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Arsenic in Santa Catarina soils

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ABSTRACT

Arsenic (As) is one of the most harmful chemical elements known to man and to the environment, mainly due its high toxicity and wide distribution; the content of this element within the soils is a genuine concern, thus making it paramount to know its natural contents in a regional context. The present study aimed to determine the natural Arsenic content in the A horizon of 31 soil profiles from the state of Santa Catarina, Brazil, which is useful in determining reference values, monitoring, remediation of contaminated areas, legal regulation and Brazilian laws. Soil samples were prepared following the USPEA 3051A SW-846 method and were previously chemically reduced from As(V) to AS(III) by using the BCR method. The determination was performed in an Inductively Coupled Plasma - Optical Emission Spectrometry - Hydride Generation (ICP-OES-HG at cold vapor). Results obtained from the soil groups reveal the materials of basaltic origins as the ones with more As content while those of sediment origins had lesser content. Evaluated soil profiles fit into the following descending order regarding their As content: Latossolos, according to EMBRAPA (Oxisols according to Soil Taxonomy) > Nitossolo (Ultisols, Oxisols (Kandic), Alfisols) > Chernossolos (---) = Cambissolo (Inceptisols) = Argissolo (Ultisols) > Neossolos (Entisols).

Keywords: arsenic content, reference value, soils, trace element.

Arsênio em solos de Santa Catarina

RESUMO

O arsênio (As) é listado como um dos elementos químicos mais nocivos ao homem e ao meio ambiente, devido a sua alta toxidade e por ser amplamente distribuído na crosta terrestre, destaca-se a sua preocupação dos teores deste elemento em solos, sendo de suma importância conhecer os teores naturais de As no contexto regional. O objetivo do presente estudo foi determinar o teor de arsênio no horizonte A de 31 perfis de solos do estado de Santa Catarina Brasil, podendo este trabalho auxiliar nos valores de referência, monitoramento, remediação de áreas contaminadas, regulamentos e leis brasileiras. As amostras de solos foram preparadas segundo o método USEPA 3051A SW-846 e pré-reduzidos quimicamente do As(V) para As(III) através do método BCR. A determinação foi realizada em Espectrômetro de Emissão Óptica com Plasma Acoplado Indutivamente com Geração de Hidreto. Os resultados obtidos dentre o conjunto de solos, mostram que o material de origem basáltica, foram os que apresentaram os maiores teores de As e o material de origem de sedimentos com os menores.

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Os perfis de solo se enquadram na decrescente ordem no quesito dos teores de As na seguinte sequência: Latossolos > Nitossolo > Chernossolos = Cambissolo = Argissolo > Neossolos.

Palavras-chave: conteúdo de arsênio, elemento traço, solos, valor de referência.

1. INTRODUCTION

Arsenic (As), a semimetal, part of Group 15 of the periodic table, is the twentieth most abundant element on Earth (Roy *et al.*, 2015); thus, studying and monitoring this element due to its extensive distribution over the atmosphere, hydrosphere and biosphere is an important matter. According to the World Health Organization (WHO, 2018), Arsenic is one of the ten high-toxicity chemical elements, responsible for causing great concern to public health. Contamination by As of water sources, be they groundwater or surface water, is a global problem (Xu *et al.*, 2020; Gao *et al.*, 2020), with the natural sources of this element generated by the weathering of rocks, biological activities and volcanic emissions (Alonso *et al.*, 2014); in natural soils, this contamination is mainly due the parent material and weathering degree (Marrugo-Negrete *et al.*, 2017). On the other hand, contamination by anthropogenic sources, i.e. not natural ones, is done by production and usage of herbicides, phosphorus fertilizers, mining, industrial waste/residue and activities related to chemical preservation of timber (Chirenje *et al.*, 2003; Alonso *et al.*, 2014; Roy *et al.*, 2015; Gong *et al.*, 2020). As for the toxicity degree, the inorganic As^{3+} form (arsine AsH_3, arsenate $As(OH)_3$, arsenate $AsO(OH)_3$) is ten times more toxic than the As^{5+} form (Rosas *et al.*, 2014); both forms are carcinogenic, mutagenic and genotoxic. While in the organic methylated form, such as the case of MMA Monomethylarsonic and DMA Dimethylarsinic, organic As is a hundred times less harmful to health in comparison to its inorganic structures (WHO, 2018). As a result of these factors, even in low concentrations As can promote negative effects to health (ATSDR, 2015; Mandal, 2017) and its accumulation, be it because of agricultural or industrial activities, is worrisome due to a possible transference of this element to wild animals or humans (Su and Yang, 2008). In Brazil, there are reports of As-contaminated waters (up to 0.36 mg L^{-1}), soils (up to 860 mg kg^{-1}) and sediments (up to 3.200 mg kg^{-1}) situated in vicinity of industrial or mining areas (De Magalhães and Pfeiffer, 1995; Mirlean and Roisenberg, 2006; Pereira *et al.*, 2009; Alves and Rietzler, 2015).

Soil plays an important role in the environment by acting as a natural buffer, controlling the As transport to other compartments, although with limited adsorption (retention) capacity. In this system, toxicity, mobility, solubility, availability and bioavailability in the soil depend on specific conditions such as pH, redox potential, CEC, competition with other elements in different chemical equilibria, and composition and ionic strength of the soil solution (Qiao *et al.*, 2019). Arsenic is a chalcophile element (Goldschmidt, 1958), therefore its mobility is regulated by its oxidation state (Tarvainen *et al.*, 2013); it can be found in the As^{5+} form when under oxic conditions (Eh>200 mV; pH 5–8), and in the As^{3+} form under anoxic conditions (Mcbride, 1994; Singh *et al.*, 2015). When in the soil solution, under anaerobic conditions, it is found in the $Ca_3(AsO_4)_2$, $Mg_3(AsO_4)_2$ and As_2O_5 forms and, when under anaerobic conditions, in the As, As_2S_3 and As_2O_3 forms (Hayes and Traina, 1998). Another interesting factor is that the behavior of arsenate ($AsO(OH)_3$) in the soil is similar to phosphate (PO_4^{3-}) and vanadate (VO_4^- (McBride, 1994; Rosas *et al.*, 2014), as it is adsorbed onto Fe and Al oxides, such as non-crystalline aluminosilicates and onto argillo silicates as well, to a lesser extent.

The first studies on natural As contents in soils were by Curi and Franzmeier (1987), with "Latossolos Ferríferos", according to EMBRAPA, (Ferric Oxisols, according to Soil Taxonomy) in Minas Gerais, and Campos *et al.* (2007), with seventeen "Latossolos" (Oxisols) in Brazil. After publication of the CONAMA 420 Resolution (Conama, 2009), several scientific papers (Pereira *et al.*, 2009; Paye *et al.*, 2010; Campos *et al.*, 2013; De Souza *et al.*, 2016; De

Menezes *et al.*, 2020) were published with information on natural contents or quality reference values for Brazilian soils.

Determining natural trace element contents in the soil, having no human interference, is necessary for defining quality reference values, monitoring and remediating contaminated areas and, furthermore, contributing in understanding the magnitude of the risks to which the population is exposed to daily (Tsuji *et al.*, 2007).

Considering the above, the advanced agricultural and industrial development of Santa Catarina and its geological and pedological diversity, it is of utmost importance to determine the natural arsenic contents for the soils of the state, which is the objective of the present study.

2. MATERIAL AND METHODS

Soils used in this research were collected from the following regions in the state: western area; eastern mountains; Basaltic Slopes; Itajaí Valley; Santa Catarina Mountains; and southern Santa Catarina. Figure 1 illustrates the geographic distribution of the profiles.

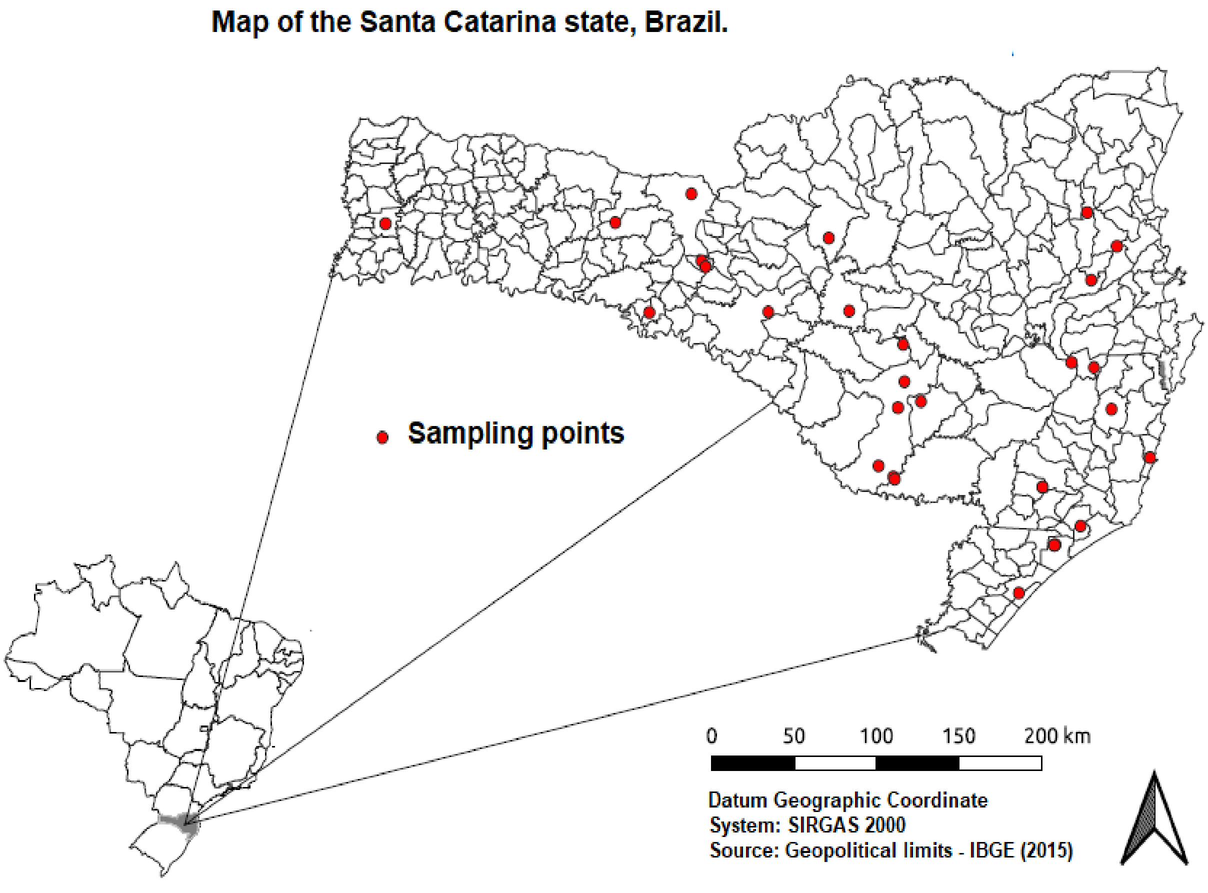

Figure 1. Map with the location of the 31 sample profiles in the Santa Catarina state.

Soil samples are from the A horizons of 31 profiles that were later described and sampled in roadside artificial gully in places under natural vegetation formations of fields or forests. The same authors who performed, described and classified the soils in this study also determined their physical and chemical attributes, described and classified in Table 1. All profiles were described in areas not subjected to anthropogenic arsenic contamination.

Samples were air-dried, had their clods broken, were homogenized and then passed through a sieve with an opening of 2.0 mm. In sequence, they were ground and homogenized in an agate mortar until forming a fine powder and finally sieved at an aperture of 0.297 mm.

Table 1. Classes, parent material, physical and chemical attributes of evaluated soils.

Soil class *EMBRAPA (Soil Taxonomy)	**Lithology**	**Sand**	**Clay**	**TOC**	**T**	**SB**	**V**	**Al**	**Fe**
			g kg-1		Cmolc kg^{-1}		%	g kg-1	
Nitossolo Bruno Distrófico típico (Oxisol)	Basalt	106	578	34	16	2.8	18	46	98
Nitossolo Bruno Distrófico rúbrico (Oxisol)	Basalt	45	641	46	20	1.2	6	41	103
Nitossolo Bruno Distroférrico típico (Oxisol)	Andesite basalt	164	446	38	17	4	24	57	165
Nitossolo Bruno Distrófico húmico latossólico rúbrico (Oxisol)	Rhyodacite	102	614	33	19	12	62	127	68
Latossolo Vermelho Distrófico retrático úmbrico (Oxisols)	Basalt	16	774	22	16	1.45	9	71	131
Neossolo Regolítico Húmico típico (Entisol)	Phonolite	230	540	30	15	4.3	28	156	25
Cambissolo Háplico Alumínico típico (Inceptisols)	Porphyritic phonolite	260	500	21	12	1.6	12	149	50
Argissolo Bruno-Acinzentado Alítico típico (Ultisol)	Argillites and siltstone	160	320	30	21	2	9	32	16
Argissolo Amarelo Distrófico Típico (Ultisol)	Granite and granulite	230	330	35	11	1.3	12	44	25
Argissolo Vermelho Distrófico abruptico (Ultisol)	Siltstone and Sandstone	463	170	15	6.2	5.2	83	12	14
Argissolo Vermelho-Amarelo Distrófico latossólico (Ultisol)	Sandstone and Siltstone	718	157	13	5.8	2.7	47	5.8	11
Cambissolo Háplico Alumínico úmbrico (Inceptisol)	Rhyodacite	60	580	34	24	1.8	7	99	41
Cambissolo Húmico Distrófico típico (Inceptisol)	Rhyodacite	192	600	39	19	0.9	5	108	44
Nitossolo Vermelho Distroférrico típico (Oxisols)	Basalt	149	590	32	23	10	42	47	116
Cambissolo Háplico Alítico típico (Inceptisol)	Rhyodacite	99	570	33	23	3.7	16	127	39
Argissolo Amarelo Distrófico latossólico (Ultisol)	Migmatito	290	370	33	9.0	2.6	26	93	24
Neossolo Regolítico Eutrófico típico (Entisol)	Granite	650	140	7.0	2.2	0.6	26	2.7	12
Argissolo Vermelho distrófico (Ultisol)	Siltstone and Sandstone	680	180	17	6.2	5.1	83	31	13
Argissolo Vermelho-Amarelo Distrófico latossólico (Ultisol)	Sandstone and Siltstone	620	300	20	5.8	2.7	44	5.6	12
Nitossolo Bruno Distrófico húmico latossólico rúbrico (Oxisol)	Basalt	22	684	38	19	4.4	23	102	60
Argissolo Vermelho Distrófico abruptico (Ultisol)	Siltstone and Sandstone	463	170	15	6.2	5.2	83	28	17
Argissolo Amarelo Alítico típico (Ultisol)	Mica schists	530	230	22	16	6.4	41	6.0	13
Argissolo Vermelho-Amarelo Alumínico típico (Ultisol)	Metaarenito	510	380	27	14	2.7	18	7.9	10
Argissolo Vermelho-Amarelo Alumínico típico (Ultisol)	Mafic Granulite	580	240	25	15	5.3	35	7.1	14
Chernossolo Argilúvico Férrico típico (---)	Basalt	220	420	30	20	18	90	34	86
Nitossolo Vermelho Eutroférrico típico (Oxisol)	Basalt	170	370	51	19	15	79	31	134
Nitossolo Háplico Distrófico típico (Oxisol)	Basalt	70	670	46	15	7.1	46	24	108
Nitossolo Vermelho Eutrófico típico (Oxisol)	Basalt	210	420	28	12	8.1	68	11	117
Nitossolo Háplico Distrófico típico (Oxisol)	Rhyodacite	140	280	33	23	19	83	33	99
Neossolo Quartzarênico Órtico típico (Entisols)	Sandy sediments	943	36	4	-	1.3	-	3.1	1.6
Neossolo Quartzarênico Órtico típico (Entisols)	Sandy sediments	919	58	7.4	-	1.8	-	4.7	0.4

CO = organic carbon by the Walkley-Black method, total organic carbon; T value = CEC at pH 7.0; SB = Sum of bases; V= Base saturation; Al and Fe obtained by sulfuric attack. **Source:** based on Almeida *et al.* (2003), Corrêa (2003), Paes Sobrinho *et al.* (2009), Bringhenti *et al.* (2012), Da Costa *et al.* (2013), Lunardi Neto and Almeida (2013), Teske *et al.* (2013).

The USEPA 3051A SW-846 method was employed as the extraction means. For this purpose, 1.5 g of soil was weighed and 5 mL of 37% HCl PA Merck® was added. Samples were in contact with the acid for 12h00 and then digested in the microwave (Anton PAAR Multiwave 3000®) inside Teflon tubes. As a form of control and method validation, NIST certified sample SEM 2709A (San Joaquin soil) and reference sample EMBRAPA CRM-Agro E2002a (MR-06/2013) were used, and the recovery values are displayed in Table 2.

Table 2. As recovery percentage for SRM 2709A and CRM-Agro E2002a samples.

Sample	Recovered content	Certified content	Recovery
	mg kg^{-1}		%
SRM 2709A	9.85	10.5±0.3	93.81
CRM-Agro E2002a	53.38	59.3 ±7.2	90.02

Soil analyses were performed in the Instrumentation Laboratory of the Department of Soils and Natural Resources from the Centre of Agroveterinary Sciences – UDESC/CAV. Determination of As contents was performed in an Inductively Coupled Plasma Optical Emission Spectrometer Hydride Generator (ICP-OES-HG at cold vapor). Prior to the determination, a chemical pre-reduction step from As(V) to As(III) by the BCR method (Varejão *et al.*, 2009) was applied in all samples, adjusting and improving the efficiency in hydride generation. For such, a potassium iodide solution (KI 5% w/v) and ascorbic acid (5% w/v), enough to reach 0.2% v/v, was added in all samples, in the calibration standard solutions and blank samples. After resting for 12h00, As was quantified in ICP-OES-HG at cold vapor (Optima 8300 - Perkin Elmer).

All samples were digested in duplicates and the determination was performed in triplicate per sample. As content readings in the blank samples were used to calculate limits of detection (LOD) = 3 x Standard Deviation (blank samples) / slope of the calibration curve straight line; and limits of quantification (LOQ) = 3.3 x LOD. Obtained values were 0.015 mg kg^{-1} of LOD and LOQ of 0.050 mg kg^{-1}.

Statistical analyses were performed by using an entirely randomized design separated for each component (Soils, Classes, Parent Material). Comparisons between Soils, Classes, and Parent Material were by employing F and Scott-Knott tests. To meet the theoretical assumptions of these tests, logarithmic transformation of the arsenic content variables was applied as suggested by the descriptive analysis of the data; however, results were presented on the original scale. All analyses were conducted with the R software (R CORE TEAM, 2016). As contents found were also subjected to correlation analysis with the following variables: clay content, silt/clay ratio, organic carbon, sum of bases (SB) and base saturation value (V%), Fe and Al contents by sulfuric attack. For all performed tests, a minimum significance level of 5% was considered.

3. RESULTS AND DISCUSSION

Basalt-derived soils averaged the highest As content (11.59 mg kg^{-1}) while the lowest content was observed on soils derived from sandy sediments (0.82 mg kg^{-1}) (Table 3). Higher contents in soils derived from effusive mafic rocks are related to the presence of higher arsenic contents in rock when compared to the other parent materials of evaluated soils in this study. Arsenic contents in basalt (mafic effusive) vary between 0.18 and 113 mg kg^{-1} (Mandal and Suzuki, 2002). Arsenic is classified as chalcophile, with basalts and andesites richer in chalcophile elements while granites are poor (Goldschimidt, 1958). As^{3+} can replace Fe^{3+} in many rock-forming minerals (Reimann *et al.*, 2009). These As content differences in the rocks may explain the low As contents in soils derived from granite, granite-granulite and mafic granite (Table 4).

Table 3. As mean content (mg kg^{-1}) for soils derived from different parent material.

Parent material	As content (mg kg^{-1})
Basalt	11.59 a
Siltstone and Sandstone	10.12 a
Argillite and Siltstone	8.08 a
Migmatite	7.79 a
Rhyodacite	7.72 a
Andesite basalt	7.50 a
Metasandstone	5.84 a
Siltstone and Sandstone	5.36 a
Phonolite	5.06 a
Porphyritic phonolite	3.73 b
Mica schists	2.84 b
Granite and granulite	2.77 b
Sandstone and Siltstone	2.18 b
Mafic granulite	2.10 b
Granite	1.42 b
Sandy sediments	0.82 b

Table 4. Mean As content (mg kg^{-1}) for the main soil orders from Santa Catarina state.

Order * EMBRAPA (Soil Taxonomy)	As content (mg kg^{-1})
Latossolo (Oxisols)	26.59 a
Nitossolo (Ultisols, Oxisols (Kandic), Alfisols)	10.92 b
Chernossolo (--)	6.96 c
Cambissolo (Inceptisols)	4.95 c
Argissolo (Ultisols)	4.67 c
Neossolo (Entisols)	1.64 d

The decreasing sequence of As contents was observed in the following soil Orders: Latossolos, according to EMBRAPA (Oxisols according to Soil Taxonomy) > Nitossolo (Ultisols, Oxisols (Kandic), Alfisols) > Chernossolos (---) = Cambissolo (Inceptisols) = Argissolo (Ultisols) > Neossolos (Entisols) (Table 4). The first three orders group soils derived mainly from basic and intermediate magmatic rocks. The soil “Latossolo Vermelho Distrófico retrático úmbrico” (Oxisols), derived from basalt (Serra Geral Formation) and located in Campos Novos (Table 6), had the highest As content (26.59 mg kg^{-1}) of all 31 evaluated soils. Whereas, the “Neossolo Quartzarênico Órtico típico” (Entisols) profile located in Imbituba city, with the original material coming from sandy sediments, had the lowest As content (0.56 mg kg^{-1}).

A natural As content of 31.7 mg kg^{-1} was found by Campos *et al.* (2007) for “Latossolo Vermelho Distroférrico típico” (Oxisols) derived from basic and intermediate magmatic rocks of the Serra Geral Formation, and contents of 4.5 mg kg^{-1} for “Latossolo Amarelo coeso típico” (Oxisols) derived from tertiary sediments. Arsenic content in “Neossolo Quartzarênico órtico típico” (Entisols) collected from the Cerrado, derived from sandstone of Aerado Formation, had 0.28 mg kg^{-1} (Campos *et al.*, 2013). These results corroborate the observations in this present study.

In a predictive modeling study of spatial variability using environmental covariates (contents of organic carbon, clay, sand and TiO_2) representing the soil formation factors in Brazil, De Menezes *et al.* (2020) found mean As contents of 11.97±1.62 for the Santa Catarina state; however, only six profiles out of the 31 evaluated in the present study demonstrated similar contents.

Natural As contents within the soils "Latossolo Vermelho Distrófico retrático úmbrico" (Oxisols from Campos Novos) of 26.59 mg kg^{-1} and "Nitossolo Vermelho Eutroférrico típico" (Oxisols from Luzerna) of 17.63 mg kg^{-1} (Table 5) were higher than the prevention guideline value (15 mg kg^{-1}) established by CONAMA 420 Resolution (Conama, 2009), reinforcing the need for scientific studies that generate guideline values for soils from different Brazilian states. Nevertheless, an important issue is that trace elements in uncontaminated soils have less mobility than trace elements from anthropogenic contamination, because the former are bound to or are part of the structure of minerals, while those from anthropogenic sources may be more available (Botsou *et al.*, 2016). Therefore, natural contents higher than prevention values in soils do not necessarily indicate risks to living beings, due to their lesser availability.

Table 5. As mean content for the main soil profiles in the State of SC.

Soil Class: EMBRAPA (Soil Taxonomy)	**Location**	**As Content**
		mg kg^{-1}
Latossolo Vermelho Distrófico retrático úmbrico (Oxisols)	Campos Novos	26.59 a
Nitossolo Vermelho Eutroférrico típico (Oxisols)	Luzerna	17.63 a
Nitossolo Vermelho Distroférrico típico (Oxisols)	Lages	14.16 a
Argissolo Vermelho Distrófico (Ultisols)	Içara	13.57 a
Nitossolo Bruno Distrófico húmico latossólico rúbrico (Oxisols)	Ponte Serrada	13.19 a
Nitossolo Bruno Distrófico húmico latossólico rúbrico (Oxisols)	Curitibanos	12.45 a
Nitossolo Háplico Distrófico típico (Oxisols)	Luzerna	12.38 a
Nitossolo Bruno Distrófico rúbrico (Oxisols	Lebon Régis	10.96 a
Cambissolo Háplico Alítico típico (Inceptisols)	Lages	10.96 a
Nitossolo Vermelho Eutroférrico típico (Oxisols)	Ipira	9.42 a
Cambissolo Húmico Distrófico típico (Inceptisols)	Lages	9.38 a
Argissolo Bruno-Acinzentado Alítico típico (Ultisols)	Alfredo Wagner	8.08 a
Argissolo Amarelo Distrófico latossólico (Ultisols)	São Bonifácio	7.79 a
Nitossolo Vermelho Eutrófico típico (Oxisols)	Luzerna	7.73 a
Nitossolo Bruno Distrófico típico (Oxisols	Painel	7.72 a
Nitossolo Bruno Distroférrico típico (Oxisols)	Água Doce	7.50 a
Argissolo Vermelho Distrófico abruptico (Ultisols)	Içara	7.49 a
Chernossolo Argilúvico Férrico típico (---)	Descanso	6.97 a
Argissolo Vermelho-Amarelo Alumínico típico (Ultisols)	Gaspar	5.84 a
Argissolo Vermelho Distrófico abruptico (Ultisols)	Içara	5.36 a
Neossolo Regolítico Húmico típico (Entisols)	Lages	5.06 a
Cambissolo Háplico Alumínico típico (Inceptisols)	Palmeira	3.73 b
Argissolo Amarelo Alítico típico (Ultisols)	Botuverá	2.84 b
Argissolo Amarelo Distrófico típico (Ultisols)	Rancho Queimado	2.77 b
Argissolo Vermelho-Amarelo Distrófico latossólico (Ultisols)	Lauro Müller	2.71 b
Argissolo Vermelho-Amarelo Alumínico típico (Ultisols)	Blumenau	2.10 b
Argissolo Vermelho-Amarelo Distrófico latossólico (Ultisols)	Lauro Müller	1.73 b
Neossolo Regolítico Eutrófico típico (Entisols)	Sangão	1.42 b
Cambissolo Háplico Alumínico úmbrico (Inceptisols)	Lages	1.14 b
Neossolo Quartzarênico Órtico típico (Inceptisols)	Araranguá	1.12 b
Neossolo Quartzarênico Órtico típico (Inceptisols)	Imbituba	0.56 b

Such discrepant contents as those obtained in the present study (26.59 – 0.56 mg kg^{-1}) may indicate the need for standardizing more than one quality reference value (QRV), thus reducing the possibility of classifying natural contents as contamination or allowing soils with very low contents to be contaminated. VRQs can be split into groups with different clay and/or iron oxide contents, since this study (Table 6), as well as several others (Campos *et al.*, 2013, De Menezes *et al*., 2020, Almeida *et al.*, 2020), found positive correlation between arsenic content and those said attributes.

Table 6. Pearson's correlation (r) between As content and soil attributes. Values of p < 0.05 means significant correlation.

	Silt	Clay	CO	pH H_2O	T value	SB	V	Al_2O_3	Fe_2O_3
r	0.32	**0.61**	**0.46**	0.04	0.34	0.29	0.05	0.23	**0.60**
p	0.08	**0.00**	**0.01**	0.82	0.08	0.12	0.80	0.21	**0.00**

CO = organic carbon by the Walkley-Black method, total organic carbon; T value = CEC at pH 7.0; SB = Sum of bases; V= Base saturation; Al_2O_3 and Fe_2O_3 obtained by sulfuric attack.

Source: Author's own production, 2020.

4. CONCLUSIONS

The difference in As content is due to the different genealogical formations of Santa Catarina soils. Effusive mafic rocks, as well as basic and intermediate magmatic ones, had the highest As content in comparison to the other parent materials.

Concerning soil class, different As content was found in the following descending sequence: Latossolos, according to EMBRAPA (Oxisols according to Soil Taxonomy) > Nitossolo (Ultisols, Oxisols (Kandic), Alfisols) > Chernossolos (---) = Cambissolo (Inceptisols) = Argissolo (Ultisols) > Neossolos (Entisols). Both the "Latossolo Vermelho Distrófico retrático úmbrico" (Oxisols) from Campos Novos and the "Nitossolo Vermelho Eutroférrico típico" (Oxisols) from Luzerna presented natural As contents above the prevention value established by the CONAMA 420 resolution (Conama, 2009).

There was positive correlation between the clay content and iron oxide and the natural As content.

5. ACKNOWLEDGEMENTS

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