Physical Properties of Magnesium Affected Soils in Colombia

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Introduction

Magnesium has some capacity to develop higher exchangeable sodium levels in clays and soil materials. The Mg^{+2} accumulation on the exchange complex of soils to a very high saturation levels affect their physical, chemical and biological properties. Colombia has a large area of these soils, located mainly in the main rivers valleys and in the Caribbean Region. In the Cauca River Valley there are about 117.000 hectares affected. There is a lack of information about the soil forming processes, the Mg^{+2} effects on soils, the type and source of compounds responsible for the magnesium enrichment, their relationship with the landscape and the way this accumulation occurs.

Materials and Methods.

To identify and quantify soil Mg^{+2}enriched areas over 2500 soil profiles from different landscape positions of the Cauca River Valley were studied. The information was processed to generate Mg-saturation maps, to identify the different soil profile types and to estimate the affected area. A topographic sequence from the alluvial inundation plain to the hills was used to explore the presence of diagnostic horizons and to determine the main soil characteristics and genetic, mineralogical or chemical evidences of soil forming processes. Two 180 kilometer transects parallel to the river were used to: a) study the type and source of Mg-compounds responsible for the Mg-enrichment and the way this accumulation occurs. b) the soil hydraulic properties like infiltration, saturated hydraulic conductivity and matric potential at different depths were also measured. Samples of nine profiles were collected and the porosity and soil volume changes at different water content were examined. The program RETC was used for prediction of the hydraulic properties of non saturated soils. These properties involved the retention curve, the function of hydraulic conductivity and the diffusivity of the water in the soil.

Results.

By grouping together the soil profiles, five main type of Mg-affected soils were identified as being predominant in the different landscape units. Their distribution in the landscape units showed two different origins: soils developed under hydromorphic conditions and soils related to igneous Mg-materials.

The toposequence studied showed the presence of natric or gypsic horizons on the basin soil profiles and evidence of Ca^{+2} and Mg^{+2} precipitation as calcite and/or aragonite. As the hydromorphic conditions changed from the basin to the hills the vertic characteristics disappeared but calcium accumulation and precipitation still occurred. Light alkalinity is ordinary in all the strata but in the upper horizons. Sulphate and bicarbonate ions were found in all profiles but the later was not found in the soil parent materials of the lower plains. As the soil becomes deeper, sulphate ions become predominant and gypsum accumulation appears due to reductive environment. The mineralogical composition of the clay fraction showed the presence of vermiculite and smectite in all profiles but predominant in the basin and lower plains.

Calcium and Mg bicarbonates were also the predominant salts in the surface (0 to20 cm) of the soils located in the transect parallel to the river. In the deeper layers (20 to 40 cm and 40 to 60 cm) Mg-sulphate acquired predominance. The presence and activity of the Ca and Mg ions in the deeper layers of the profiles played a decisive roll in the physical-chemical relationships of these soils.

Wetting and drying periods facilitate calcite concentration and precipitation out the soil solution, affecting soil capacity to water and gas flow and making it easy to SO_4^{+2} and Mg^{+2} ions to predominate into the profile. The Ca^{+2} decrement allows a relative accumulation of Mg and, later on, of Na. In this way Mg^{+2} determines the soil chemical and physical properties depending on its saturation in the exchange complex and high hydration energy. It was considered $CaCO_3$ precipitation as the main chemical process affecting soil physical properties.

High bicarbonate and sulphate waters used to perform laboratory experiments showed the effect of irrigation on this soils causing soil sealing and crusting, decrease of aggregate stability, hydraulic conductivity and soil permeability associated to ESP and EMgP increments (Tables 1 and 2). The presence of illite on the clay fraction was related to low soil tolerance to chemical and physical degradation .

After several days representative 5 cm core samples of selected soils (Udic Pellustert, Typic Pellustert, Typic Haplustalf, Fluvaquentic Haplustoll and Vertic Ustropept), did not reach the saturation point when they were left in water to capillarity rise. The levels of relative saturation showed small changes at different hydraulic heads, but it was observed the water film formed on the soil surface was expelled to low suction (0,1 bar).

The nonsaturation of magnesic soils by hydrophobic forces is possible. The water content under different suctions (0,1 up to 15 bar) showed small differences due to the low hydraulic conductivity limiting the effective saturation and the residual water capacity of the soil, being the hydraulic adjustments strongly restricted by the high matrix energies that govern the water-soil relationships associated to the microporosity of the soils.

In the magnesic vertisols, porosity is limited by the lack of spaces for the water and air movement the total porosity is very low (15-30%), with micropores prevalence and high water retention capacity.. Soils don't have any structural arrangement to form macropores due to dispersion of the clays caused by the magnesium saturation and the reorientation of their layers by the attraction forces. The content of clays is high (45-75%), The drainage is slow to imperfect which it is associated to the dominance of vertic conditions (Cole >0.09), high plasticity (PI>20%), high residual humidity, structural uncertainty, rigidity in dry and impediment to reach the total saturation (Tables 3 and 4).

Soil volume changes from saturation to dryness with a measured mean value of 30%. When the water retained in pores is extracted the soil mass contraction give place to cracks of different size which explain the volume reduction. The function change of volume was: $\Delta V = 3.65h^{0.203}$.

Precipitations of $CaCO_3$ and other salts are observed on the flat court surfaces, sealing of pores and high removal potential when they are exposed to watering or rain. The nature of the clays and the mineral solubility processes have favored the Mg enrichment of the soils of the valley, causing clay peptization and dispersion and affecting the porosity and the hydraulic conductivity of the soil.

Additional Index words: salinity, soil Mg-enrichment, soil hydraulic properties porosity, soil volume changes.

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Table 1.- Changes in the Exchangeable Magnesium Percentage (EMgP) and Exchangeable Sodium Percentage (ESP) of three Colombian soils treated with high bicarbonate and sulphate waters.

	EMgP		ESP	
Soil	%			
	Initial	**Final**	**Initial**	**Final**
Alfisol	26.7	31.5	4.2	4.5
Mollisol	24.8	45.1	0.7	7.8
Vertisol	28.5	33.8	2.2	3.7

Table 2. Saturated Hydraulic Conductivity of three Colombian soils treated with high bicarbonate and sulphate saline water (40 cmol (+) L^{-1})

Hydraulic Conductivity (Ksat) mm/h					
Alfisol		**Mollisol**		**Vertisol**	
Before	**After**	**Before**	**After**	**Before**	**After**
95.1	86.0	60.1	5.0	46.4	27.5

Table 3.-Physical characterization of the three Mg-enriched soils of the Valley of the Cauca River (Colombia)

Soil	Texture	O.M. (%)	Bulk density (g/cm^3)	Dr g/cm^3)	PI (%)	CD (%)	H.W (%)	SI	Porosity (%)	WR_{15}bar
Typic Haplustalf	**ArL**	**2.79**	**1.37**	**2.63**	**35.9**	**1.81**	**1.93**	**0.97**	**42.96**	**31.01**
Pachic Haplustoll	**FL**	**2.50**	**1.17**	**2.73**	**20.7**	**11.53**	**1.47**	**0.51**	**57.14**	**14.28**
Typic Haplustert	**Ar**	**2.37**	**1.43**	**2.56**	**34.7**	**48.69**	**2.71**	**1.38**	**40.41**	**31.39**

O.M=Organic Matter, Dr=density, PI= plasticity Index, DC=Dispersion coefficient, HW=hygroscopic water, SI= stability Index, WR_{15} bar = Water retention to 15 bar.

Table 4. Some physical properties of Mg enriched soils from the Cauca river Valley (Colombia).

Soil	Depth (cm)	Bulk density Mg m^{-3}	Density Mg m^{-3}	Porosity (%)	Compaction susceptibility (%)	Cut resistance (Kgcm^{-3})	Hydraulic Conductivity. (cm hr^{-1})
Berginie	0-20	1,95	2,79	27,41	91,93	4,08	1,17
	20-40	1,79	2,67	27,69	93,87	5,00	2,15
	40-60	1,59	2,70	32,83	86,53	5,58	3,14
Cabaña1	0-20	1,80	2,57	30,57	97,20	3,17	1,16
	20-40	1,84	2,71	32,09	97,86	2,67	0,17
	40-60	1,74	2,74	28,24	95,20	2,08	2,21
Cabaña 2	0-20	1,41	2,54	29,2	96,98	2,83	0,80
	20-40	1,41	2,64	28,85	98,52	4,00	0,00
	40-60	1,41	2,69	33,58	97,45	3,50	0,80
Cabaña 3	0-20	1,61	2,61	15,15	95,85	4,03	0,27
	20-40	1,20	2,87	15,15	95,36	3,92	0,00
	40-60	1,20	2,67	15,15	91,28	4,33	0,00
Cabaña 4	0-20	1,51	2,73	32,16	94,70	3,38	1,17
	20-40	1,45	2,75	31,37	95,46	3,22	0,27
	40-60	1,22	2,73	36,19	97,68	2,33	1,41
Argelia	0-20	1,23	2,62	24,63	91,85	5,00	0,87
	20-40	1,20	2,67	22,85	94,33	4,50	0,00
	40-60	1,19	2,66	22,85	95,52	4,50	0,00
Trinidad	0-20	1,09	2,67	16,1	92,24	5,50	25,45
	20-40	1,18	2,42	20,45	97,23	5,70	0,40
	40-60	1,18	2,47	20,45	100,00	6,00	0,67
Esperanza	0-20	1,15	2,58	26,13	97,20	5,18	2,01
	20-40	1,26	2,73	20,82	97,86	5,18	0,00
	40-60	1,16	2,67	20,82	95,20	5,18	0,00
Cabaña Rozo	0-20	1,24	2,72	24,44	92,33	3,50	0,00
	20-40	1,89	2,71	26,04	93,41	3,50	0,13
	40-60	1,09	2,71	26,04	95,36	2,83	0,00
Ceniuva	0-20	1,85	2,64	29,57	91,93	5,75	0,00
	20-40	1,47	2,60	24,71	93,80	6,50	0,00
	40-60	1,84	2,56	24,71	86,53	5,83	0,06
Paso Ancho	0-20	1,57	2,78	39,56	98,49	3,33	4,63
	20-40	1,50	2,66	45,39	99,20	3,58	1,88
	40-60	1,46	2,66	45,39	98,72	4,33	30,49
VillaClara	0-20	1,83	2,63	29,15	97,92	3,33	21,76
	20-40	1,91	2,57	24,33	97,68	3,58	9,84
	40-60	1,88	2,66	24,33	95,68	4,33	26,25