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VARIATION OF TRACE ELEMENT CONCENTRATIONS IN THE SOIL: CHALLENGES AND IMPLICATIONS FOR ENVIRONMENTAL QUALITY

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Abstract: Environmental quality, related to trace elements present in very low concentrations in the soil, is closely linked to food production. These elements, whether of natural or anthropogenic origin, have the potential to accumulate in plants and enter the food chain. The lack of some elements in the soil represents a deficiency in the population. Therefore, it is crucial to monitor these elements to avoid contamination, knowing the natural quantities and ensuring the sustainability of production environments. In this work, the challenges in the evaluation and management of the following elements are analyzed: cadmium, selenium, molybdenum, arsenic, cobalt, nickel, lead, copper, zinc, chromium and manganese. A systematic literature review was carried out on natural levels, using descriptive statistics techniques. The results demonstrate great variation between the locations analyzed, influenced by different geological formations. Therefore, it is essential to assess the soil carefully, knowing the actual natural levels. This will make it possible to identify sources of contamination and diagnose the nutrient potential in different environments. In this sense, appropriate public policies are necessary for environmental management and, consequently, for food quality.

Keywords: Reference for Environmental Quality, Food Quality, Geochemistry, Environmental Sustainability, Environmental Management.

INTRODUCTION

Food and environmental security involves knowledge of the constitution of the soil, mainly about elements that are present in very low concentrations, those commonly known as trace elements (TEs). These are considered stable, non-degradable and being in the soil, consequently, they can accumulate in plants and enter the food chain.(REBÊLO et al., 2020).Some of these are essential for biological processes in soil and plants, others are beneficial, but can also have a toxic effect when present in quantities other than tolerable levels.

Therefore, they have the potential to negatively impact ecosystems and, consequently, human health.As (arsenic), Cd (cadmium), Hg (mercury) and Pb (lead) are examples of elements that have no biological function, while Cr (chromium), Ni (nickel), Se (selenium) and Zn (zinc) are important for humans and/or plants, as they have a defined biological function at tolerable levels(OKEREAFOR et al., 2020). However, it is important to highlight that ETs can be found naturally in the soil, due to the weathering and pedogenetic processes caused in the soil's source material. These are reported as “background” levels by geochemists (REBÊLO et al., 2020), but can be added to the soil by anthropogenic actions.

Considering this problem, it is important to monitor the soil and identify possible contamination. In this sense, resolution number 420, of December 28, 2009(BRAZIL, 2009), from the National Environmental Council (Conama) establishes criteria and a list of guiding values for soils and groundwater related to the chemical substances present, to prevent possible contamination.In view of the variability in soil composition, Conama established a period of 4 years for each state to define its Quality Reference Value (VRQ). However, even today most states do not have this reference, only the states of São Paulo (SÃO PAULO, 2005), Minas Gerais(MINAS GERAIS, 2010), Pernambuco (PERNAMBUCO, 2014), Rio Grande do Sul (RIO GRANDE DO SUL, 2014) and Paraíba (PARAÍBA, 2014)established their VRQ. Therefore, studies and efforts by researchers are necessary so that each Brazilian state has its VRQs.

However, soils present a notable diversity in ET concentrations – over a short distance, around 1 km in radius, they undergo small variations, but over tens of kilometers the variation can be very large, even in the same type of soil.(MELLO; ABRAHÃO, 2013). These variations bring significant challenges to establishing quality standards. Therefore, establishing a single VQR per state could have important implications for human health and environmental preservation. In this work, the challenges faced in assessing and managing this diversity were explored, as well as the consequences for environmental quality. The emphasis here was on eleven (11) elements, it is them: Cd, Se, Mo (molybdenum), As, Co (cobalt), Ni, Pb, Cu (copper), Zn (zinc), Cr, Mn (manganese).

MATERIAL AND METHODS

The proposed methodology consists of carrying out a bibliographic study covering 21 Brazilian and 4 international works, on the level"background"[1]inETs in 18 Brazilian states, published to date. The analyzed data was provided as mean, or median, or 75 percentiles and, or 90 percentiles, all in milligrams per kilograms of soil – described here in parts per million (ppm). These were treated using descriptive statistics techniques, thus, measures of central tendency, such as the median, dispersion and variance were described and analyzed. To this end, it was built boxplot graphs to visualize the distribution of trace elements in different soils, using the 'ggplot2' package (version 3.4.1) in the R programming environment (RStudio - version 2022.12.0).

RESULTS AND DISCUSSIONS

Central trends in the concentrations of ETs in the regions analyzed are identified, however, a large dispersion is observed in the data, shown in table 1 and figure 1. Among the ETs analyzed, the most abundant is Mn, a trend in all the works analyzed and Cd showed lower abundance. However, for US soils, Cd has a VRQs of 1.6 ppm and Mo in these soils are lower – 0.59 ppm(PAYE et al., 2010). It was possible to group the elements by trends in concentrations, they are: Cd, Se and Mo – concentration up to 8 ppm (figure 1A); As and Pb – concentration up to 36 ppm (figure 1B); Co and Ni – concentration up to 75 ppm (figure 1C); Cr, Cu and Zn – concentration up to 125 ppm (figure 1D); and Mn – concentration up to 557 ppm (figure 1E).

ETs	Median (ppm)	Variance
CD (31)*	0.1	0.17
If (5)	0.4	0.02**
Mo (26)	0.6	2.76
As (29)	2.0	18.51
Co (37)	6.0	221.55
Ni (42)	9.6	1593.26
Pb (39)	13.0	41.60
Ass (41)	13.5	1481.34
Zn (42)	30.6	656.71
Cr (42)	38.3	1444.96
Min (22)	149.3	22967.60

Table1: Analysis of variance and median of trace element concentrations in different soils

* In parentheses are the number of data analyzed.

**Referring to only 5 observations.

1. Measure used to identify the natural concentrations of an element.

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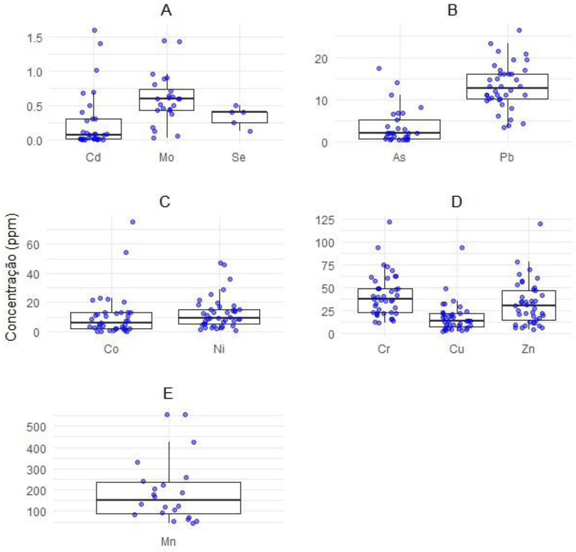

Figure1: Boxplots of trace element concentrations in soil samples.

Source: Author, 2023

Most elements showed great variation in the data and Cd, Se, Mo, As and Pb showed variance below 50%. In the Cd, Mo and Pb graph, it is possible to observe some "outliers" and it is important to say that the low variance observed for Se is related to the low number of observations – only five of the studies analyzed the element. Furthermore, to improve data visualization in the "boxplots", some very extreme values were excluded: 4 and 8 ppm for Mo; 36 ppm for Pb; 147 and 203 ppm for Cu; 262 ppm for Ni; and 237.7 ppm for Cr. These dispersions and "outliers" present reflect the phenomena of geochemical change in the soil over geological periods, which are responsible for the variety of rocks and minerals present. (MELLO; ABRAHÃO, 2013).

Therefore, studies on food and environmental safety must consider data dispersion to properly identify possible sources of contamination. Cd, for example, despite having had the smallest variation, in Russia, in different soils varies between 0.01 and 1.15 ppm(LUKIN; ZHUIKOV, 2023). Its quality reference in the United States is 1.6 ppm (PAYE et al., 2010) and for Brazilian states between 0.4 and 0.68 ppm(NASCIMENTO; BIONDI, 2013; SÃO PAULO, 2005). In the case of Mo in Minas Gerais, places with 0.5 to 23.1 ppm were identified in preserved areas(SOUZA et al., 2015), but the state reference value is less than 0.9 ppm (MINAS GERAIS, 2010)and in São Paulo the reference is less than 4 ppm(SÃO PAULO, 2005). Cu in the United States has a quality reference of 17 ppm (PAYE et al., 2010), while in northwest China the natural average is 21.4 ppm(DENG et al., 2020)and in southern Turkey 22.6 ppm(KURT, 2018). In Brazilian soils, these Cu levels vary in different regions, in Minas Gerais the average value found was 31.7 ppm (SOUZA et al., 2015), the same value was recorded in Rondônia, 17.6 ppm in Pará(ALLEONI; FERNANDES; SANTOS, 2013), 9.4 ppm in Rio Grande do Norte(PRESTON et al., 2014), 7.69 ppm in Mato Grosso(PIERANGELI et al., 2015) and 5.57 ppm in Espírito Sando (PAYE et al., 2010). The highest levels found in Minas Gerais were in clayey soil rich in iron oxides (SOUZA et al., 2015).

This evidence shows that establishing a single VRQs per state is a challenge, making it possible to have more than one reference. This issue is observed in the works analyzed, in the states of Minas Gerais(MINAS GERAIS, 2010; SOUZA et al., 2015; VIGLIO et al., 2022), São Paulo(NOGUEIRA et al., 2018; SÃO PAULO, 2005; VIGLIO et al., 2022)and Pernambuco(FABRICIO NETA et al., 2018; PERNAMBUCO, 2014; VIGLIO et al., 2022). These works reveal the difficulty in reaching consensus in establishing a single VRQ. It is important to highlight that there are divergences in the methodologies used and Conama itself leaves room for two extraction methods: USEPA 3050 and USEPA 3051.

CONCLUSION

The lack of knowledge of natural levels hinders the verification of possible damage caused to the environment by human activities. Such knowledge makes it possible to determine the soil's VRQs, in addition to diagnosing the nutrient potential. Therefore, adequate public policies for environmental management in monitoring and legal intervention that correspond to the local and real situation are necessary.

It is essential to establish natural levels in the different regions of the Brazilian states, only then will it be possible to measure the impacts caused by human action.

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