Relation among the processes of erosion-sedimentation-pollution in soils from the Distrito Pecuario "Alturas de Nazareno", Cuba

J. M. Febles González[1], N. Amaral Sobrinho[2], Y. Pérez López[3], J.H. Zoffoli[2], M.O. Lima Magalhães[2] and N. Guedes[2]

[1]*Universidad de La Habana, Zapata y G, Vedado, Plaza de la Revolución, Ciudad de La Habana, C.P: 10 400.*
[2]*Universidade Federal Rural do Rio de Janeiro. Br 465 km 7, Seropédica - R J, Brasil*
[3]*Universidad Agraria de La Habana "Fructuoso Rodríguez Pérez" Carretera Jamaica- Tapaste, km 21/2, San José de Las Lajas, Cuba*
Email: febles@rect.uh.cu

The geological environments and their influence on the processes of erosion-sedimentation-pollution in soils due to heavy metals in the Distrito Pecuario "Alturas de Nazareno" were evaluated, with a functional biological diversity supported by the natural regeneration of the tree component. The work of pedological prospection: identified four types of soils, described and sampled at 0-20 cm and 20-40 cm deep. It was confirmed the prevalence of erosive processes and the possible access of the grass roots into a layer of peculiar alteration (level 25 - 30 cm) in "Alturas de Nazareno", with considerable proportions of NiO_2, Zn, Cd, Cr and Fe. In the Polje of San José, there was a preeminence of the sedimentation-pollution from the surface (level 0 - 30 cm), associated to toxic organic compounds, nutrients and organic matter, where any not controlled action in the cattle systems could move the heavy metals present in the soil to the pastures and the water provided to the animals.

Key words: *heavy metals, trace elements, geo-chemical bank, reference values, polje*

The heavy metals (HM) are naturally present within the soils. The increase of their concentrations can occur due to natural processes or anthropogenic activities (Guilherme *et al*. 2005 and Amaral Sobrinho *et al*. 2009).

The total natural concentration of HM within the soils depends mainly on the original material, formation processes and the proportion of the components of the solid phase. This concentration is less evident in soils formed over sediments (Fadigas *et al*. 2006 and Utermann *et al*. 2006).

Researches carried out in the carcasic regions of Havana province, in the sub-basin Mampostón and in the Distrito Pecuario "Alturas de Nazareno", have revealed the soil losses due to the erosion in ferrallitic environments, which propitiate the sequential degradation of the most productive soils of Cuba (Febles *et al*. 2012).

In this context, there are still unspecific regularities and genetic bonds of the processes of sedimentation and contamination with the manifestations of soil erosion, whether they have geological character in less disturbed environments or induced by the agricultural and livestock activity (Febles *et al*. 2010). As it is known, the HM can be present naturally within the soils, even though they have not had anthropic disturbance (Guilherme *et al*. 2005). Starting from this point, this study has the objective of making an integral evaluation of the geological environments and their influence on the processes of erosion-sedimentation-pollution in soils due to heavy metals in the Distrito Pecuario "Alturas de Nazareno"

Materials and Methods

The Distrito Pecuario "Alturas de Nazareno" is located in the center of Mayabeque province, in the Western part of Cuba. It has an extension of 71261. 5 ha. It starts with a small tectonic-structured height, like horst type, with flat top (Iturralde-Vinent 2011), pertaining to the regions of Bejucal-Madruga-Coliseo Heights. They descend abruptly through a well defined escarpment into a denudative plain, developed over a rock bed (of plinth), slightly dissected (H = 100 – 120 m).

It receives, approximately, between 76 and 80 % of the annual precipitations of the province (INSMET 2012), which are superior to 1,580 mm per year. This fact makes this agro-ecosystem to be considered as one of the most humid in Cuba. The minimum absolute temperatures per year in the territory show average values of 19.5 ºC. The maximum absolute temperatures per year are of 26.33 ºC and the annual mean temperature is 23.47 ºC.

The main soils (table 1) are characterized by a functional biological diversity, supported by the natural regeneration of the tree component, with "healing" species like marabou (*Dichrotechys glomerata*), aroma (*Acacia farmesiana*) and palm trees (*Roystonea regia*), which act as an induced fallow land and favor certain resilience or stability in the processes, with some independence of the energy value of the relief. Nevertheless, during the 80´s, the cover was treated, in some sectors, with a non differentiated management technology.

Twelve main profiles were characterized. Soil samples were taken from the superior, medium and inferior flexures of the micro-relief, in order to examine the dynamic, manifestation and intensity of the erosion

Table 1. Area occupied by the main types of soil in the Distrito Pecuario “Alturas de Nazareno”, Mayabeque province

Type (Paneque *et al*.. 1991)	Area (ha)	World Reference Base (2006)	New version Classification (Hernández *et al*. 1999)
Typical red ferrallitic	38 106.496	Ferralsol Rhodic	Ferrallitic grouping. Red type
Carbonated brown	24 658.760	Cambisol Calcic	Brown sialitic grouping. Brown type
Red rendzine	5 823.987	Feozem - Calcaric-Rhodic - Skeletic	Humic grouping. Rendzine type
Brown red Fersialitic	2 634.142	Cambisol Chromic-Humic	Fersialitic grouping. Brown red Fersialitic type

through a comparative-descriptive analysis, at deeps of 0-20 cm and 20- 40 cm.

The samples were pounded, grinded up to 210 µm particle size. They were subjected to an extract of aqua regia ($3HNO_3$ + 1HCl) to quantify the pseudo-total contents (do not destroy the structures of the silicates) (ISO 1995). The fractions of metals in the soil samples were determined by the “European Communities Bureau of Reference” (BCR), according to Sahuquillo *et al*. (1999).

The geochemical fractions were: F1extracted with a solution of acetic acid 0.11 mol L^{-1} (soluble acid fraction), F2 extracted with a solution of hydroxylamine hydrochloride 0.1 mol L^{-1} (fraction linked to the Fe and Mn oxides), F3 extracted with the solutions of hydrogen peroxide 8.8 mol L^{-1} and ammonium acetate of 1.0 mol L-1, fraction linked to the organic matter) and F4 extracted with aqua regia – Σ from the previous fractions (residual fraction). The analyses of HM were performed with five analytic repetitions per sample. The mean values of the repetitions per each type of soil were considered.

The concentrations of the elements in the extracts resulting from the soil were quantified with an inductively coupled plasma optic emission spectrometer(ICP-OES), Pekín Elmer trademark, ÓPTIMA 3 000 model, with LD[1] (mg kg^{-1}) of 0.508 and LQ (mg kg^{-1}) of 1.69 for Zn; LD (mg kg^{-1}) of 0.026 and LQ (mg kg^{-1}) of 0.097 for Cd; LD (mg kg^{-1}) of 0.020 and LQ (mg kg^{-1}) of 0.067 for Pb; LD (mg kg^{-1}) of 0.01and LQ (mg kg^{-1}) of 0.05 for Fe; LD (mg kg^{-1}) of 0.01 and LQ (mg kg^{-1}) of 0.020 for Mn; LD (mg kg^{-1}) of 0.03. The certified material of reference NIST SRM 2709a (San Joaquin Soil, with Zn concentrations of 103 ± 28 mg kg^{-1}; Cd, 0.371 ± 0.002 mg kg $^{-1}$, Pb 17.3 ± 0.1; Mn of 529 ± 18 mg kg^{-1}; Fe of 33.6 ± 0.7 g kg^{-1}) was used for validating the determination of the pseudo-total content of Zn, Cd, Fe, Mn, Pb and Cr in the soil,.

Results and Discussion

Due to that the edaphic cover “stores” features and properties inherited from past geological and climatic phases, which are not in balance with the current edaphogenic processes (Guerasimov 1983), this analysis started from the paleo-geografic evolution of sub-district of the Habana-Matanzas Heights, which has been very complex. It has also been necessary to reflect on the possible origin of the HM currently present in the soils of the Distrito Pecuario “Alturas de Nazareno”. The paleo-geografic evolution of this sub-district started from the sediments of the Laramide basement, which bended profoundly with frequent thrust faults during the development stage of the isles bow (Iturralde 1996).

This sub-district can be considered as part of the Continental Paleomargin of Bahamas, where appeared the carbonated rocks from the inferior Eocene (P_2^3) to the inferior Miocene (N_1^1) (Albear and Iturralde - Vinent 1985), in a complex combination with other very different rocks (table 2), like tufa, marlstones and sandstones (Campos *et al*. 2004). There are also, underlying, the ophiolites from the Capdevila (P_2^3) formation.

In these enclaves (Febles *et al*. 2009), the balance of morphogenesis-pedogenesis depend on the morpho-structural, and very specially, on the chemical-mineralogical composition of rocks. This process can be very slow, as happens with the ophiolites, in which the morphogenesis can even inhibit the edaphogenesis on the rocks, due to the erosion of the eluvia while they are forming. It can also be fast, like in the tufa stones, in which it is possible to go from the denudation to the formation of deep soils.

There are geological and geomorphologic peculiarities in these environments, which influence directly on the erosion processes, whether they are geological or induced by the agricultural and livestock activity, with more extended actions through time regarding other environments. A significant characteristic of the soils from the Distrito Pecuario “Alturas de Nazareno” is, precisely, their moving towards the bedrock. There is no C horizon, and it goes suddenly from B horizon to the underlying limestone (figure 1). This happens in most cases through a very thin layer, determined by its reaction to acid, which is similar to the peculiar alteration described by Lamoureux (1972) in Lebanon and by Bosch *et al*. (1984) in ferrallitic soils from Cuba.

Specifically, this layer contains, at around

[1]LD: Limit of detection and LQ: Limit of quantification, of the analytic methods used.

Table 2. Main rocks in the formation of ferrallitic eluvia in soils from the Distrito Pecuario "Alturas de Nazareno", Mayabeque province

Rocks	Characteristics	References
	Nazareno Group (nz)	
Aleurites	Constituted by angular and sub-angular grains of quartz, with some fragments of plagioclases, mica and dark minerals. The relative proportion of the different lytologies is variable, with a predominance of limes and the limes-aleuritas-argilitas rythm.	Albear and Iturralde (1985)
	Capdevila formation (subjacent to Nazareno group) Inferior Eocene	
Ophiolites Greywackes	They are associations of ultramafic, mafic and mafic-volcanic rocks. Constituted by mica, feldspar, and other grain constituents, including quartz (although in lower proportions). All those elements are united by an also dentritic cement.	Bronnimann and Rigassi (1963)
	Husillo formation (hs)	
Relictus-organic and crystalline limes	They appear at open sky quarries in Camoa and Somorrostro, with a light grey color and black	Bronnimann y Rigassi (1963)

20-30 cm deep in the non carbonated residues, considerable proportions of NiO_2, Zn, Cd, Cr, Fe, among other elements. According to Camacho *et al*. (1980) and Camacho *et al*. (1985), for some limestone studied in Cuba, these elements enrich the cortexes of metheorization with HM, where the greatest proportion of forages roots and is concentrated. This fact has been confirmed in the researched region, because there is a good correspondence between the mineralogy of rocks and soils. They are much related to the degree of impurities of limestone, their speed of dissolution and the time passed, which has been confirmed by Ortega (1984) and Jaimez and Ortega (2001) in similar territories.

The previously mentioned has been also confirmed by the comparative analysis of the natural values of the HM in the main soils from the "Alturas de Nazareno" (table 3), regarding the reference values, used internationally (Lista holandesa 2000, Kabata-Pendias and Pendias 2001, CETESB 2005 and Fadigas *et al*. 2006). There is also evidence that the brown red fersialitic, typical red and carbonated brown ferrallitic soils present natural values over those limits.

In some cases, these soils can be classified as "contaminated". However, these concentrations are found naturally, due to the presence of these elements in the minerals that form the rocks and the geological environments of formation, which coincides with those found by Fadigas *et al*. (2002) in studies carried out in Brazil.

The geo-chemical behavior of the HM in these soils shows some similarities for the different fractions (table 4). The Cu, Zn, Ni, Fe and Cr showed higher percentages in the residual fraction (F4), which indicates this elements are found in the most stable geo-chemical fraction, with the least solubility and bioavailability, generally related to primary and secondary minerals, which can contain metals within their crystalline structure, hardly released in less disturbed environments or in biostasia (Dang *et al*. 2002).

The geo-chemical distribution of Mn is mostly found in the fraction associated with the oxides of Fe and Mn (F2). On this matter, Rodríguez *et al*. (2009) point out that the association of metals with oxides does not guarantee the immobilization in the surface because these elements are still unstable in this fraction and they may be released by the reduction of oxides and, consequently, cause a negative effect on the soil and on the biota (Cholpecka 1996).

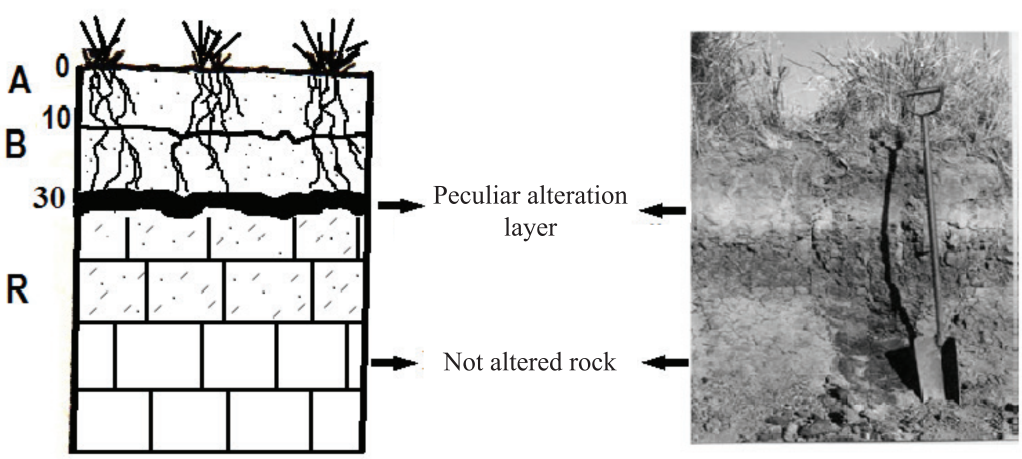

Figure 1 Scheme of the peculiar alteration layer, generally associated with primary and secondary minerals that enrich the cortexes of metheorization with HM.

Table 3. Natural values of HM in soils from the Distrito Pecuario "Alturas de Nazareno", with relation to the reference values proposed by the international literature

	Cu	Zn	Mn	Ni	Cd	Pb	Fe	Cr
	mg kg^{-1}							
B.R.F.[1]	84.0	171.5	2599.0	161.1	3.1	50.3	28639.0	90.3
T.R.F.[2]	129.5	469.1	2725.0	308.1	11.3	65.4	48120.0	290.0
B.C.[3]	44.4	65.9	992.0	57.7	2.4	44.4	21567.0	33.2
Q.R.[4]	35.0	60.0	*	13.0	0.5	17.0	*	*
Prev.[5]	60.0	300.0	*	30.0	1.3	72.0	*	*
Res.[5]	200.0	450.0	*	70.0	3.0	180.0	*	*
Fadigas[6]	2.0 - 119	6.0 - 79	*	5.0 - 35	0.3 - 1.5	3.0 - 40	*	19.0 - 65
Holland[7]	36.0	140.0	*	35.0	0.8	85.0	*	100.0
World[8]	0.3 - 495	1.5 - 264	80 - 1315	0.7 - 269	0.005 - 2.4	0.5 - 135	*	6.0 - 80

[1] Brown red Fersialitic. [2] Typical Red Ferrallitic. [3] Carbonated Brown. [4] Quality reference (Cetesb 2005). [5] Prevention and research (Conama 2009). [6] Reference values for Brazilian soils (Fadigas *et al*. 2006). [7] Reference values of Dutch soils (Crommentuijn *et al*. 2000). [8] Concentration range of HM in soils of around the world (Kabata - Pendias and Pendias 2001)
* Not informed values

Table 4. Sequential extraction of pseudo-total HM in the main types of soils at 0-40 cm deep. Distrito Pecuario "Alturas de Nazareno", Mayabeque province

Fraction	Cu	Zn	Mn	Ni	Cd	Pb	Fe	Cr
	mg kg^{-1}							
	Brown red fersialitic							
F1	1.8 (2)	0.0 (0)	56.9 (2)	2.5 (2)	0.9 (30)	9.2 (18)	1.8 (0.1)	0.0 (0)
F2	11.0 (13)	7.5 (4)	1771.1 (68)	22.3 (14)	0.7 (24)	20.3 (40)	611.8 (2)	0.6 (1)
F3	12.9 (15)	3.7 (2)	361.5 (14)	16.2 (10)	0.8 (26)	36.2 (72)	58.2 (0.1)	11.3 (13)
F4	58.5 (70)	160.3 (93)	409.7 (16)	120.1 (75)	0.6 (19)	0.3 (1)	27964.7 (97.8)	50.7 (56)
	Typical red ferralitic							
F1	0.8 (1)	8.6 (2)	349.9 (13)	2.0 (1)	2.2 (19)	2.8 (4)	0.0 (0)	0.0 (0)
F2	1.0 (1)	14.8 (3)	1722.7 (63)	6.9 (2)	4.3 (38)	0.5 (1)	914.9 (2)	0.1 (0)
F3	14.5 (11)	13.8 (3)	98.8 (4)	8.7 (4)	1.4 (13)	0.0 (0)	576.1 (1)	12.3 (4)
F4	113.2 (87)	431.8 (92)	554.0 (20)	290.5 (93)	3.3 (29)	62.0 (95)	46629.7 (97)	277.9 (96)
	Carbonated brown							
F1	1.7 (4)	2.9 (4)	149.7 (15)	4.4 (8)	0.9 (40)	12.3 (28)	3.4 (0)	0.7 (3)
F2	0.5 (1)	1.7 (3)	572.8 (58)	2.8 (5)	0.6 (24)	4.8 (11)	0.0 (0)	0.0 (0)
F3	6.1 (14)	8.4 (13)	214.2 (22)	12.0 (21)	0.4 (16)	12.8 (29)	664.1 (3)	5.5 (16)
F4	36.1 (81)	52.8 (80)	55.3 (6)	38.4 (67)	0.5 (20)	14.4 (32)	20899.1 (97)	27.0 (81)

Values in parenthesis represent the percentage regarding the total; F1: soluble acid fraction; F2: fraction linked to oxides of Fe and Mn; F3: fraction linked to organic matter; F4: residual fraction

The Cd and Pb are distributed in a differentiated manner, according to the type of soil. The brown red fersialitic soil, like the carbonated brown soil, presented the highest tenors of Cd in the acid soluble fraction (F1). That fraction contains the elements of the solution, weakly adsorbed by electrostatic interaction, and precipitated with carbonates (Marín *et al*. 1997 and Filgueiras *et al*. 2004). Their high content could be a problem from the environmental point of view, mainly in the fractions of higher lability (Sastre *et al*. 2001 and He *et al*. 2005).

Pb presented a higher tenor in the fraction linked to the organic matter (F3) in the brown red fersialitic soil, while for the typical red ferrallitic soil, the highest percent was found on the residual fraction (F4). For the carbonated brown soil, there was no predominance in a determined fraction. Very proximate values were found, and in all the fractions.

In a general evaluation, the majority of the elements in all the soils are mainly distributed in the residual fraction, as a consequence of the low solubility and strong adsorption in the surface of the soil particles (Chaney 1991), and the erosion is the main process for the removal of these elements. This coincides with the informed by Núñez *et al*. (2006).

"Alturas de Nazareno" is the main source of porous sediments, which sequentially descend towards sectors of the relief of minor hypsometry

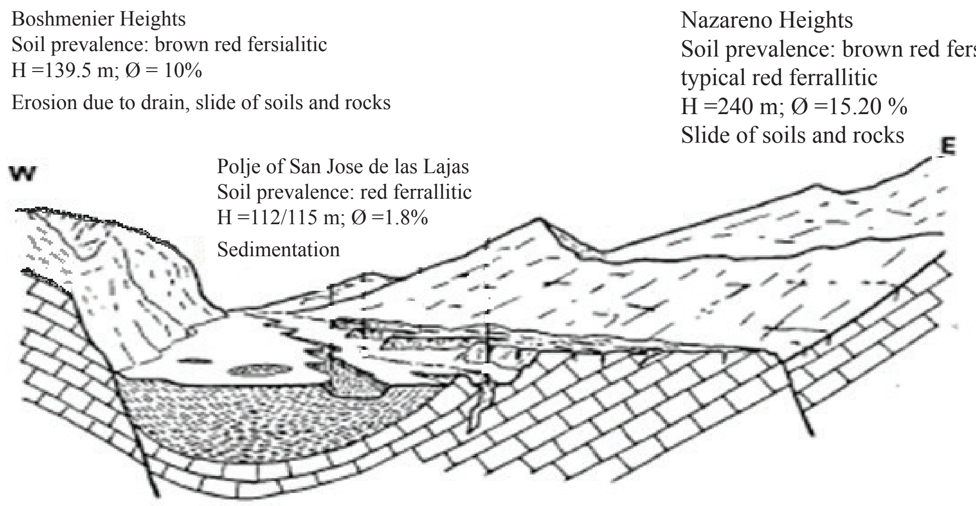

Figure 2 Scheme of the main geological and geo-morphological traits in the Distrito Pecuario "Alturas de Nazareno", Mayabeque province

and geo-morphological stability (figure 2), where the competition for the courses of water is decreasing, which provokes the consequent abandonment of sediments (Febles 2007).

Nevertheless, it has been confirmed that, with certain independence of the energy value of the relief, in those sectors where the anthropogenic activity has not taken place, there is a tendency to pedogenesis, with a very slow, positive or practically zero areal removal of the soil fractions (Febles *et al*. 2007 and Febles *et al*. 2008).

It is important to say that during the 80´s, the traditional system of soil preparation towards the slopes, the burning and over-grazing increased the acting of the natural processes and induced the development of a group of erosive-gravitational and karstic-erosive processes, which limited the productive capacity and fertility of soils.

This material, while descending, produces the obstruction of the drain lines, as well as the progressive sedimentation of agricultural areas, water bodies and grazing areas, where the grass roots concentrated on the first 30 cm extract the HM, consumed later by the cattle (Febles and Ruiz 2007 and Febles *et al*. 2012a).

Additionally, the remains of the superficial flow moves towards the polje (figure 3), towards the central zone of San José de Las Lajas municipality, where the heterogeneity of the superficial karstic forms, like dolines, uvales, sump and some other, exert an strict control over the drain (Vega and Febles 2006), with an almost total predominance of sedimentation.

These deposits usually contain high concentrations of HM from even the surface (level 0-30 cm), toxic organic compounds, nutrients and organic matter. It is necessary to have an especial care because any uncontrolled action could activate the toxic compounds retained on the sediments towards urban, aquiferous or cattle areas, which coincides with the reported by Guzmán *et al*. (2010) in studies carried out in this locality.

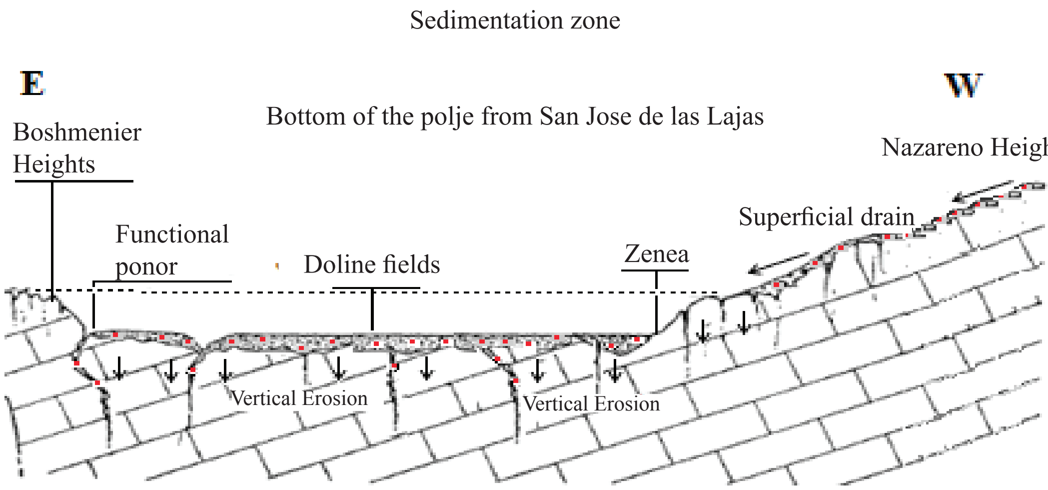

Figure 3. Dynamics of the processes of erosion-sedimentation-pollution of soils by heavy metals in different environments from the Distrito Pecuario "Alturas de Nazareno"

It was confirmed the existent relations among the processes of erosion-sedimentation-contamination in different environments and levels of acting in soils from the district "Alturas de Nazareno". There is, among them, a prevalence of erosive processes and possible access of the grass roots into the layer of peculiar alteration (level 25 - 30 cm), with considerable proportions of NiO2, Zn, Cd, Cr and Fe, among other elements. In the polje of San José, it was confirmed the predominance of the sedimentation-pollution, with high concentrations of heavy metals from the surface (level 0 - 30 cm), associated to toxic organic compounds, nutrients and organic matter.

In every soil, the Cu, Cd, Zn, Ni, Fe and Cr elements are mainly distributed in the residual fraction (F4), while in the carbonated brown and brown red fersialitic soils, the Cd and Pb elements are distributed in the soluble acid fraction (F1). This aspect could be a problem from the environmental point of view, mainly in the fractions of higher lability.

The results of this study represent a relevant approach to design more balanced management systems in risk scenarios for the cattle establishment, with a prevalence of grasses and forage. These results can also be useful for any productive purpose in Cuba.

References

Albear, J. F. de & Iturralde - Vinent, M. 1985. Zonación estructuro-facial de las provincias de La Habana. En: Contribución a la geología de las provincias de La Habana y Ciudad de La Habana. p. 68-76

Amaral Sobrinho, N.M.B., Barra, C.M. & Lã, O.R. 2009. Química dos Metais Pesados no Solo. In: Melo, V. F. & Alleoni, L. R. F.. Química e Mineralogia do Solo. Parte II. Aplicações. Viçosa-MG: SiBCS. 2v. 685 p.

Bosch, D., Camacho, E., & Ortega Sastriques, F. 1984. Influencia de las rocas calizas en la génesis de los suelos Ferralíticos Rojos de las llanuras cársicas de Cuba. Ciencia de la Tierra y el Espacio 9: 125

Bronnimann, P. & Rigassi, D. 1963. Contribution to the geology and paleontology of the area of the city of La Habana, Cuba and its surroundings. Ecolog. Geol. Helv. 56: 193

Camacho, E., Bosch, D. & Pérez, J. M. 1985. Caracterización de una secuencia de suelos ferralíticos del Sur de La Habana, Cuba. Coloquio Inter. Suelo y Agua. ORSTOM. Paris. p. 135-150

Camacho, E., Bosch, D., & Ruíz, J. 1980. Contenido y formas del hierro en suelos ferralíticos rojos de Cuba. Ciencias de la Agricultura 5: 73

Campos, M., Guerra M., Jaimez, E.S. & Olivera J. 2004. Caracterización geólogo-ambiental de las provincias habaneras. Instituto de Geofísica y Astronomía. Proyecto Evaluación geólogo ambiental de las provincias habaneras. Código 30302. Ciudad de La Habana, Cuba

Companhia De Tecnologia De Saneamento Ambiental. 2006. "Dispõe sobre a aprovação dos Valores Orientadores para Solos e Águas Subterrâneas no Estado de São Paulo – 2005, em substituição aos Valores Orientadores de 2001, e dá outras providências". Available: http://www.cetesb.sp.gov.br/Solo/relatorios/tabela_valores_2005.pdf. [Consulted: 15 feb. 2006]

Chaney, R.F. 1991. Sludge utilization, land application and food chain impact. In: The biocycle to the art and science of composting. Pennsylvania, J. G. Press. p. 240-253

Crommentuijn, T., Sijm, D., De Bruijn, J., van Leeuwen, K. & van De Plassche, E. 2000. Maximum permissible and negligible concentrations for some organic substances and pesticides. J. Environmental Management 58: 297

Chlopecka, A.1996. Assesment of form of Cd, Zn and Pb in contaminated calcareus and gleyed soils in southwest Poland. Sci. Total Envirom. 188: 253

Dang, Z., Liu, C. & Haigh, M.J. 2002. Mobility of heavy metals associated with the natural weathering of coal mine spoils. Environ. Pollut. 118:419

Fadigas, F.S., Amaral Sobrinho, N.M.B., Mazur, N., Anjos, L.H.C. & Freixo, A.A. 2006. Proposição de valores de referência para a concentração natural de metais pesados em solos brasileiros. R. Bras. Eng. Agríc. Ambiental. 10: 699

Febles, G. & Ruiz, T.E. 2007. Algunos resultados alcanzados en el desarrollo de los pastos y forrajes en Cuba y elementos de su desempeño en el sector productivo agropecuario. IV Foro Latinoamericano de pastos y forrajes. Instituto de Ciencia Animal, Cuba

Febles, J.M. 2007. Integración de métodos para evaluar la erosión de los suelos en las regiones cársicas de Cuba. PhD Thesis. Universidad Agraria de La Habana "Fructuoso Rodríguez Pérez". La Habana, Cuba

Febles González, J.M., Amaral Sobrinho, N. M. B., Balbín Arias, M. I., Neira Seijo, X. & Pérez López, Y. 2010. Buenos suelos y suelos "vírgenes" en extinción. IX Congreso de SEAE "Calidad y seguridad alimentaria". Lleida. España. Availo: www.agroecologia.net

Febles, J. M, Tolón, A. & Vega, M.B. 2009. Edaphic indicators for assesment of soil erosion in karst regions, province of Havana, Cuba. Land Degradation and Development 20: 522

Febles, J.M., Vega, M.B. & Febles, G. 2008. Integrating system of qualitative and quantitative methods to assess the erosion of the soils in the karstic regions of cattle rearing use in Cuba. Cuban J. Agric. Sci. 42:313

Febles González, J.M., Vega, M.B., Sobrinho, N.A., Tolón, A. & Lastra, X. 2012. Soil loss from erosion in the next 50 years in karst regions of Mayabeque province, Cuba. Land Degradation & Development Editorial John Wiley & Sons Ltd. Manchester, England. wileyonlinelibrary.com. DOI: 10.1002/ldr.2184.

Febles González, J.M., Vega, M.B., Tolón, A. & Lastra, X. 2012a. Assessment of soil erosion in karst regions of Havana, Cuba. Land Degradation & Development. Ed. John Wiley & Sons Ltd. Manchester, England

Filgueiras, A.V., Lavilla, I. & Bendicho, C. 2004. Evaluation of distribution, mobility and binding behaviour of heavy metals in surficial sediments of Louro River (Galicia, Spain) using chemometric analysis: a case study. Sci. Total Environ. 330: 115

Guerasimov, I. P. 1983. El concepto de suelo "cuerpo natural" y su derivados "suelos-régime", "suelo-reproducibilidad" y "suelo-memoria" Pochvovedenie 4: 205

Guilherme, L. R. G., Marques, J. J., Pierangeli, M. A.P., Zuliane, D.Q., Campos, M.L. & Marchi, G. 2005. Elementos traços em solos e sistemas aquáticos. Tópicos em Ciências do Solo 4:345

Guzmán, A.R. 2010.Caracterización agroecológica y procesos morfogenéticos actuantes en áreas agrícolas contaminadas

con metales pesados en el municipio de San José de las Lajas. III Taller Nacional de Biorremediación

He, Z. L., Yang, X. E. & Stoffella, P. J. 2005. Trace elements in agroecosystems and impacts on the environment. Journal of Trace Elements in Medicine and Biology, v.19, n. 2-3. Pp. 125-140

Hernández, A., Cabrera, A., Ascanio, M., Morales, M. & Rivero, L. 1999. Claves para la Nueva Versión de Clasificación Genética de los Suelos de Cuba

INSMET 2012. Datos climáticos. Centro de clima. Instituto de Meteorología. La Habana, Cuba

ISO 11466. 1995 International Standard: Soil quality– Extraction of trace elements soluble in aqua regia, 03–01.

Iturralde - Vinent, M.A. 1996. Introduction to Cuban geology and tectonics. In: Ofiolitas y arcos volcánicos de Cuba. IUGS / UNESCO. Proj. 364, Spec. Contr. N.1 MIAMI, USA. Pp. 3-35

Iturralde-Vinent, M.A. 2011. Compendio de Geología de Cuba y del Caribe. Primera Edición. Ed. CITMATEL. La Habana, Cuba

Jaimez Salgado, E., & Ortega Sastriques, F. 2001. Paleoregimen hídrico en suelos con relictos edáficos. Implicación en la reconstrucción paleoclimática del Pleistoceno Superior para Cuba Occidental. CD-ROM. Congreso Geología

Kabata-Pendias, A. & Pendias, H. 2001. Trace elements in soils and plants. 3.ed. Boca Raton, CRC Press. 413 p.

Lamoureux, M. 1972. Etat et comportement du fer dans les sols formés sur roches carbonatées au Liban. Science du Sol 1: 85

Marín, B., Valladon, M., Polve, M. & Mónaco, A. 1997. Reproducibility testing of a sequential extraction scheme for the determination of trace metal speciation in a marine reference sediment by inductively coupled plasma-mass spectrometry. Anal. Chim. Acta.342: 91-112

Núñez, J. E.V., Amaral Sobrinho, N.M.B. & Mazur, N. 2006. Sistema de preparo do solo e acúmulo de metais pesados no solo e na cultura do pimentão (*Capsum annum* L.). Ciência Rural. Santa Maria. 36: 113

Ortega Sastriques, F. 1984. Las hipótesis paleoclimáticas y la edad de los suelos de Cuba. Ciencias de la Agricultura 21: 46

Paneque, J., Fuentes, E., Mesa, A. & Echemendía, A. 1991. El Mapa Nacional de Suelos Escala 1 : 25 000. XI Congreso Latinoamericano y II Congreso Cubano de la Ciencia del Suelo. D. R. Villegas y D. Ponce de León, eds. La Habana, Cuba. p. 1345-1347

Rodriguez, L., Ruiz, E., Alonso-Azcarate, J. & Rincon, J. 2009. Heavy metal distribution and chemical speciation in tailings and soils around a Pb–Zn mine in Spain. J. Env. Management. 90:1106

Sastre, I., Vicent, M.A., Lobo, M.C. 2001. Behavior of cadmium and nickel I a soil amended with sewage sludge. Land degradation and development. 12: 27

Sahuquillo, A., López-Sánches, J.F., Rubio, R., Rauret, G., Thomas, R. P., Davidson, C. M. & Ure, A. 1999. Use of certified reference material for extractable trace metals to asses sources of uncertainty in the BCR three stage sequencial extraction procedure. Analytic. Chem. Acta. 382: 317

Utermann, J., Düwel, O. & Nagel, I. Contents of trace elements and organic matter in European soils. Part II. En: B.M. Gawlik and G. Bidoglio. Background values in European soils and sewage sludges. Results of a JRC-coordinated study on background values. 2006. Available: http://www.jrc.ec.europa.eu.

Vega, M.B. & Febles, J.M. 2006. Evaluation of the rainfall erosion in cattle regions from the central part of Havana province. Cuban J. Agric. Sci. 40:203

World Reference Base. 2006. Mapa Mundial de Suelos, escala 1: 30 000 000. World Soil Res.

Received: January 23, 2013