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STRONTIUM CONTENT IN SANDY SOILS IN AGRICULTURE FIELDS (CASE STUDY: MOUNDOU, CHAD)

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ABSTRACT

During evaluation of physical and chemical properties of sandy soils and their fertility in Southern part of Republic of Chad it has been revealed that some soils have very high content of strontium. Its content varies from 10 to 270 mg/kg of soil depending on type of soil, depth of soil layers, clay and organic content. Strontium content negatively correlates with total content of calcium and phosphorus in layers of soil. Low CEC (CEC - Cation-exchange capacity) of soil may be a reason of possible translocation of strontium from higher to lower layers of soils. Strontium content in soils do not relates with level of radioactivity of soil measured. The highest content of strontium has been found in soils developed on some eolian and colluvio-alluvium deposits. Some researchers hypothesize that some endemic and chronic diseases such as Kashin-Beck disease, `Dysostosis enchondralis endemic`, endemic hoiter, osteoarthritis might be caused by high content of strontium in water and plant foods contaminated with it. Absence of consensus on etiological factors of these diseases confirms that it is worth considering necessity of further studies of different affects of high content of strontium in water and foods on human health directly or indirectly through causing misbalance in mineral nutrition.

Keywords: *strontium, sandy soil, Ca/Sr ratio, radioactivity, eolian deposit.*

INTRODUCTION

Analyzing physical, chemical composition and level of fertility of sandy soils on agricultural fields around city of Moundou in Southern part of Republic of Chad it has been found that some soils have extremely high content of strontium. Soils of this area have very specific physical and chemical properties for they are have been formed on eolian and colluvio-alluvium deposits. Along the river Logon in some places may be found hydromorphic clay soils. On sandy soils at higher places farmers usually grow corn, peanut, cassava, and taro. On lower places along the river they cultivate rice, root vegetables, banana, and green vegetables. Commercial produce of these crops compose main part of people`s diet. Analytical data obtained and known general information on etiological factors which may cause Kashin-Beck disease and other diseases, mostly bone abnormalities, led us to analyzed more deeply strontium status of sandy soils in mentioned area.

Chemical properties of strontium are very similar to those of barium, calcium, as may form the same salts and basis, but being heavier strontium forms less movable hydroxide, what leads to its accumulation in soils and plant and live organism tissue. This fact is supported by high content of this element in all kind sediments. For example, rests of sea acantarium (radiolarium) mainly composed from $SrSO_4$. Sea weeds contain 26-140 mg per 100 g of dry matter, whereas grasses contain around 2-3 mg/100 g d.m. Main forms of strontium salts in sea sediments are carbonate and phosphate. In all geochemical and biochemical processes calcium and strontium accompanies each other. Their ration (Ca/Sr) in soils formed on mother rock or eolian and alluvial sediments unavoidably determines content of strontium in plants. Of cause, it worth mentioning that soils and plants may be polluted by radioactive ^{90}Sr precipitated after nuclear explosions or accidents at nuclear objects. In any case, while evaluating qualities of soil, as an agricultural object, it worth paying attention to total content of strontium and its ratio to calcium. It will be helpful in finding coincidence with of such diseases as Kashin-Beck and other bone abnormalities and finding means of its prevention (Bowen, Dymond, 1955; Петренко, 2008; Вощенко, Смекалов, 2001). Strontium-isotope ratios vary in nature because one of the strontium isotopes (^{87}Sr) is formed by the radioactive decay of the naturally occurring element rubidium (^{87}Rb). The $^{87}Sr/^{86}Sr$ ratios are mainly used as tracers of water–rock interaction (Blum at al., 1994; Negrel et al., 2001). The primary sources of Sr in groundwater are atmospheric input, dissolution of Sr-bearing minerals, and anthopogenic input (Negrel, Petelet-Giraud, 2005). Due to the physico-chemical similarities of caesium (Cs^+) to potassium (K^+) on the one hand and strontium (Sr^{2+}) to calcium (Ca^{2+}) on the other hand, both elements can easily be taken up by plants and thus enter the food chain. This could be detrimental when radionuclides such as ^{137}Cs and ^{90}Sr are involved (Kanter et al., 2010).

MATERIAL AND METHODS

City Moundou (8°34′00″N, 16°05′00″W, fig. 1) is a capital of the Southern province in Chad. All fields around the city are allocated for crop production and pastures. Soils may be considered as very young as they are formed by periodic wind-driven and alluvial deposits.

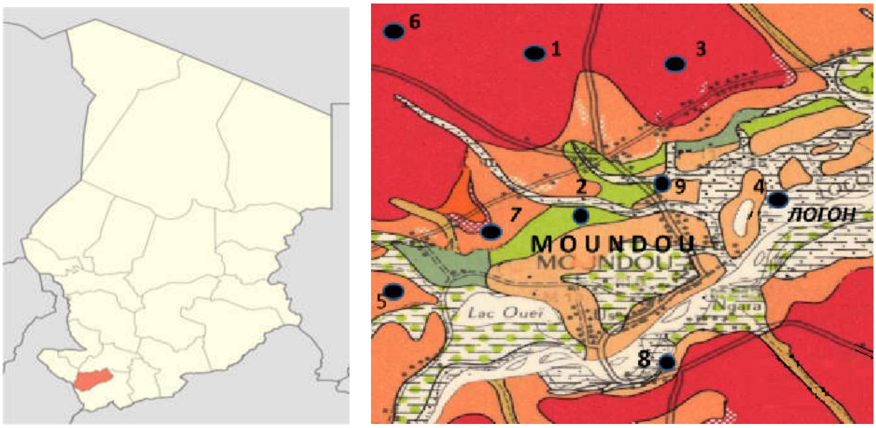

Fig. 1. Location of city Moundau and pedons

Locations of pedons excavated (fig. 1., table 1) were purposely chosen to study influence of height above sea level, hydrology, notable difference in soil profiles, mode of soil use (arable, pasture, crops cultivated).

Table 1. Location and principal properties of soils studded in province Moundou (Chad)

Pedon	Coordinates	High above sea level *, m	Total content in 30 cm layer, mg/kg		Ca/Sr ratio		Level of diation, $\mu Sv/h$*
			Sr	Ca	mass	atomic	
1	2	3	4	5	6	7	8
1	8º 37' 26.94''N 15º59'33.28'W	4748	15	469	31	69	20
2	8º35'57.96''N 16º03'33.34'W	400	235	827	4	7,7	16
3	8º35'22.52''N 16º06'20.28'W	389	16	714	45	99	15
4	8º37'49.24''N 16º05'51.60'W	411	14	851	61	125	9
5	8º33'58.79''N 16º00'18.10'W	412	11	422	38	82	18
6	8º39'52.64''N 16º01'38.36'W	481	8	500	63	139	14
7	8º34'30.40''N 16º00'38.06'W	409	12	347	29	62	13
8	8º32'59.59''N 16º05'49.36'W	396	9	381	42	95	13
9	8º36'14.68''N 16º04'46.58'W	3961	273	2310	9	19	8

*Level of natural radiation = 9-10 $\mu Sv/h$

NB: Level of water above sea level in the river = 380 m.

Soils at different locations are represented by pedons excavated at different fields around the city Moundou. Some fields along the river Logon experience periodic but prolong flooding (pedons 2, 8 and 9). All pedons were excavated up to 100-120 cm depth. As there no distinguished genetic soil horizons soil sample were taken from regular layers 0-30, 30-50 and 50-100 cm. All agrochemical properties such as pH of salt solution, CEC, content of total and exchangeable phosphate, calcium, magnesium, potassium for each soil sample were determined by appropriate techniques (Nagornyy, 2013). Total content of P, Ca. Sr, Fe, Mn, Mg, K was determined using by X-ray spectrometer `Spectroscan Max G`. According to Atlas Cartographique (2003) these soils pertain to sandy ferritique and ferrallitic groups (pedons: 1, 3, 4, 5, 6, 7). Upper layers of sandy ferrallitic soils have light brown or gray-brown color. Soils with some hydromorphic features (pedons: 2, 8, 9) have dark gray color. All soils have sandy granulometric composition. Clay content in soils is in the range 2-3%, cation exchange capacity varies from 1 to 2 meq./100g. Soil acidity measured in KCL extraction was in the range 3.9 – 5.,2. Content of exchangeable aluminum was very low (0.2 – 0.5 meq./100 g). Organic matter content in soils on higher places was in the range 0.6 -0.8%. In the soils with hydromorphic features OM (OM - soil organic matter) content was in the range 1.1 – 1.3%.

RESULTS AND DISCUSSION

The main goal pursued in our research was to evaluate physical, chemical, hydrological, and agronomical qualities of soils used for crop production in the province Moundou in Chad. The Data obtained revealed very wide variation in content of strontium in different soils of the province (table 2). Nowadays it is recognized that high accumulation of strontium in human body may cause Kashin-Beck disease osteoarthritis and different metabolic disorders (Вощенко, Смекалов, 2001; Ильин, 2000). Russian researchers have accumulated big volume of information on nature of strontium content in soils and biological tissues, its mobility in different conditions, and its influence on health of people. They classified soils on basis of strontium content and established level of ratio Ca/Sr in soils which may be dangerous for human being, and find the way for soil remediation. More over on basis of this data a special State regulation has been adopted (Петренко, 2008). Having this in mind we trying to evaluate data obtained on strontium content in sandy soils of the province Moundou in Chad.

Main part of soils in the province may belong to three main groups, Arenosols, Ferrasols, Flivisols (Atlas…, 2003). Eolian nature of soil formation at the area and very high content of sand allow us to expect high risk of mobility of strontium in soil profiles and high content of strontium in ground water. As other researchers found these parameters directly depend on granulometric composition of soil, OM content, soil acidity, calcium and phosphate content (Khaleghpanah et al., 2010; Shalex et al., 2013). Total strontium content and other properties of soils influence uptake of strontium by plants what may be determined by value of transfer factor (TF).

Table 2. Level of content of OM, clay, sand and selected elements in soils at different locations and depth of soil pedons

Pedon	Layer, *cm*	OM,%	Sand,%	Clay,%	Silt,%	pH		Total content, mg/kg		
						2O	KCl	P	Ca	Sr
1	0-30	0.79	98.67	0.8	0.6	5.3	4.8	0.075	469	75
	30-50	1.18	96.6	1.6	1.8	5.3	5.0	0.067	664	105
	>100	0.99	95.8	3.2	1.0	4.8	4.8	0.063	796	125
2	0-30	1.13	943.0	2.6	3.4	4.8	4.5	0.086	827	1175
	30-50	0.78	97.2	1.4	1.4	4.8	4.1	0.095	510	1170
	>100	0.45	96.6	1.6	1.8	4.6	4.2	0.068	880	1035
3	0-30	1.43	99.2	0.4	0.4	5.3	5.2	0.066	714	80
	30-50	0.53	98.6	0.6	0.8	5.0	5.4	0.078	246	65
	>100	0.59	96.2	1.6	2.2	4.8	4.1	0.074	389	105
4	0-30	0.84	97.6	1.0	1.4	5.2	4.9	0.109	851	70
	30-50	0.64	97.6	0.8	1.6	4.9	4.5	0.104	536	105
	>100	0.96	99.2	0.6	0.2	4.8	4.0	0.081	263	130
5	0-30	0.58	98.6	0.4	1.0	5.1	4.6	0.096	422	55
	30-50	0.71	98.2	0.8	1.0	4.6	4.0	0.080	274	85
	>100	0.51	99.2	0.6	0.2	4.3	3.9	0.083	137	130
6	0-30	0.65	99.6	0.2	0.2	5.4	4.9	0.064	499	40
	30-50	0.51	99.0	0.2	0.8	5.3	4.7	0.080	370	55
	>100	0.72	98.2	0.4	0.6	4.8	4.2	0.080	290	75
7	0-30	0.85	97.8	0.8	1.4	5.3	4.5	0.087	347	60
	30-50	0.45	97.8	1.2	1.0	5.1	4.2	0.076	312	75
	>100	0.26	97.2	2.2	0.6	4.7	3.9	0.044	279	145
8	0-30	1.04	99.4	0.4	0.2	5.6	5.0	0.084	381	45
	30-50	0.45	98.3	0.6	1.2	5.1	4.3	0.072	187	50
	>100	0.52	98.0	1.2	0.8	4.8	4.0	0.068	470	95
9	0-30	1.54	95.0	2.2	2.8	5.5	4.8	0.136	2310	1365
	30-50	0.84	98.0	1.2	0.8	5.3	4.3	0.075	1322	1260
	>100	0.51	94.3	2.7	3.1	5.0	4.1	0.101	1249	1185

Data presented in the Table 3 shows that the range of strontium content in soils varies very much: from very low (8-12 mg/kg) to extremely high (235-273 mg/kg). Low content of native strontium prevail in profile layers of most soils studded. Let it be noted that in some soils lower layers have higher content of Strontium, what may be explained by (a) different content of strontium in wind-brought material in previous times, and (b) by lixiviation of strontium together with silt into lower layers of soil. But as it is suggested by soil scientists (Andersen, 1973; Khaleghpanah et al., 2010) abundance of strontium are to be compared to that of its homologous element which is calcium. Wide variation in total content of Strontium and Calcium has been found in parent rocks and minerals (Kate et al, 2011, Twining et al., 2003). Whereas content of extractable form of these elements in soils is less variable due to use of the same salt solution for extraction of exchangeable forms of both elements. It has been found (Khaleghpanah et al., 2010), that mobility of strontium highly depends on mass or atomic ratio Ca/Sr (see table 3). Value of these ratios matters for assessment of the strontium status of the soils, and this value have been used in Russia for classifying soils and drinkable water. For example, water which contains 7 mg and more of strontium is per one liter is not to portable and not to be used in kitchen. Soils which have wide ratio Ca/Sr (more than 100) are not to be used for production of food crops (Петренко, 2008). The reason is much recognized: such levels of strontium in water and wide ratio Ca/Sr may cause Kashin-Beck disease, osteoarthritis, `strontium-caused rachitis`, other physiological abnormalities (Вощенко, Смекалов, 2001). It is accepted that these diseases are a consequence of misbalance between Ca and Strontium in water and food diet, what causes displacement of Ca by Sr (Худяев, 2008).

Table 3. The Pearson`s correlation matrix among measured levels of OM, clay and selected elements

	OM,%	Sand,%	Clay, %	Silt,%	pH		Total content, mg/kg		
					H2O	KCl	P	Ca	Sr
OM,%	1								
Sand,%	0,2397	1							
Clay,%	0.1511	0.3455	1						
Silt,%	0.2065	0.5019	0.6737	1					
pH-H2O	0.0600	-0.0384	-0.0878	0.0469	1				
pH-KCl	0.5074	0.0118	-0.1815	-0.0668	0.0104	1			
P	0.3669	0.0516	0.0434	0.4845	0.0654	0.1132	1		
Ca	0.5484	0.0975	0.5260	0.5851	-0.1074	0.1914	0.5556	1	
Sr	0.2512	0.3501	0.55558	0.6445	-0.1143	-0.1904	0. 4085	0.7481	1

Data presented in Table 1 show that at some places should be of big concern as cultivation of food crops may bring problems with health of people living there. Higher content of strontium in low layers of some soils may be explained at least by two obvious factors. Firstly, it may be caused by downward movement of strontium in sandy soils during rainy season [Twinnong Netta salex]. Sandy soils with low content of clay and silt and, as consequence, with low CEC are not able to hold basic elements in upper layers of soil. Wind-translocation of weathered material from Northern part of the country (Tibetsy area) is the second factor. That area is rich in strontium-containing material originated from ocean deposits of Pleistocene period. Lowest layers of soil may be formed from send deposits brought by the North-West wind decades before, whereas other layers has been formed later by sand and dust delivered by wind from other directions.

Strontium translocation along the soil profile and sorption of this element by soil depend on prevailing chemical composition of soil (salt: sulphate, carbonate, chloride, and phosphate; OM, clay and silt content). All these suggest possible measures of soil remediation. Such measures may include enrichment of soil with in organic material (Andersen, 1973; Bowen, Dymond 1955; Khaleghpanah et al., 2010), use of phosphate fertilizers (Kate at al., 2011; Twining et al., 2003). This measures may reduce transfer factor of Strontium from 0.2-0.3 to as low as 0.01-0.008 (Худяев, 2008).

CONCLUSIONS

Grate majority of soil of Moundou province in Chad pertain to group of light sandy Arenosols, Ferralsols, Fluvisols of low fertility. Some soils have comparatively high content of strontium and calcium due to their formation from wind-brought materials originated from ocean deposits of Pleistocene period. Such soils have bigger Ca/Sr ratio what may cause higher transfer of strontium from soil to plant produce. Future many-side and versatile research is needed to establish correlation between Strontium content in soils, rate of transfer of this element to plant produce, and frequency and severity of diseases thought to be caused by high accumulation of strontium in human body.

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