Determination of Magnesium Salinity in Belozem Region, Bulgaria

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Abstract

Salinisation is an important soil-forming process (primary or secondary), characterized by an excess of water-soluble salts and/or exchangeable sodium. The amount of exchangeable magnesium is also essential for the more detailed determination of the physico-chemical properties of saline soils. The determination of magnesium salinity is still a debatable issue, but there are already criteria in the literature for its estimation. The Belozem region is representative of Bulgaria for the processes of alkaline salinisation, but the presence and extent of magnesium salinity has not been determined. For this purpose, data from ten soil profiles and four criteria for determining magnesium salinity were used. In three of the profiles there is an increased content of exchangeable magnesium, which covers all four indicators of magnesium salinity, in three of the profiles the magnesium salinity is determined only in some horizons and in the other four cannot be clearly defined. The study also showed that the application of all four criteria is necessary in order to make a strong claim for the presence of magnesium salinity.

Keywords: alkaline soils, exchangeable sodium, exchangeable magnesium, magnesium salinity, salinisation

Introduction

Salinisation is one of the most widespread soil degradation processes on the earth and occurs mainly in the arid–semiarid regions. Climate changes in recent years strengthened the occurrence of salinisation processes. According to Tóth et al. (2008) salt-affected soil can be divided into five main groups: *Solonchak* with high amount of water-soluble salts; *Solonetz* with high alkalinity and high exchangeable sodium percentage (ESP); *Magnesium soil* with high magnesium (Mg) content in the soil solution; *Gypsiferous soil* with strong gypsum or calcium sulphate accumulation; *Acid sulphate soil* with highly acidic iron or aluminium sulphate accumulation.

In the World Reference Base (WRB, 2006) soil classification system, saline soils mainly occur in the Reference Soil Group of Solonchaks. However, some other Reference Groups may also have a salic horizon (indication of certain degree of salinisation) such as Histosols, Vertisols and Fluvisols. Sodic soils mainly occur in the Reference Soil Group of Solonetz. However, Solonetz may be associated with Histosols, Gleysols, Chernozems, Kastanozems, Vertisols and Solonchaks. In WRB (2015) Solonetz is soils with a high content of exchangeable sodium, and in some cases also magnesium ions; having natric horizon with high content of exch. Na and in some cases, a relatively high content of exchangeable Mg and more exch. Mg plus Na than Ca plus exchange acidity (at pH 8.2) throughout the entire natric horizon or its upper 40 cm. Solonetz can be defined with supplementary qualifiers magnesic (mg) by an exchangeable Ca to Mg ratio of < 1 in the major part within 100 cm of the soil surface. Magnesium salinity is also mentioned by Valkov et al. (2004). According to them, the presence of magnesium in the soil-absorption complex maintains the salinity property and in some cases may lead to the formation of a separate soil type – magnesium Solonetz.

Although magnesium has been mentioned as a diagnostic criteria along with sodium, magnesium salinity has not yet been clearly defined and soils with high magnesium content are not separated as a single genetic order of soils. The role of magnesium in the formation of soil salinity has not been sufficiently clarified and this issue is considered debatable. According to Gogolev and Voloshin (1968) magnesium salinity is observed at exch. Mg content as a percentage of the sum of exchangeable cations (CEC) above 25%. According to unpublished data, Kavardzhiev proposes that magnesium saline soils should be defined as soils with a content of more than 65% of the amount of exch. Na and exch. Mg of exch. Ca (Trendafilova, 1997). Penkov et al. (2003) provide a classification scheme for estimating the parameters of exchangeable magnesium percentage (EMP) in clay soils divided into 5 classes from 16% to 42%, respectively, from a slight degree of saturation to super strong.

Magnesium is an essential element for plant growth and development. The availability of magnesium to plants depends on various factors: the distribution and chemical properties of the source rock material and its grade of weathering, site specific climatic and anthropogenic factors (Scheffer and Schachtschabel, 2002). The difference in the magnesium content of soils depends mainly on the richness of the magnesium in soil-forming rock. In plant tissues, magnesium is present in the form of a free or sorption bounded ion in the form of chelates, in the composition of organic compounds such as chlorophyll, phytin, pectin and an activation agent of enzymes. Magnesium binds and forms some organic and inorganic salts like oxalates, phosphates, sulfates, chlorides and more. The entry of magnesium into plants can be hindered by the acid reaction of the soil and higher amounts of sodium, potassium and aluminum ions in the soil solution. With increasing soil moisture, the ratio of monovalent and divalent ions changes in favor of monovalent ones and therefore the mobility of magnesium in the soil decreases. The main source of plant food from magnesium is the mobile part of metabolic exchange (Maguire and Cowan, 2002, Gorbanov et al., 2005). However, under certain conditions it can be toxic to plants grown on highmagnesium soils (Proctor, 1970).

Magnesium is considered to behave similarly to calcium in soils. However, a contrasting attribute between the two divalent cations in soil systems can arise from the distinct effects of magnesium on physical properties of the soils. High levels of magnesium may cause deleterious effects on soil structure similar to those caused by sodium (Oster and Jayawardane, 1998). In contrast to other cations like K, Ca, and NH_4^+, Mg is comparatively mobile in soils. The properties orthe 'behaviour' of Mg in soils can be ascribed to its unique chemical properties. Whereas the ionic radiusof Mg is smaller than that of Ca, K or Na, its hydrated radius is substantially larger (Maguire and Cowan, 2002). One consequenceis that magnesium is less strong bound to soil charges (CEC) leading to compared to other cations higher Mg concentrations in the soil solution. This has consequences for the mobility of magnesium in the soil and implications for plant magnesium nutrition.

Saline soils in Bulgaria cover about 1% of the total territory. Because of their poor agricultural properties, these soils are not useful for farming, in rare cases they can be used for pastures. The most common reason for soil salinisation process is high levels of ground waters with high content of soluble salts. Such conditions are created near to the river terraces, lowlands and closed hollows, filled with fine granular sediments. These lands have poor drainage, the ground water runoff is very slow and the evaporation from the soil surface – very high. In general the territory of Bulgaria belongs to transit salt-regime zones, which is a perquisite for developing of salinisation process.

Saline soils in Bulgaria are formed and located into two main geographical areas – Northern Bulgaria (Karaboaz lowland; Veliko Turnovo and Rousse regions; Varna region) and southern Bulgaria (Thracian lowland). Salinisation is in most cases related to intensive irrigation (secondary salinisation), but influence also have the natural hydrological factors (Dzuninski and Kavardzhiev, 1985). The land of Belozem (Plovdiv region) is one of the most representative and well researched (Buckorestliev, 1936, Vodenicharov, 1968, Dzuninski and Kavardzhiev, 1985, Penov et. al, 2011) in terms of salinity from high content of exch. Na (meadow Solonetz). They are also founded mixed saline soils (meadow Solonchak-Solonetz).

Despite the good study of the area, till yet has not been considered the question of magnesium salinity determined, although an increased content of exch. Mg has been commented in some publications. It gives grounds to make a revision of existing data and applying the already known criteria for magnesium salinity to assess the extent to which the exchange magnesium determines the overall soil salinity in Belozem.

Materials and Methods

Kavardziev (1986) gives a description of the land of Belozem, which occupies the second floodplain and a small part of the floodplain of the Maritza River. The low parts of the relief are mostly swamped and saline. The micro relief, the poor water permeability and the lack of vegetation in many places are the cause of severe water and wind erosion.The soil-forming materials in the plain part of the region are Pliocene sediments and quaternary materials. Pliocene deposits are high-density lake sediments composed of sandy and fine clays, clayey sands, gravels and sands in alternation to each other.The presence of montmorillonite minerals and heavy clay materials is the result of the destruction of tufogenic and marl layers. The quaternary cover is of river sediment, mainly of sandy clays and clay sands. The salinisation of soils depends mainly on the proportion of clay materials. The predominant soil type in the area of Belozem is leached cinnamon-forest soils and meadow-marsh soils. The saline leached cinnamon-forest soils are salinized mainly with chlorides and sodium sulphates. Saline meadow-marsh soils are distinguished by a greater variety of salinisation levels. The most common are slightly saline meadow sodic Solonetz, followed by Solonchak-Solonetz and Solonetz-Solonchak.

According to Penov et al. (2011) in Belozem, 40% of the land is affected by salinisation processes. Salinisation in Belozem is mainly secondary in nature. The secondary salinisation is caused by human activities such as improper irrigation, drainage and cultivation practices. There are four main soil types: Luvisols, Solonetz, Vertisols and Gleysols. Except

Solonetz, large part of Fluvisols are also strongly affected by the salinisation processes (Fig.1).

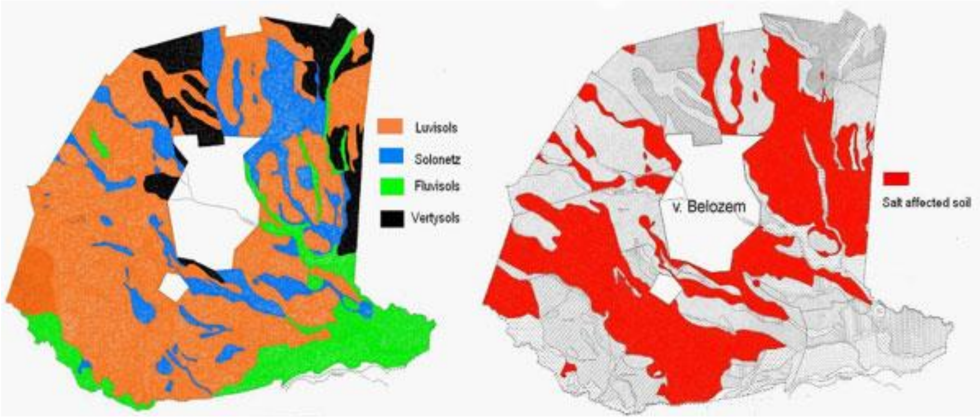


Figure 1. *Soil types and saline soils in the village of Belozem (Penov et al., 2011)*

For the purpose of this study, literature data from 10 representative profiles (soil analysis methods are not given) from the Belozem area were used (Pic. 1) and the existing magnesium salinity criteria were applied.

The four criteria to determine the magnesium salinity are:

1) Exchangeable Magnesium Percentage as **"EMP"** = 100 (exch. Mg/CEC) more than 25% (Penkov et al. 2003, Andreeva, 2011; Qadir et al. 2018)

2) magnesic qualifier – exch. Ca : exch. Mg < 1 as **"Ca:Mg"** (FAO, 2015)

3) 100 (exch. Na + exch. Mg)/exch. Ca more than >65% as **"Na+Mg in % from Ca"** (unpublished Kavardziev)

4) 100 (exch. Na + exch. Mg)/CEC more than >20% as "**Na+Mg in % from CEC"** (Penkov, 1983).

Figure 2. *Solonchak – Solonetz from Belozem region*

Results and Discussion

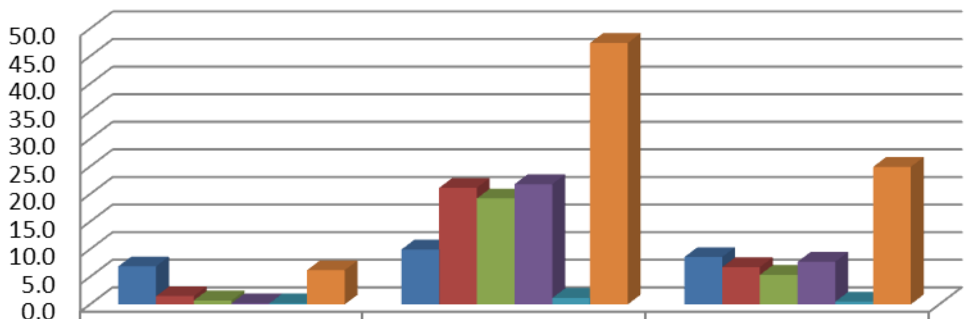
In Table 1 are presented the basic chemical properties of the selected profiles (exchange cations, sorption capacity and pH) as they are given by their authors in the different literature sources. In Fig.1 are presented basis statistic data for those properties.

The data show that almost all profiles are well developed and reach depths of 160 cm or more. Where pH values in H_2O are given, an increase in depth is found, generally ranging from 7 to 9.9. Only in *Profile 2* (Solonetz) the pH is higher in the mid-horizons (B-horizon). Average for all ten profiles pH is 8.6 (moderately alkaline).

The cation exchange capacity (CEC) is in the wide range from < 10mequ/100g to > 45mequ/100g, which corresponds to the general characteristic of these soils (Gurov and Artinova, 2001). Predominantly the CEC for all profiles is medium to large (in the intervals 11-20 and 21-30) but in some horizons it reaches excessively large (Penkov et al., 2003). Average for all ten profiles the CEC is 25mequ/100g.

In terms of the exchange cations only potassium shows a relatively uniform distribution. The amounts of exchangeable Ca, Mg and Na vary widely, respectively for Ca from 2 to 15 mequ/100g, for Mg from 1 to 19 mequ/100g, and for Na from <0.5 to 22 mequ/100g, which leads to the vastly differences in the CEC. Average for all ten profiles exch. Ca is 6.7 mequ/100g, exch. Mg is 5.3 mequ/100g, exch. Na is 7.7 mequ/100g and exch. K is 0.5 mequ/100g. Based on the average values exch. Na is more than exch. Ca, respectively the sum of exch. Mg and exch. Na is more than exch. Ca (Fig. 3).

A correlation between the pH values and cation exchange capacity for each profile is made (Fig. 4). The results show that a good correlation between these two soil properties appear only in profile #1, #3 and #4.



	min	max	aver
pH	6.9	9.9	8.6
Ca	1.5	21.1	6.7
Mg	0.7	19.2	5.3
Na	0.2	21.8	7.7
K	0.2	1.2	0.5
CEC	6.2	47.4	24.9

Figure 3. *Minimum, maximum and average values for the basic soil properties (pH; exchangeable cations* and cation exchange capacity*) of ten soil profile from Belozem*
**in mequ/100g*

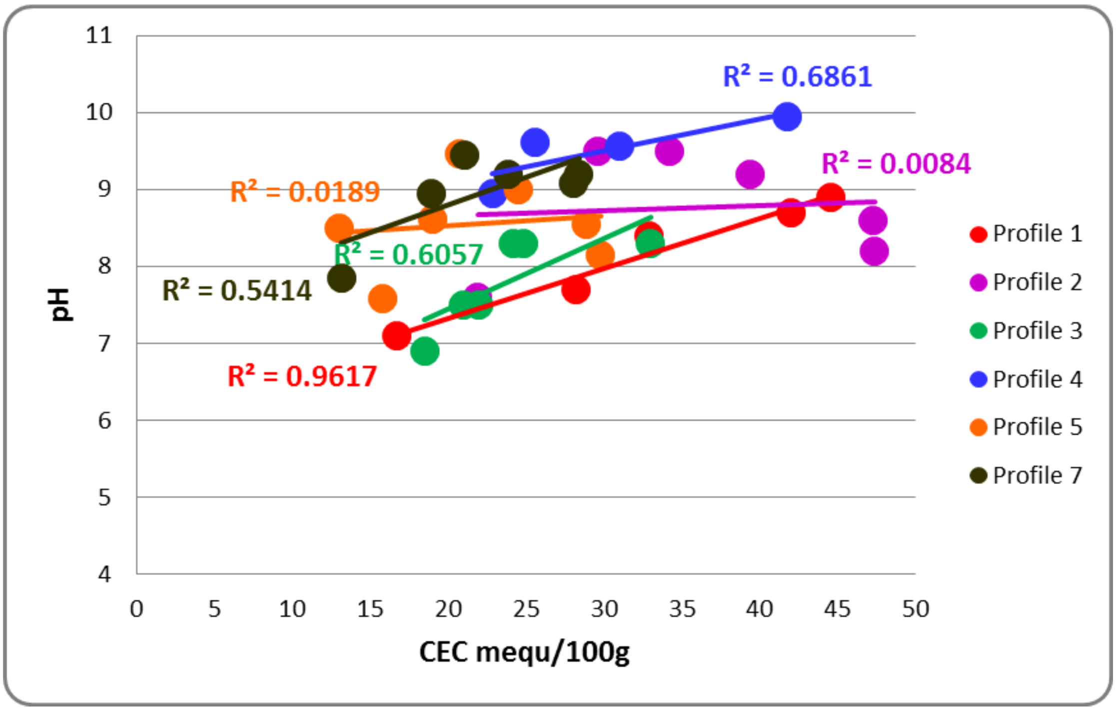


Figure 4. *Correlation between pH and cation exchange capacity in six of the profiles from Belozem with R2-values*

In Table 2 are presented the calculated results for the individual criteria for magnesium salinity.

Profile 1–the criteria are applied only to the first two horizons. Based on ESP, the soil is defined as Solonchak-Solonetz. However, the "EMP" is over 25% and significantly exceeds the ESP. The "Ca:Mg" ratio is about 1; "Na+Mg in % from Ca" is about 2.5 times the 65% marginal value, and "Na+Mg in % from CEC" is almost 3 times the 20% marginal value. Thus, magnesium salinity is found in these horizons according to 3 of the selected criteria, and in terms of "Ca:Mg" we can speak of a marginal case. In depth, "Ca:Mg" increases while all other indicators decrease, which is in line with the increasing content of exch. Ca.

Profile 2 – again, the criteria are applied only to the first two horizons. On the basis of ESP, the soil is defined as Solonetz. In this profile, however, the relationship between ESP and "EMP" is inversely proportional, respectively in A1, in the absence of sodium salinity (exch. Na), exch. Mg is well above 25%, while in aB exch. Na has an extremely high content (ESP 69%), which persists in B1kg and then drops sharply. The "Ca:Mg" ratio is clearly above 1; "Na+Mg in % from Ca" is near 71% and increases sharply to 495%, and "Na+Mg in % from CEC" is 2 to 4 times above 20%. So based on 3 of the criteria there is magnesium salinity in the first horizon. Taking into account the large differences in the amount of exchangeable cations, the dominant role of exch. Na in the B1kg horizon and the lack of more data, the presence of magnesium salinity cannot be uniquely determined.

Profile 3 – data is available for 4 horizons. Based on ESP, soil is defined as Meadow Solonetz. "EMP" increases in depth and exceeds ESP 2 to 3 times. "Ca:Mg" clearly decreases in depth, reaching 0.4. Respectively, "Na+Mg in % from Ca" and "Na+Mg in % from CEC" increase in depth and significantly exceed the marginal values. In this profile magnesium salinity is found too according to 3 of the criteria and the Mg-salinity develops in depth. The "Ca:Mg" ratio is marginal.

Table 1. *Basic chemical properties, exchangeable cations and cation exchange capacity of ten soil profiles from Belozem.*

Atlas of soils in Bulgaria, Koynov et al., 1998 – Solonchak-Solonetz (*Profile 1*)											
Horizon	Depth, cm	pHin H_2O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-12	7.1	6.15	6.24	4.29		16.68	36.87	37.41	25.72	
B1	15-25	7.7	12.50	9.98	5.46		28.25	44.25	35.33	19.33	
B2k	30-40	8.4			3.71		32.90			11.28	
B_{Ck}	48-58	8.7			4.54		42.00			10.81	
BC_k	68-78	8.9			8.82		44.60			19.78	
C1k	110-120	8.9									
C2k	157-167	8.7									
Atlas of soils in Bulgaria, Koynov et al., 1998 – Solonetz (*Profile 2*)											
Horizon	Depth, cm	pHin H_2O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-9	7.6	12.00	8.30	0.21		21.90	54.79	37.90	0.96	
aB	18-28	9.5	4.73	2.90	20.52		29.60	15.98	9.80	69.32	
B1kg	18-28	9.5			20.98		34.20			61.35	
B2kg	44-54	9.2			10.71		39.40			27.18	
BCkg	95-105	8.6			5.11		47.30			10.80	
C1kg	137-147	8.2			2.40		47.40			5.06	
Atlas of soils in Bulgaria, Koynov et al., 1998 – Meadow Solonetz (*Profile 3*)											
Horizon	Depth, cm	pHin H_2O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-13	7.5	8.65	7.80	3.82		20.95	41.29	37.23	18.23	
AB	13-23	6.9	6.60	6.80	3.60		18.50	35.68	36.76	19.46	
B1	26-36	7.5	7.00	10.00	5.00		22.00	31.82	45.45	22.73	
B2	51-61	8.3	6.90	19.20	6.90		33.00	20.91	58.18	20.91	
BCkg	88-98	8.3			5.80		24.85			23.34	
C1kg	105-115	8.3			1.80		24.20			7.44	
C2kg	136-146	8.3									
Soil reference databaseinBulgaria, Teoharov et al., 2009 – Solonetz (*Profile 4*)											
Horizon	Depth, cm	pHin H_2O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-30	8.9	13.98	4.62	1.36	0.41	22.83	61.24	20.24	5.96	1.80
B1	30-60	9.6	8.88	8.10	7.69	0.50	30.98	28.66	26.15	24.82	1.61
B2C1	60-115	9.6	4.01	10.29	9.72	0.52	25.54	15.70	40.29	38.06	2.04
C2	115-160	9.9	2.56	8.12	5.00	0.25	41.74	6.13	19.45	11.98	0.60
Soil reference database in Bulgaria, Teoharov et al., 2009 – Solonchaks-solonetzsalic-sodic (*Profile 5*)											
Horizon	Depth, cm	pHin H_2O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-3	7.6	9.10	2.52	0.45	0.74	15.80	57.59	15.95	2.85	4.68
A2	3-7	8.5	5.77	2.07	1.14	0.40	13.00	44.38	15.92	8.77	3.08
B1	7-15	8.6	4.26	4.75	5.24	0.47	19.00	22.42	25.00	27.58	2.47
B2	15-36	8.2	15.00	7.48	6.25	0.53	29.80	50.34	25.10	20.97	1.78
B3	36-70	8.6	12.52	8.76	10.22	0.54	28.90	43.32	30.31	35.36	1.87
B4C1	70-125	9.0	1.80	12.99	9.13	0.47	24.50	7.35	53.02	37.27	1.92
C2	125-170	9.5	5.16	10.00	5.15	0.31	20.70	24.93	48.31	24.88	1.50

Table 1. *Basic chemical properties, exchangeable cations and cation exchange capacity of ten soil profiles from Belozem – (Continue)*

Penkov et al., 1985 – Meadow Solonetz (sodic) (Profile 6)												
Horizon	Depth, cm	pH in H_2O	Exchangeable cations in mequ/100g				CEC inmequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-4		1.48	0.72	3.06	0.18	8.12	18.23	8.87	37.68	2.22
B1	4-12		4.40	1.78	9.12	0.26	16.86	26.10	10.56	54.09	1.54
B2	12-32		5.36	1.83	11.15	0.26	19.15	27.99	9.56	58.22	1.36
B3	32-60		5.82	1.64	13.05	0.41	22.72	25.62	7.22	57.44	1.80
B4C1	60-125		4.18	1.46	10.82	0.36	18.18	22.99	8.03	59.52	1.98
C2	125-165		5.92	1.15	4.18	0.32	15.25	38.82	7.54	27.41	2.10
Penkov et al., 1985 –MeadowSolonchak-Solonetz (sodic-sulfatic) (Profile 7)												
Horizon	Depth, cm	pH in H_2O	Exchangeable cations in mequ/100g				CEC inmequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
A1	0-3	7.85	3.35	1.69	4.56	0.92	13.15	25.48	12.85	34.68	7.00
A2	3-12	8.95	3.26	2.13	10.15	1.05	18.93	17.22	11.25	53.62	5.55
B1	12-36	9.08	3.68	4.10	12.35	1.16	28.02	13.13	14.63	44.08	4.14
B2	36-38	9.20	4.32	3.98	12.48	1.05	28.38	15.22	14.02	43.97	3.70
B3C1	68-120	9.20	4.86	2.92	13.52	0.69	23.82	20.40	12.26	56.76	2.90
C2	120-165	9.45	3.74	3.18	8.16	0.61	21.06	17.76	15.10	38.75	2.90
Penkov, 1995 – Solonchak-Solonetz (*Profile 8*)												
Horizon	Depth, cm	pH in H_2O	Exchangeable cations in mequ/100g				CEC inmequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	N	K
Als	0-15		1.80	0.80	3.40	0.20	6.20	29.03	12.90	54.84	3.23
B1tsl	15-40		7.20	2.60	18.50	0.40	28.70	25.09	9.06	64.46	1.39
B2tsl	40-80		8.20	1.90	21.50	0.40	32.00	25.63	5.94	67.19	1.25
B3tsl	80-120		8.60	1.60	21.80	0.40	32.40	26.54	4.94	67.28	1.23
Ck	120-160		7.00	1.80	18.20	0.30	27.30	25.64	6.59	66.67	1.10
Vodenicharov, 1968 – Section 13 (*Profile 9*)												
Horizon	Depth, cm	pH in H_2O	Exchangeable cations in mequ/100g				CEC in mequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
	0-15		9.48	3.45	2.17		15.10	62.78	22.85	14.37	
	15-25		16.06	4.57	1.91		22.54	71.25	20.28	8.47	
	25-35		21.11	5.51	2.70		29.32	72.00	18.79	9.21	
Vodenicharov, 1968 – Section 15 (*Profile 10*)												
Horizon	Depth, cm	pH in H_2O	Exchangeable cations in mequ/100g				CEC inmequ/100g	Exchangeable cations in % from CEC			
			Ca	Mg	Na	K		Ca	Mg	Na	K
	0-1		6.66	2.46	3.52		12.64	52.69	19.46	27.85	
	1-8		2.73	4.42	3.70		10.85	25.16	40.74	34.10	
	8-17		2.37	9.89	7.22		19.48	12.17	50.77	37.06	
	23-42		3.33	13.31	9.57		26.21	12.71	50.78	36.51	
	42-70		5.75								
	70-80		4.79								

Table 2. *Calculated criteria for magnesium salinity applied to each soil horizon*

Profile 1		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
Ah	0-12	37.41	25.72	1.0	171.2	63
B1	15-25	35.33	19.33	1.3	123.5	55
B2k	30-40		11.28			
BCk	48-58		10.81			
BCk	68-78		19.78			
Profile 2		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
Ah	0-9	37.90	0.96	1.4	70.9	39
aB	18-28	9.80	69.32	1.6	495.1	79
B1kg	18-28		61.35			
B2kg	44-54		27.18			
BCkg	95-105		10.80			
C1kg	137-147		5.06			
Profile 3		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
Ah	0-13	37.23	18.23	1.1	134.3	55
AB	13-23	36.76	19.46	1.0	157.6	56
B1	26-36	45.45	22.73	0.7	214.3	68
B2	51-61	58.18	20.91	0.4	378.3	79
BCkg	88-98		23.34			
C1kg	105-115		7.44			
Profile 4		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
A1	0-30	20.24	5.96	3.0	42.8	26
B1	30-60	26.15	24.82	1.1	177.8	51
B2C1	60-115	40.29	38.06	0.4	499.0	78
C2	115-160	19.45	11.98	0.3	512.5	31
Profile 5		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
A1	0-3	15.95	2.85	3.6	32.6	19
A2	3-7	15.92	8.77	2.8	55.6	25
B1	7-15	25.00	27.58	0.9	234.5	53
B2	15-36	25.10	20.97	2.0	91.5	46
B3	36-70	30.31	35.36	1.4	151.6	66
B4C1	70-125	53.02	37.27	0.1	1228.9	90
C2	125-170	48.31	24.88	0.5	293.6	73
Profile 6		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
A1	0-4	8.87	37.68	2.1	255.4	47
B1	4-12	10.56	54.09	2.5	247.7	65
B2	12-32	9.56	58.22	2.9	242.2	68
B3	32-60	7.22	57.44	3.5	252.4	65
B4C1	60-125	8.03	59.52	2.9	293.8	68
C2	125-165	7.54	27.41	5.1	90.0	35
Profile 7		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
A1	0-3	12.85	34.68	2.0	186.6	48
A2	3-12	11.25	53.62	1.5	376.7	65
B1	12-36	14.63	44.08	0.9	447.0	59
B2	36-38	14.02	43.97	1.1	381.0	58
B3C1	68-120	12.26	56.76	1.7	338.3	69
C2	120-165	15.10	38.75	1.2	303.2	54

Table 2. *Calculated criteria for magnesium salinity applied to each soil horizon – (Continue)*

Profile 8		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
Als	0-15	12.90	54.84	2.3	233.3	68
B1tsl	15-40	9.06	64.46	2.8	293.1	74
B2tsl	40-80	5.94	67.19	4.3	285.4	73
B3tsl	80-120	4.94	67.28	5.4	272.1	72
Ck	120-160	6.59	66.67	3.9	285.7	73
Profile 9		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
	0-15	22.85	14.37	2.7	59.3	37
	15-25	20.28	8.47	3.5	40.3	29
	25-35	18.79	9.21	3.8	38.9	28
Profile 10		EMP	ESP	Ca:Mg	Na+Mg % Ca	Na+Mg % CEC
Horizon	Depth, cm					
	0-1	19.46	27.85	2.7	89.8	47
	1-8	40.74	34.10	0.6	297.4	75
	8-17	50.77	37.06	0.2	721.9	88
	23-42	50.78	36.51	0.3	687.1	87

Profile 4 – soil is defined as Solonetz. Accumulation of exch. Na is distinct in the B-horizon, where exch. Mg is accumulated. The criteria for ESP and “EMP” are approximately equal, with a slight preponderance of “EMP”. Due to the heterogeneous content of all exchangeable cations in different horizons, the magnesium salinity indexes also vary considerably. Thus, only in B2C1 is clear indication of magnesium salinity, but in this horizon ESP is also crucial for overall salinisation. Therefore, in this profile magnesium salinity can only be mentioned in the B2C1 horizon.

Profile 5 – the soil is defined as Solonchaks-solonetz, salic-sodic. The data for the entire profile, made up of 7 horizons, is available. In depth, “EMP” increases, with B1 downwards exceeding 25%, and in the lower horizons exceeding ESP values. The “Ca:Mg” ratio is below 1 in B1 and the lowest two horizons. In the other horizons it is well above 1. The “Na+Mg in % from Ca” and “Na+Mg in % from CEC” criteria are below their marginal values in the surface horizons and then increase sharply. The mixed salinisation plays a decisive role in the redistribution of the cations in the individual horizons, with the more mobile Na and Mg being removed from the surface horizons, but in depth they accumulate in sufficient quantities for the manifestation of both strong Na and Mg salinity.

Profile 6 — in this profile, defined as Meadow Solonetz (sodic), the content of exch. Mg is low; respectively “EMP” barely reaches values of more than 10%. The “Ca:Mg” ratio is well above 1. The “Na+Mg in % from Ca” and “Na+Mg in % from CEC” criteria show magnesium salinity, but take into account the high content of exch. Na those criteria cannot be taken as an unambiguous indicators. Thus, in this profile the magnesium salinity cannot be determined.

Profile 7 – here the “EMP” is below 25% too (from 11 to 15%). The “Ca;Mg” ratio ranges from 0.9 to 2.0 in different horizons. The “Na+Mg in % from Ca” and “Na+Mg in % from CEC” are again extremely high due to the high content of exch. Na. Again, magnesium salinity cannot be clearly determined.

Profile 8 – the results for this soil are similar to those of profile 6 and no magnesium salinity is determined.

Profile 9 – this soil is given as an example of Solonetz, but all indicators show a lack of salinity from exchangeable Na and Mg cations. Only by "Na+Mg in % from CEC" the values are above the 20% margin, but all others are below their margins.

Profile 10 – immediately impresses the higher values for "EMP" and ESP, as EMP is more than ESP. With the exception of the surface horizon, the depth "Ca:Mg" sharply and significantly decreases below 1. The "Na+Mg in % from Ca" and "Na+Mg in % from CEC" are extremely high. Thus, this soil is with well-expressed magnesium salinity.

Conclusions

From the analysis of the available literature data for 10 soil profiles from the land of Belozem, the following conclusions are done:

1. In three of the profiles (#1, #3, #10) it can be clearly stated that there is an increased content of exchanged Mg and this lead to manifestation of magnesium salinity respectively. At least the values of 3 criteria are fulfilled and the fourth is marginal.

2. In four of the profiles (#6, #7, #8, #9) the content of the exchangeable Mg doesn't reach levels to indicate magnesium salinity. The "EMP" is low, below 20% even less than 10%, "Ca:Mg" is more than 2 (by marginal value less than 1), and in *Profile 9* even one of the criteria, which assume the exchangeable Na, is also below its marginal value.

3. In three of the profiles (#2, #4, #5), the magnesium salinity is found unevenly in different horizons.

4. Considering the existing magnesium salinity criteria, it is recommended to use all of them in combination, since the use of only one of them can lead to misleading conclusions, especially in combination with high values of exchangeable Na.

5. The examined profiles revealed that there are horizons in which EMP is crucial for salinisation (ESP < 20%), as well as whole profiles in which EMP exceeds ESP at ESP > 25%. This should be taken into account when interpreting the criteria for magnesium salinity.

The obtained results can serve as a new classification definition of the selected soil profiles (adding a magnesium index for the designation of diagnostic horizons, as well as marking magnesium in the main name), further evaluating the role of the exchangeable magnesium for their physical and chemical properties and their structural properties and to look for new concepts for the reclamation of these soils in view of the high content of exchangeable magnesium.

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