keywords: Peat, Trace elements, Siberia

1. INTRODUCTION

Peat bogs in Tomsk region are typical bogs of cool regions, dominated by the growth of bog mosses, *Sphagnum fuscum*. The peat bogs in Tomsk region constituent approximately 60% of the whole number of wetlands of this region (Inisheva *et al*., 1995).

With the retardation of decomposition of the dead moss, a *Sphagnum* peat develops under the living plants. This is particularly the case in areas where there is a mean annual temperature of below 10 ? (50 ?), which also retards decay (Verhoeven *et al*., 2006).

Peat bogs are fed predominately by atmospheric deposition. The peat underlying a *Sphagnum* bog is composed largely of partly decomposed moss. There may be some inclusion of windblown particles, pollen, and dust. These inclusions, precipitated from the atmosphere, can be of natural or anthropogenic origin.

Geochemical composition of peat is of interest for various directions of human activity. Peat is widely used in cosmetology, agriculture, and as a fuel. Thus, the estimation of trace elements concentrations in peat profiles is a primary task for its further use. The data on peat geochemistry are also important for ecological studies when moss and peat are used as environmental indicators (Glooschenko and

Capobianco, 1978; Headley, 1996; Shotyk *et al*., 1996, 2001; Martinez-Cortizas *et al*., 1997; West *et al*., 1997; MacKenzie *et al*., 1998; Weiss *et al*., 1999; 2002; Kempter and Frenzel, 2000; 2007; Ukonmaanaho *et al*., 2002; Wang *et al*., 2011).

Trace elements in Siberian peat bogs have been studied by several investigators. In the biggest marsh in Siberia, Great Vasyugan moor, geochemical peculiarities of stagnant water and wetland plants are well correlated with the climatic changes and lithological peculiarities of rocks (Rasskazov *et al*., 2002). First studies of trace elements in peat of Tomsk region belong to Arkhipov *et al*. (1988), Bernatonis *et al*. (1990), Boyarkina *et al*. (1993), and Inisheva L.I. (1994).

Present research accomplishes earlier studies on trace elements in peat of West Siberia, particularly in Tomsk region, and represents a wide range of studied chemical elements and peculiarities of their special and vertical variability.

2. METHODS

16 peat bogs of Tomsk region have been studied. The location of these bogs is represented at the Figure. 1. For this study we used own analytical data and published data on peat geochemical composition of V.M. Gavshin *et al*., 2003 (1 bog).

Peat samples were taken from the central parts of bogs where surface flow is minimal. The upper 30 cm of peat bogs were sampled by the method of trial pit. Below this interval samples were collected using geological peat drill (with a volume of 50 cm^3) to the bottom of a peat deposit. Intervals of the sampling were ranged from 2 cm (in the upper part of the peat bogs) to 25 cm.

The samples were dried at room temperature and then were reduced to powder. For analytical research the dry fine-particle samples were formed in tablets with a diameter of 8 mm and weight of 100 mg. Dry peat powder was also ashed to determine the ash yield.

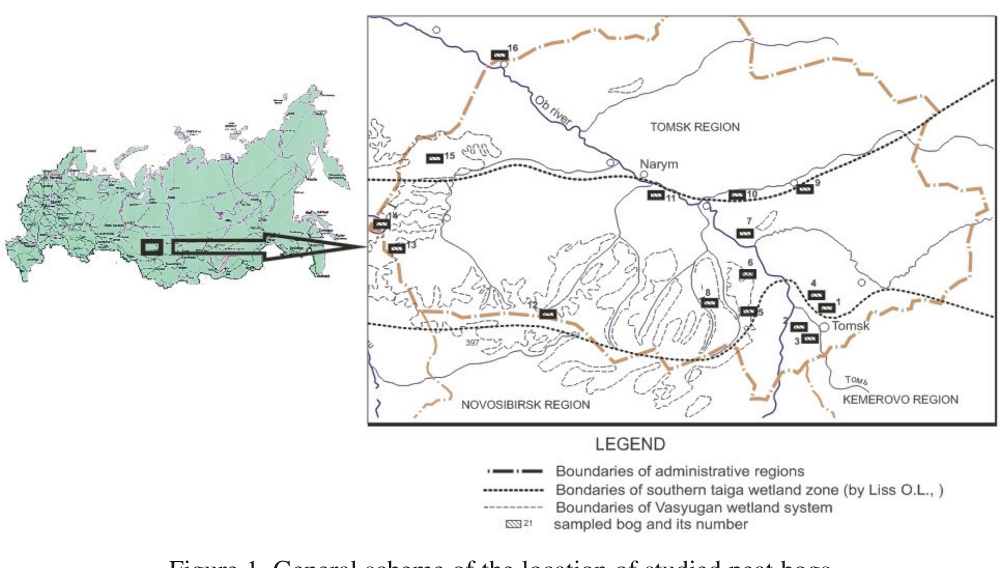

Figure 1. General scheme of the location of studied peat bogs.

For analytical investigations of peat the method of instrumental neutron-activation analysis (INAA) is more perspective as it does not need for special sample preparation and has a low detection limit (Arkhipov *et al*., 1988). Laboratory measurements of trace elements were carried out at the Nuclear-Geochemical Laboratory (NGL) of the Department of Geoecology and Geochemistry of Tomsk Polytechnic University (TPU) (analysts A.F. Sudyko and V.M. Levitskiy) using the research nuclear reactor IRT-T at the Scientific Research Institute of Nuclear Physics of TPU. Using this method, 25 trace elements were detected.

To show a contrast of element concentrations the concentration coefficient was calculated:

$$CC = C/C_b \ (1),$$

where C is an element concentration and C_b is its mean content in sedimentary rocks according to Grigoriev N.A. (2003).

3. RESULTS AND DISCUSSION

The accumulation of trace elements in peat bogs of Tomsk region can be described by a concentration coefficient (*CC*) in relation to the mean content in sedimentary rocks by Grigoriev N.A. (2003). Based on the data of the Table 1 this coefficient, calculated according the formula (1), allowed to outline some specific for Tomsk region elements. As a whole the peat bogs of Tomsk region selectively accumulate Au, Br, Sr, Ba, Fe, Cr (Fig. 2). The data on Au accumulation in studied peat are confirmed by our previous studies on Au accumulation in coal and peat of Western Siberia (Arbuzov *et al*., 2006).

Table 1. Mean contents of some trace elements in peat bogs of Tomsk region (Russia), mg kg^{-1} (Mezhibor *et al*., 2009).

Elements	Concentration in dry matter, mg kg^{-1} (1441 samples)	Elements	Concentration in dry matter, mg kg^{-1} (1441 samples)
Na (%)	0.037±0.006	La	1.6±0.4
Ca (%)	0.57±0.05	Ce	3.8±0.8
Sc	0.56±0.06	Sm	0.40±0.08
Cr	11.6±3.3	Eu	0.08±0.02
Fe (%)	0.43±0.12	Tb	0.040±0.005
Co	1.5±0.2	Yb	0.12±0.01
Br	17.7±3.7	Lu	0.019±0.001
Rb	1.7±0.2	Hf	0.17±0.02
Sr	42±19	Ta	0.015±0.003
Ag	0.028±0.009	Au	0.019±0.011
Sb	0.11±0.02	Th	0.45±0.08
Cs	0.14±0.02	U	0.31±0.08
Ba	37.7±6.6	Ad (%)	3.2±0.3

Comments: Ad is the ash yield of the peat.

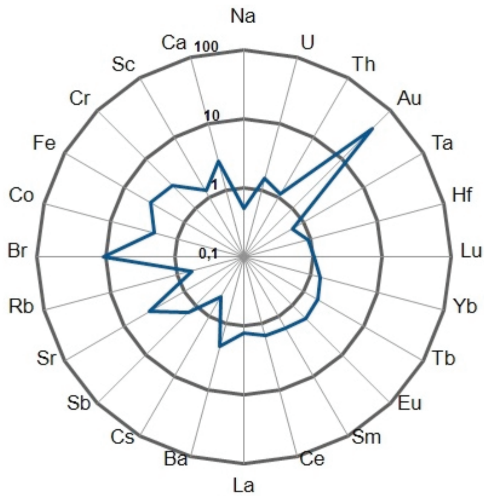

Figure 2. Concentration coefficient of trace elements in the ash of peat bogs of Tomsk region in relation to the mean content in sedimentary rocks by Grigoriev N.A. (2003).

3.1. Spacial variability of trace elements

3.1.1. Ash content

Figure 3 shows the distribution of ash content in the ombrotrophic peat of Tomsk region. The maximum of it is in the south-eastern part of Tomsk region - around the industrial centers Tomsk and Seversk. If to exclude high-ash samples from the bog near Tomsk-Seversk industrial agglomeration, we can observe the increase of ash-content in the ombrotrophic peat from south to north.

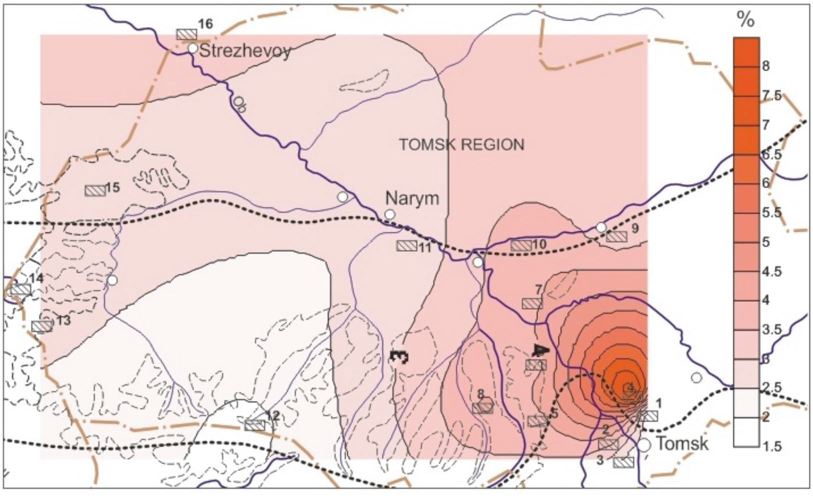

Figure 3. Ash content variability in peat bogs of Tomsk region.

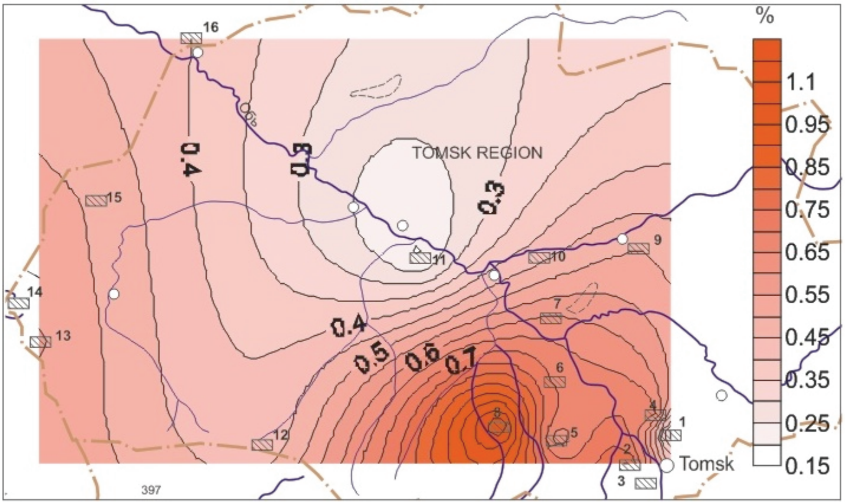

Figure 4. Ca variability in peat bogs of Tomsk region.

3.1.2. Ca

Ca is one of essential elements for any plant, therefore it is well accumulated by bog plants. From the Figure. 4 it is obvious, that Ca concentration decreases from south to north. Such changes in Ca concentration can be confirmed by the data of Rasskazov *et al*. (2002), who noted a decrease of Ca concentration in ground waters of Tomsk region from south to north.

3.1.3. Cr

At the Figure 5 we can see a pronounced increase of Cr concentration from south to

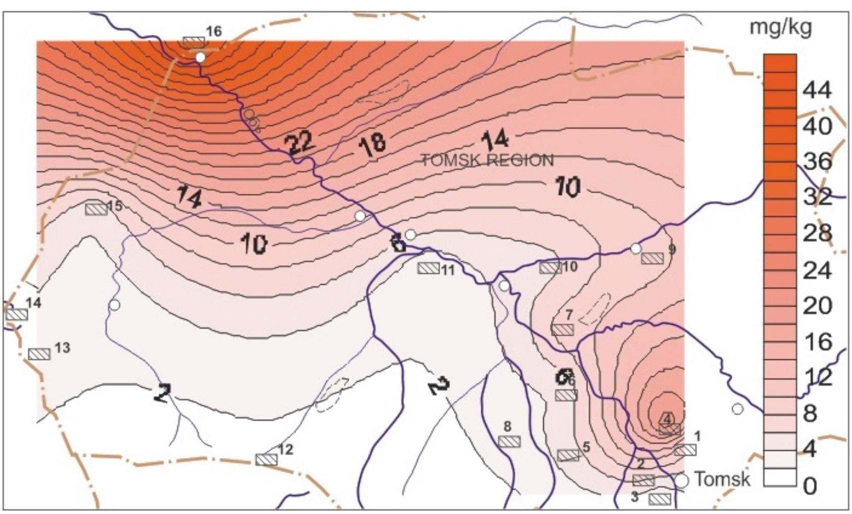

Figure 5. Cr variability in peat bogs of Tomsk region.

north. Cr concentration in peat generally reflects the amount of mineral matter present (Shotyk *et al*., 1990). Tomsk-Seversk industrial agglomeration is notable for high concentrations of Cr in peat because of the industrial specificity of this area (Mezhibor *et al*., 2009).

3.1.4. Sc

In studies of peat cores Sc is considered as a conservative reference element (Shotyk *et al*., 2001) and Sc concentration in peat bogs reflects its supply with soil-derived atmospheric aerosols (Steinmann and Shotyk, 1997).

In Sc space distribution we noted its increase from south-east to north-west (Fig. 6). With the exception of the south-eastern area of Tomsk region, where the complex of various industries in the cities Tomsk and Seversk created a complicated geochemical environment (Rikhvanov *et al*., 2006), Sc distribution in peat is determined by the composition of surrounded territories.

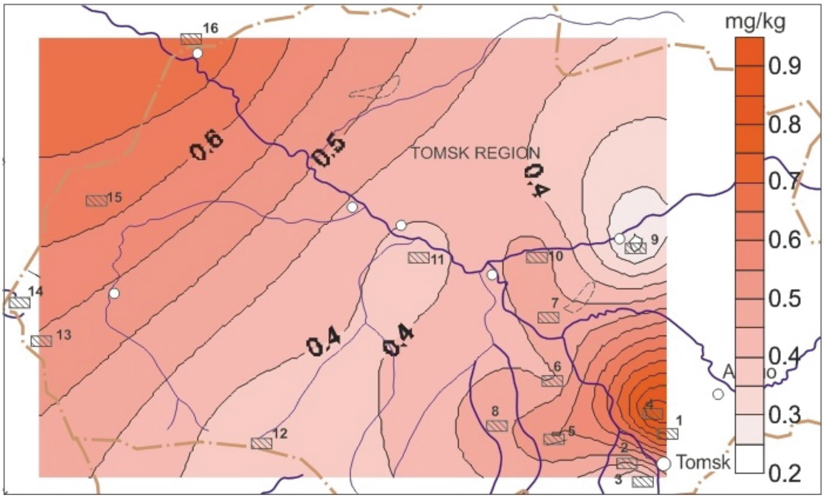

Figure 6. Sc variability in peat bogs of Tomsk region.

3.1.5. Au

Au variability in the ombrotrophic peat of Tomsk region is irregular with spots of Au localization (Fig. 7). Such localizations can be explained by the geological peculiarities of surrounded territories. For example, anomaly in the south can be connected with the existing Au deposits in the mountain system of Salayr.

3.1.6 Br

Like Au bromine has spot distribution at the territory of Tomsk region (Fig. 8). Such localization is possibly connected with the irregular allocation of marine sediments in the geological structure of the territory.

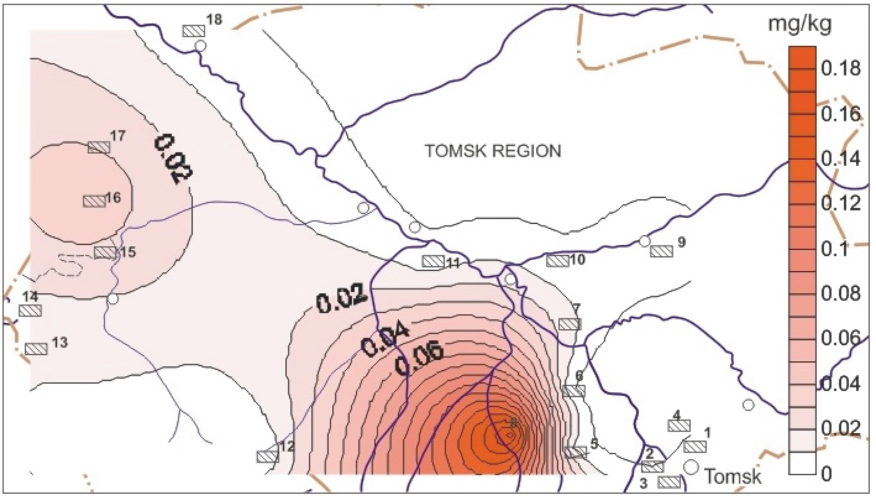

Figure 7. Au variability in peat bogs of Tomsk region.

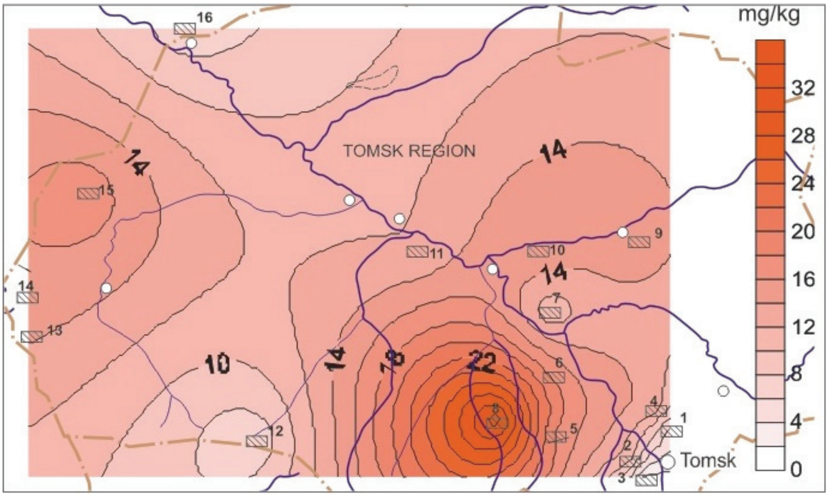

Figure 8. Br variability in peat bogs of Tomsk region.

3.1.7. Lanthanides

The accumulation and distribution of lanthanides in peat are not yet studied. Despite the common properties of all lanthanides the schemes of their distribution are not similar and have not any specific variability. Regional soil-derived lithogenic aerosols are considered as the main source of rare earth elements in peat bogs (Aubert *et al*., 2006). Thus, clay and sand particles are possible the main source of lanthanides in studied peat of Tomsk region. For almost all lanthanides we noted their higher concentrations in the south-eastern area of Tomsk region. Accumulation of REE in the south-eastern area of Tomsk region can be caused by the influence of nuclear facility in Seversk (Rikhvanov, 2009).

3.1.8. U

In the U space distribution we have noted a regularity of its increase in the northern direction (Fig. 9). Such an evident regularity is possibly connected with climatic and lithological changes from south to north.

3.2. Vertical variability

The vertical distribution and accumulation of trace elements in peat bogs depends on many factors. The most important of them are climatic and redox conditions, and the intensity of atmospheric fallouts.

When comparing the vertical distribution of trace elements in the studied bogs we outlined three types of the vertical distribution: A - type of regular distribution with weak anomalies; B - type of weakly differentiated distribution with anomalies in the top part; C - type of pronounced distribution with contrast anomalies in the top part. According to the outlined types of vertical distribution we have chosen 3 bogs for more detailed description. A bog, corresponding to the type A is located in a background area (bog number 12). A bog of the type B is located in the area of oil deposits exploration (bog number 13). A bog of the type C is located in the influence zone of Tomsk-Seversk industrial agglomeration (bog number 1). These tree bogs are described in detail below.

Like other macro and micro nutrients, *Ca* in raw peat reaches the highest concentrations in the top layers of a core (Zaccone *et al*., 2007). Ca is rather mobile and its accumulation in the top parts of bogs is connected with its migration to the

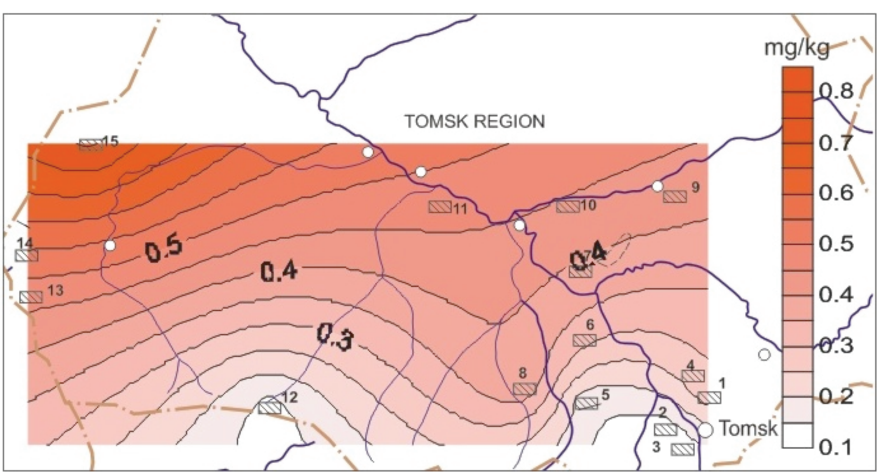

Figure 9. U variability in peat bogs of Tomsk region.

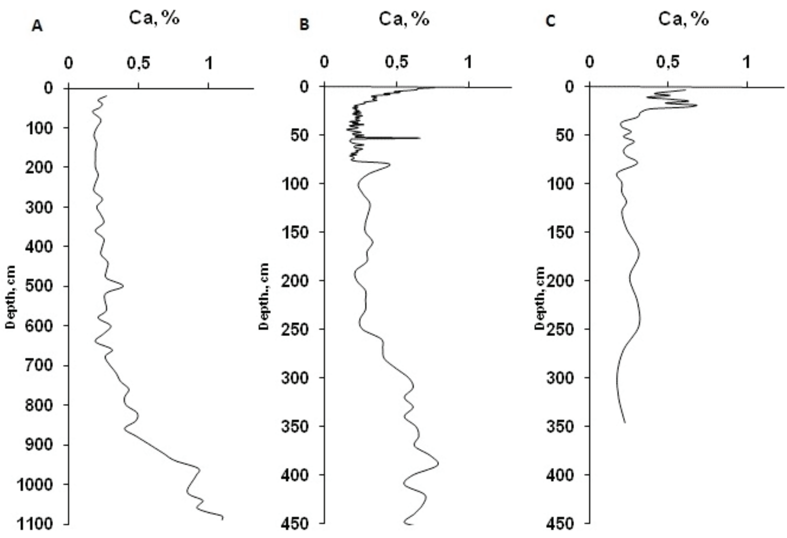

Figure 10. Ca variability in 3 peat sections from areas of different degree of antropogenic influence (types A, B, and C are described in the text).

plant roots (Urban *et al*., 1990). In studied bogs we also noted its accumulation at the bottom parts of bogs (Fig. 10).

Cr vertical variability in the peat sections is rather complicated. Background contents are low (Fig. 11 A), when in the territories with anthropogenic influence we note its increase in the top parts of bogs (Fig. 11 B, C).

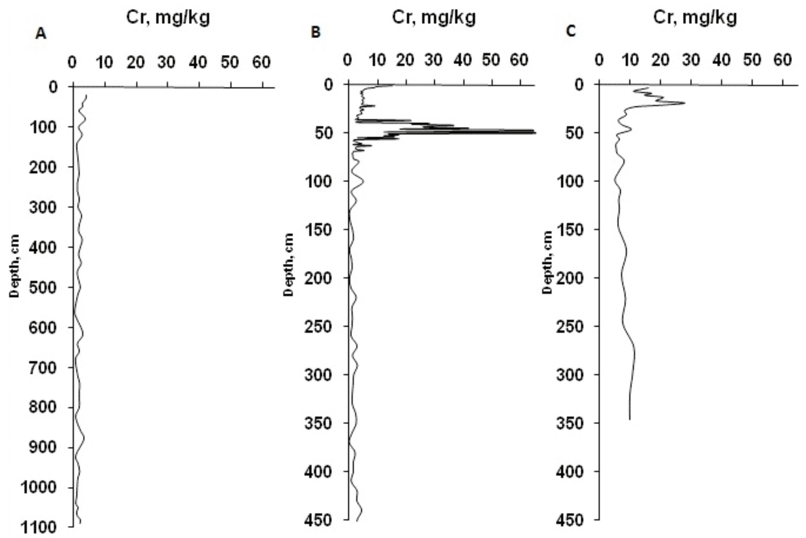

Figure 11. Cr variability in 3 peat sections from areas of different degree of antropogenic influence (types A, B, and C are described in the text).

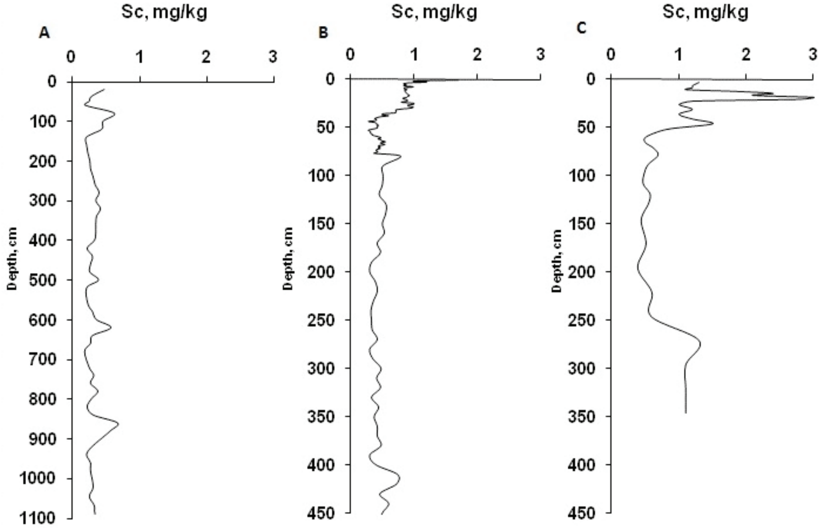

Figure 12. Sc variability in 3 peat sections from areas of different degree of antropogenic influence (types A, B, and C are described in the text).

Sc distribution in background territories is relatively regular (Fig. 12A), but its concentrations in the top part of peat bogs increase notably under the anthropogenic activity (Figs. 12B and C).

Au variability in the peat sections is irregular and explained generally by natural factors. Au does not have preferable property to accumulate in the top, central of bottom pars of bogs and is specific for every definite bog (Fig. 13).

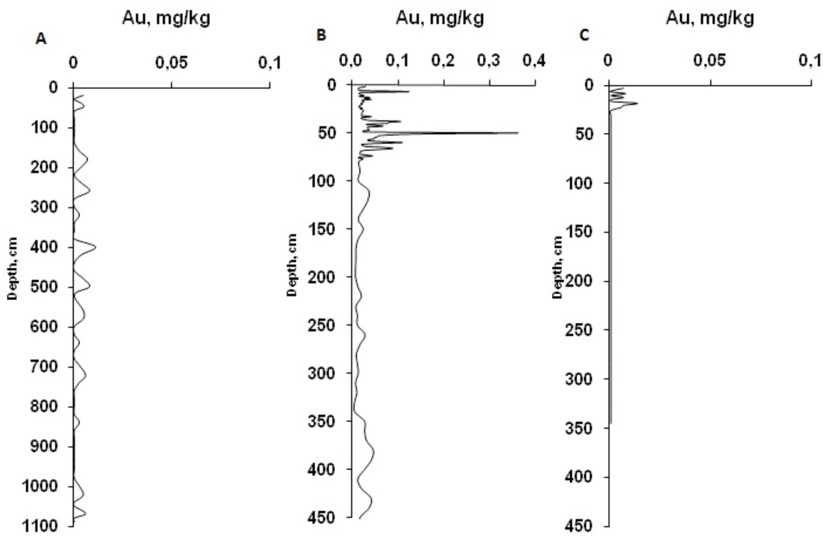

Figure 13. Au variability in 3 peat sections from areas of different degree of antropogenic influence (types A, B, and C are described in the text).

Br is considered as an element, accumulated in peat because of its strong relation with humic acids of peat (Zaccone et al., 2008). In the peat of Tomsk region it is mostly accumulated in the bottom part of bogs. This can be explained by the presence of sea sediments in geological structure of West Siberian Plate (Roslyakov and Sviridova, 1998). In the bog, located in the area of oil fields localization, Br concentration is higher and irregular (Fig. 14 B).

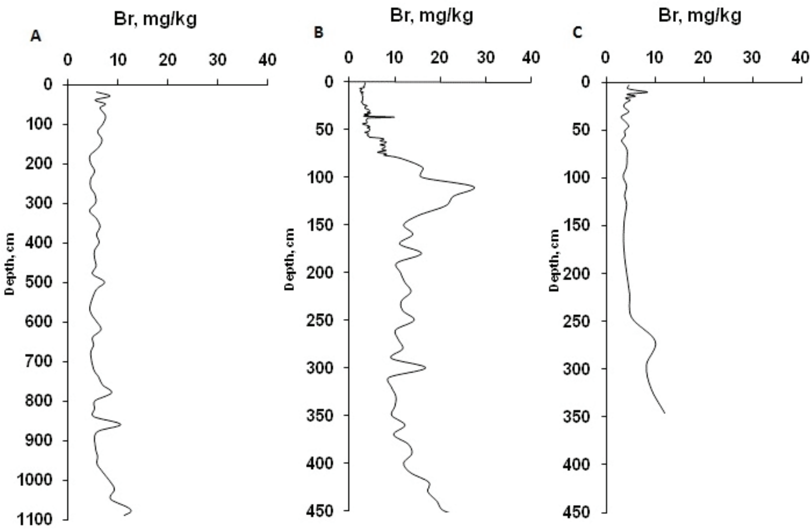

Figure 14. Br variability in 3 peat sections from areas of different degree of antropogenic influence (types A, B, and C are described in the text).

REE patterns of peat are not biologically fractionated and allow potentially the identification of an atmospheric signal (Aubert et al., 2006). The shapes of all lanthanides concentration profiles with depth in the peat sections are similar, with the profiles of La and Yb concentrations shown for example (Fig 15). From the picture we can surely note high concentrations of lanthanides in the top part of the bog near the cities Tomsk and Seversk (Fig. 15 C).

U distribution in peat sections of peat bogs is relatively regular with the exception of the bog located in the influence zone of the nuclear facility in Seversk. This bog is notable for the accumulation of U in its top part (Fig. 16 C).

4. CONCLUSION

Because of the important role of peat in human activity, particularly in Tomsk region where peat has a wide application, the estimation of trace elements concentrations in it and their variability in the territory of Tomsk region have defined the choose a problem to study.

Peat bogs of Tomsk region selectively accumulate such elements as Au, Br, Sr, Ba, Fe, and Cr. First of all their accumulation in peat is defined by the composition of dust

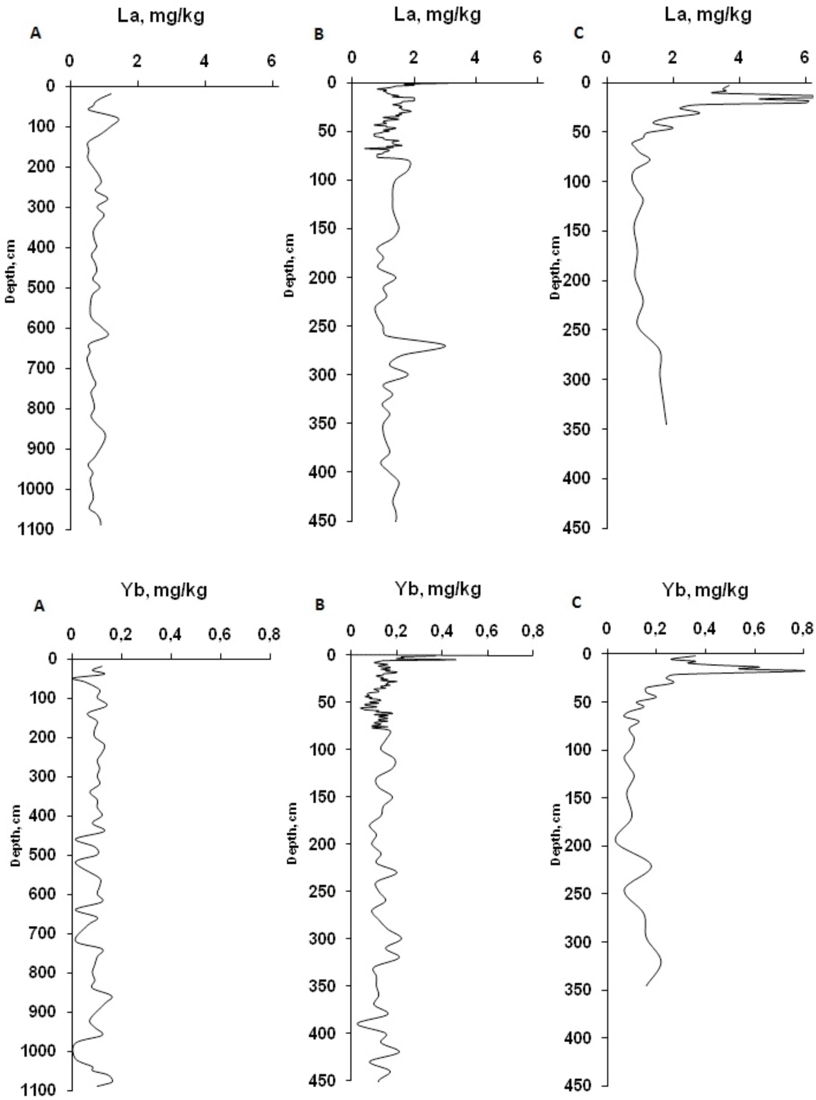

Figure 15. La and Yb variability in 3 peat sections from areas of different degree of antropogenic influence (types A, B, and C are described in the text).

and sand particles from surrounding territories. In this case spacial variability of Cr, Sc, Au, and Br depends on the lithological and mineral composition of nearest areas. Climatic factor plays also a role in the spacial variations of trace elements, for example, Ca increase in peat from south to north correlates with similar changes in water composition.

High contents of Cr, Sc, REE and U in the peat of the south-eastern part of Tomsk

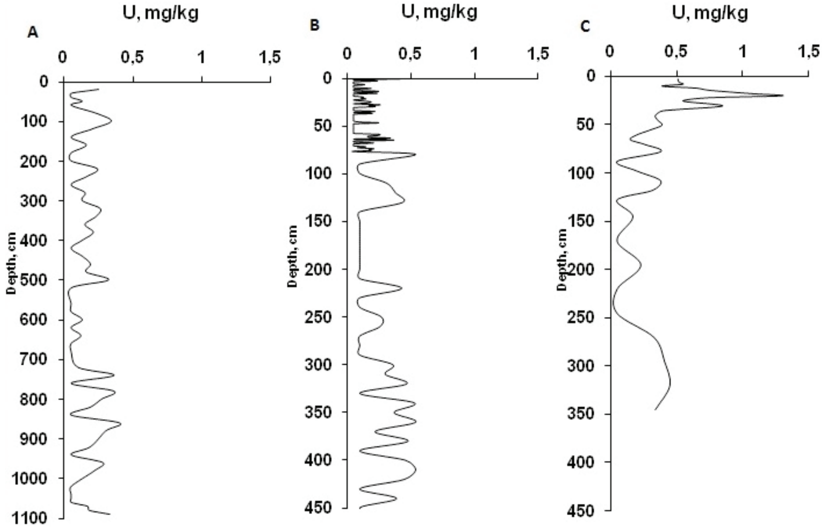

Figure 16. U variability in 3 peat sections from areas of different degree of antropogenic influence (types A, B, and C are described in the text).

region are caused by the influence of human activity in the cities Tomsk and Seversk. The data on the study of vertical variations of trace elements confirm these deductions.

The study of vertical distribution of trace elements requires to be more detailed because it depends on various factors. But this study allowed us to outline similar distribution character for bogs located in background territories without direct influence of human activity, in the areas of oil fields locations, and in the areas of intensive human activity.

AKNOWLEDGEMENTS

The research was supported by the grant of the Ministry of Education and Science of the Russian Federation (Number P1324, 11.06.2010).

REFERENCES

Arbuzov S.I., Rikhvanov L.P., Maslov S.G., Arkhipov V.S. and Belyaeva A.M., 2006. Anomalous gold contents in brown coals and peat in the south-eastern region of the Western-Siberian platform. *International journal of coal geology* **68(3-4)**, 127-134.

Arkhipov V.S., Rezchikov V.I., Smolyaninov S.I. and Tsarenkov A.I., 1988. Application of neutron-activation analysis for the study of peat composition. *Chemistry of solid fuel* **3**, 30-33. (in Russian).

Aubert D., Le Roux G., Krachler M., Cheburkin A., Kober B., Shotyk W. and Stille P., 2006. Origin and fluxes of atmospheric REE entering an ombrotrophic peat bog in Black Forest (SW Germany): Evidence from snow, lichens and mosses. *Geochimica et Cosmochimica Acta* **70(11)**, 2815-2826.

Bernatonis V.K., Arkhipov V.S. and Rezchikov V.I. 1990. Toxic elements in peat of Tomsk region. In: Natural complex of Tomsk region. Publishing House of Tomsk University, Tomsk, Russian, pp. 39-43.

Boyarkina A.P., Baykovsky V.V. and Vasiliev N.V., 1993. Aerosols in natural fields of Siberia. Publishing House of TSU, Tomsk. pp.157 (in Russian).

Gavshin V.M., Sukhorukov F.V., Budashkina V.V., Melgunov M.S. and Bobrov V.A., 2003. Evidence of the fractionation of chemical elements in the atmosphere of West Siberia according to the data of the investigation of a raised bog. *Geochemistry* **12**, 1337-1344 (in Russian).

Glooschenko W.A. and Capobianco J.A., 1978. Metal content of Sphagnum mosses from two northern Canadian bog ecosystems. *Water, air and soil pollution* **10(2)**, 215-220.

Grigoriev N.A., 2003. Mean content of chemical elements in rocks of the top part of the continental crust. *Geochemistry* **7**, 785-792 (in Russian).

Headley A.D., 1996. Heavy metal concentrations in peat profiles from the High Arctic. *The Science of the Total Environment* **177(1-3)**, 105-111.

Inisheva L.I., Arkhipov V.S., Maslov S.G. and Mikhantieva L.S., 1995. Peat resources of Tomsk region and their use. SO RASHN, Novosibirsk, pp. 88 (in Russian).

Inisheva L.I., Arkhipov V.S., Tsybukova T.N., 1994. Element composition of essential types of peat of West Siberia. In: Peat and Agriculture, Tomsk, pp. 39-47 (in Russian).

Kempter H. and Frenzel B., 2007. The geochemistry of ombrotrophic Sphagnum species growing in different microhabitats of eight German and Belgian peat bogs and the regional atmospheric deposition. *Water, air, and soil pollution* **184(1-4)**, 29-48.

Kempter H. and Frenzel B., 2000. The impact of early mining and smelting on the local tropospheric aerosol detected in ombrotrophic peat bogs in the Harz, Gemany. *Water, air, and soil pollution* **121(1-4)**, 93-108.

MacKenzie A.B., Logan E.M., Cook G.T. and Pulford I.D., 1998. A historical record of atmospheric depositional fluxes of contaminants in west-central Scotland derived from an ombrotrophic peat core. *The science of the total environment* **222(3)**, 157-166.

Martinez-Cortizas A., Pontevedra-Pombal X., Novoa-Munoz J.C. and Garsia-Rodeja E., 1997. Four thousand years of atmospheric Pb, Cd and Zn deposition recorded by the ombrotrophic peat bog of Penido Vello (Northwersten Spain). *Water, air, and soil pollution* **100(3-4)**, 387-403.

Mezhibor A.M., Arbuzov S.I. and Rikhvanov L.P., 2009. Accumulation and average contents of trace elements in the high-moor peat of Tomsk region (Western Siberia, Russia). *Energy exploration and exploitation* **27(6)**, 401-410.

Rasskazov N.M., Bernatonis V.K., Arkhipov V.S. and Zdvizhkov M.A., 2002. Zoning of the Great Vassugan Moor by geochemical conditions as a basis of the monitoring of the region. In: Great Vassugan Moor. Present condition and processes of the development. Institute of Atmosphere Optics SO RAN, Tomsk, Russian, pp. 80-82.

Rikhvanov L.P., 2009. Radioactive elements in environment. Problems of radioecology. STT, Tomsk, Russian, pp.430.

Rikhvanov L., Yazikov E., Sukhikh J., Baranovskaya N., Volkov V., Volkova N., Arkhangelsky V., Arkhangelskaya T., Denisova O., Shatilov A. and Yankovich E., 2006. Ecogeochemical features of natural environments of Tomsk district and diseases of the population. Tandem-Art, Tomsk, pp.216 (in Russian with English abstract).

Roslyakov N.A. and Sviridova V.G. (Eds.), 1998. Geological structure and mineral resources of West Siberia: Novosibirsk, Omsk and Tomsk regions. V. 1. Geological structure. Novosibirsk. pp. 228 (in Russian).

Shotyk W., Nesbitt H. W. and Fyfe W.S., 1990. The behaviour of major and trace elements in complete vertical peat profiles from three Sphagnum bogs. *International Journal of Coal Geology* **15(3)**, 163-190.

Shotyk W., Cheburkin A.K., Appleby P.G., Fankhauser A. and Kramers J.D., 1996. Two thousand years of atmospheric arsenic, antimony, and lead deposition recorded in an ombrotropic peat bog profile, Jura Mountains, Switzerland. *Earth and planetary science letters* **145(1-4)**, E1-E7.

Shotyk W., Weiss D., Kramers J.D., Frei R., Cheburkin A.K., Gloor M. and Reese S., 2001. Geochemistry of the peat bog Etang de la Gruère, Jura Mountains, Switzerland, and its record of atmospheric Pb and lithogenic trace metals (Sc, Ti, Y, Zr, and REE) since 12,370 ^{14}C yr BP. *Geochimica et Cosmochimica Acta* **65 (14)**, 2337-2360.

Steinmann Ph. and Shotyk W., 1997. Geochemistry, mineralogy, and geochemical mass balance on major elements in two peat bog profiles (Jura Mountains, Switzerland). *Chemical Geology* **138 (1-2)**, 25-53.

Ukonmaanaho L., Nieminen T., Rausch N., Shotyk W., 2002. Concentrations of Cu, Ni and Pb at ombrotrophic peat bogs at a rural site, near a Cu-Ni smelter and near a mine. *The science of the total environment* **292(1-2)**, 81-89.

Urban N.R., Eisenreich S.J., Grigal D.F. and Schurr K.T., 1990. Mobility and diagenesis of Pb and ^{210}Pb in peat. *Geochimica et cosmochimica acta* **54(12)**, 3329-3346.

Verhoeven J.T.A., Beltman B., Bobbink R., Whigham D.F. (Eds.), 2006. Wetlands and natural resource management. Springer-Verlag, Berlin-Heidelberg, pp.387.

Wang J.X., Deng X.L. and Kalkreuth W. 2011. The distribution of trace elements in various peat swamps of the No. 11 coal seam from the Antaibao Mine, Ningwu coalfield, China. *Energy Exploration and Exploitation* **29(4)**, 517-523.

Weiss D., Shotyk W., Kramers J.D. and Gloor M., 1999. Sphagnum mosses as archives of recent and past atmospheric lead deposition in Switzerland. *Atmospheric environment* **33(23)**, 3751-3763.

Weiss D., Shotyk W., Rieley J., Page S., Gloor M., Reese S. and Martinez-Cortizas A., 2002. The geochemistry of major and trace elements in a forested peat bog, Kalimantan, SE Asia, and its implications for past atmospheric dust deposition. *Geochimica et Cosmochimica Acta* **66(13)**, 2307-2323.

West S., Charman D.J., Grattan J.P. and Cheburkin A.K., 1997. Heavy metals in Holocene peats from south west England: detecting mining impacts and atmospheric pollution. *Water, air and soil pollution* **100(3-4)**, 343-353.

Zaccone C., Cocozza C., Cheburkin A.K., Shotyk W. and MianoT.M., 2007. Enrichment and depletion of major and trace elements, and radionuclides in ombrotrophic raw peat and corresponding humic acids. *Geoderma* **141(3-4)**, 235-246.

Zaccone C., Cocozza C., Shotyk W. and Miano T.M., 2008. Humic acids role in Br accumulation along two ombrotrophic peat bog profiles. *Geoderma* **146(1-3)**, 26-31.