UNIVERSIDADE FEDERAL DA BAHIA
INSTITUTO DE GEOCIÊNCIAS
PROGRAMA DE PESQUISA E PÓS-GRADUAÇÃO EM GEOLOGIA
ÁREA DE CONCENTRAÇÃO:
GEOLOGIA AMBIENTAL, HIDROGEOLOGIA E RECURSOS HÍDRICOS

DISSERTAÇÃO DE MESTRADO

PROPOSIÇÃO DE VALORES DE *BACKGROUND* PARA SOLOS E DEPÓSITOS SEDIMENTARES DA ZONA NÃO SATURADA DO POLO INDUSTRIAL DE CAMAÇARI

GABRIELA SANTOS OLIVEIRA

SALVADOR
2025

PROPOSIÇÃO DE VALORES DE *BACKGROUND* PARA SOLOS E DEPÓSITOS SEDIMENTARES DA ZONA NÃO SATURADA DO POLO INDUSTRIAL DE CAMAÇARI

Gabriela Santos Oliveira

Orientador: Prof. Dr. Ricardo Galeno Fraga de A. Pereira

Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Geologia do Instituto de Geociências da Universidade Federal da Bahia como requisito parcial à obtenção do Título de Mestre em Geologia, Área de Concentração: Geologia Ambiental, Hidrogeologia e Recursos Hídricos.

SALVADOR
2025

Ficha catalográfica elaborada pela Biblioteca Universitária de Ciências e Tecnologias Prof. Omar Catunda, SIBI – UFBA.

C48 Oliveira, Gabriela Santos

Proposição de valores de background para solos e depósitos sedimentares da zona não saturada do Polo Industrial de Camaçari. / Gabriela Santos Oliveira. – Salvador, 2025.

86 f.

Orientador: Prof. Dr. Ricardo Galeno Fraga de A. Pereira

Dissertação (Mestrado - Programa de Pós-Graduação em Geologia) – Universidade Federal da Bahia, Instituto de Geociências, 2025.

1. Solos - Polo Industrial de Camaçari (BA). 2. *Background* do solo. 3. Áreas contaminadas - Gerenciamento. I. Pereira, Ricardo Galeno Fraga de A. II. Universidade Federal da Bahia. III. Título.

CDU:550.8(813.8)

GABRIELA SANTOS OLIVEIRA

PROPOSIÇÃO DE VALORES DE *BACKGROUND* PARA SOLOS E DEPÓSITOS SEDIMENTARES DA ZONA NÃO SATURADA DO POLO INDUSTRIAL DE CAMAÇARI

Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Geologia da Universidade Federal da Bahia como requisito para a obtenção do Título de Mestre em Geologia, Área de Concentração: Geologia Ambiental, Hidrogeologia e Recursos Hídricos em 12/02/2025.

DISSERTAÇÃO APROVADA PELA BANCA EXAMINADORA:

gov.br Documento assinado digitalmente
RICARDO GALENO FRAGA DE ARAUJO PEREIRA
Data: 12/02/2025 17:42:59-0300
Verifique em https://validar.iti.gov.br

Dr. Ricardo Galeno Fraga de Araujo Pereira (Orientador) - UFBA

gov.br Documento assinado digitalmente
THOMAS VINCENT GLOAGUEN
Data: 12/02/2025 16:17:17-0300
Verifique em https://validar.iti.gov.br

Dr. Thomas Vincent Gloaguen – UFRB

gov.br Documento assinado digitalmente
DIDIER GASTMANS
Data: 12/02/2025 16:00:56-0300
Verifique em https://validar.iti.gov.br

Dr. Didier Gastmans - UNESP

SALVADOR
2025

No encontro entre a solidez das rochas e a fluidez dos dados, desvela-se uma história sussurrada há milhões de anos. A indústria, que molda nosso presente e desafia nosso futuro, ocupa um papel central nesse equilíbrio delicado. Ao entrelaçar geologia e engenharia, pragmatismo e criatividade, este trabalho convida a olhar além do visível, onde a estatística traduz a complexidade e a geologia revela as marcas do tempo, guiando-nos rumo a um futuro em que a sustentabilidade seja mais que um ideal: seja a essência do nosso caminhar.

AGRADECIMENTOS

A jornada de uma dissertação é pavimentada por desafios e conquistas, e nela jamais caminhei sozinha. A cada passo, contei com o apoio, o incentivo e o amor de pessoas que iluminaram meu caminho e tornaram este sonho possível.

À **Cetrel**, minha profunda gratidão, por acreditar no potencial deste trabalho, ao financiar os custos do projeto e ceder os dados essenciais que o fundamentaram. Obrigada por valorizar a ciência e permitir que dela brotassem frutos para um futuro mais sustentável. O futuro já começou.

Aos meu orientador, **Ricardo**, pela paciência, pela orientação que traçou as direções certas e pelo apoio em momentos de incerteza. Dessa convivência acadêmica com Ricardo, nasceu uma amizade que espero levar para a vida. Ao coautor do artigo, **Haki**, fundamental para garantir a qualidade técnica do trabalho com suas contribuições valiosas.

À **Rízia**, que deu vida à ideia deste projeto e me incentivou a dar o primeiro passo em direção ao mestrado. A **Eduardo Fontoura**, que abriu as portas para que este projeto se concretizasse, autorizando o uso dos recursos e dados que foram a espinha dorsal desta pesquisa.

Aos meus líderes atuais na Cetrel, **Augusto** e **Daiana**, que não só apoiaram este projeto como também me lideraram com respeito e inspiração, mostrando que é possível unir profissionalismo e humanidade no dia a dia.

À minha família e amigos, a base de tudo, que me sustentaram com amor e força nos momentos mais difíceis. E, em especial, à minha mãe, **Paula**, o farol da minha vida, que, com seu amor incondicional e sacrifícios silenciosos, me deu as ferramentas para desbravar o mundo. Foi ela quem me ensinou que a educação é a chave para abrir qualquer porta e que o afeto e o incentivo podem transformar qualquer sonho em realidade.

A cada um de vocês, dedico não apenas esta dissertação, mas também minha gratidão. Obrigada por acreditarem em mim e por serem parte essencial desta trajetória.

RESUMO

Este estudo estabelece valores de *background* para parâmetros inorgânicos em solos e depósitos sedimentares da zona não saturada do Polo Industrial de Camaçari (PIC), Brasil. Áreas de referência foram selecionadas para representar condições naturais e sondagens geológicas subsidiaram a elaboração de um modelo conceitual regional para a geologia, relevo e hidrogeologia da área, orientando o plano de amostragem que incluiu sedimentos das formações Marizal e Barreiras. Após a análise química das amostras e a avaliação estatística dos resultados, os parâmetros foram classificados em três grupos: (1) parâmetros com pelo menos cinco detecções, cujos valores de *background* foram calculados pelo UTL95-95 para; (2) parâmetros com uma a cinco detecções, cujos valores de *background* foram definidos pelos valores máximos detectados; e (3) parâmetros não detectados, cujos valores de *background* foram definidos como inferiores ao limite de detecção (LD). A seguir apresentam-se os valores de *background* para o Grupo 1: Al - 7308 mg/kg, As -31,57 mg/kg, Ba - 2,47 mg/kg, Ca - 91 mg/kg, Cr - 10,9 mg/kg, Cu - 14 mg/kg, Fe - 78.194 mg/kg, Hg - 0,11 mg/kg, Mg - 181 mg/kg, Mn - 26,76 mg/kg, Mo - 9,12 mg/kg, Na - 31,83 mg/kg, Ti - 178,4 mg/kg, V - 67,38 mg/kg, Zn - 21,11 mg/kg, Brometo - 2,47 mg/kg, Sulfato - 18,83 mg/kg, Sulfito - 70 mg/kg. Esses valores fornecem uma base para monitoramento ambiental, identificação de impactos industriais, avaliação de risco à saúde humana, e planos de intervenção em áreas contaminadas do PIC. Além disso, são ferramentas para subsidiar licenciamento ambiental, fiscalização e políticas públicas para o gerenciamento ambiental do PIC. A abordagem metodológica aplicada pode ser replicada em outras regiões industriais, contribuindo para o avanço científico na determinação de valores de *background* e na gestão de áreas contaminadas no Brasil e no mundo.

Palavras-chave: *Background* do solo. Polo Industrial de Camaçari. Gerenciamento de áreas contaminadas.

ABSTRACT

This study establishes Background Threshold Values (BTV) for inorganic parameters in soils and sedimentary deposits of the unsaturated zone of the Camaçari Industrial Complex (CIC), Brazil. A geological conceptual model of the region was developed to design the sampling plan, which included soil and sediment samples from each lithological layer of the unsaturated zone within the Marizal and Barreiras formations. Samples were collected from reference areas selected to represent natural conditions. Following chemical and statistical analyses, parameters were categorized into three groups: (1) parameters with at least five detections, for which BTVs were calculated using the UTL95-95 method; (2) parameters with one to five detections, where BTVs were defined as the maximum values detected; and (3) undetected parameters, for which BTVs were set as below the detection limit. The BTVs for Group 1 are as follows: Al: 7308 mg/kg, As: 31.57 mg/kg, Ba: 2.47 mg/kg, Ca: 91 mg/kg, Cr: 10.9 mg/kg, Cu: 14 mg/kg, Fe: 78194 mg/kg, Hg: 0.11 mg/kg, Mg: 181 mg/kg, Mn: 26.76 mg/kg, Mo: 9.12 mg/kg, Na: 31.83 mg/kg, Ti: 178.4 mg/kg, V: 67.38 mg/kg, Zn: 21.11 mg/kg, Bromide: 2.47 mg/kg, Sulfate: 18.83 mg/kg, Sulfite: 70 mg/kg. These BTVs provide a foundation for environmental monitoring, industrial impact assessment, human health risk evaluation, and remediation planning in CIC's contaminated areas. They also serve as critical tools for environmental licensing, regulatory enforcement, and policymaking in the CIC. The methodological framework developed is adaptable to other industrial regions, advancing scientific approaches to BTV definition and improving contaminated site management in Brazil and worldwide.

Keywords: Background threshold value. Camaçari Industrial Complex. Management of contaminated areas.

SUMÁRIO

CAPÍTULO 1

INTRODUÇÃO GERAL

Complexos industriais em operação há décadas frequentemente apresentam múltiplas fontes de contaminação, envolvendo uma ampla variedade de substâncias de interesse ambiental. Com o tempo, esses contaminantes podem se acumular no solo, gerando riscos potenciais à saúde humana e aos ecossistemas. Um dos principais desafios nessas áreas é a ausência de valores de referência estabelecidos para a qualidade do solo, que são fundamentais para distinguir impactos antrópicos das condições naturais. A falta desses valores de referência dificulta a identificação de contaminantes de interesse, a definição de metas de remediação e a avaliação da qualidade do solo em contextos regulatórios. Assim, o desenvolvimento de valores de referência robustos para zonas industriais é essencial para apoiar avaliações ambientais, estratégias de gestão de riscos e processos de tomada de decisão relacionados à contaminação do solo.

O Polo Industrial de Camaçari (PIC), localizado na Região Metropolitana de Salvador (Figura 1), é o maior complexo industrial integrado do hemisfério Sul, desempenhando um papel estratégico no desenvolvimento econômico do estado da Bahia e do Brasil. Desde sua inauguração em 1978, o complexo consolidou-se como um dos principais eixos produtivos e econômicos do país, abrigando mais de 90 empresas de diversos setores, como química, petroquímica, metalurgia, têxtil e automotivo (COFIC, 2021). Essa diversificação e concentração de atividades industriais intensificam a necessidade de estudos voltados à proteção dos recursos naturais e à gestão dos riscos ambientais associados.

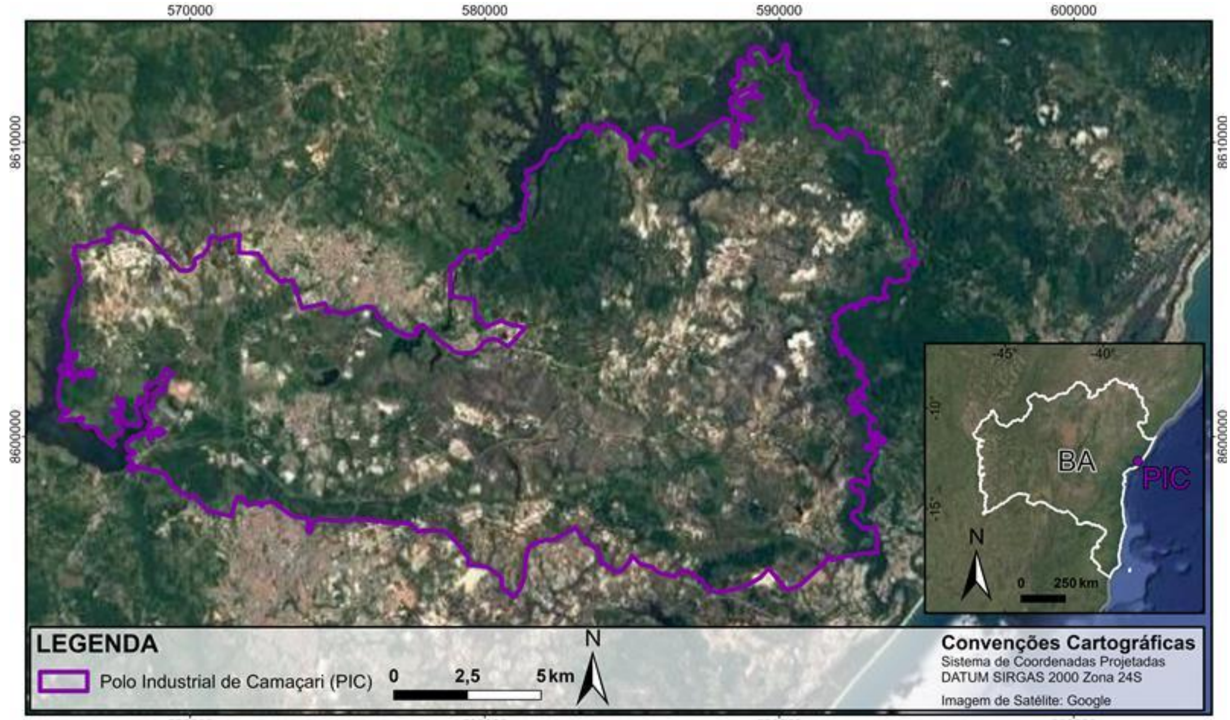


Figura 1. Localização do Polo Industrial de Camaçari

O desenvolvimento do PIC transformou profundamente a paisagem e o uso do solo na região. A implantação do complexo exigiu grandes intervenções, como terraplanagem, corte e aterro, que alteraram significativamente a configuração territorial, convertendo áreas de vegetação nativa e usos rurais em um espaço industrial de alta densidade. Essas mudanças também impactaram o sistema hídrico local, modificando padrões de drenagem e promovendo a urbanização e a infraestrutura de suporte ao complexo (COFIC, 2021). Com a expansão das atividades industriais, novas áreas foram incorporadas, demandando esforços contínuos para conciliar o crescimento econômico com a conservação ambiental e o manejo sustentável dos recursos naturais.

Geologicamente, o PIC está inserido na Bacia Sedimentar do Recôncavo, que faz parte de um sistema de riftes assimétricos, preenchido de sedimentos clásticos continentais, com idades variando do Jurássico ao Cretáceo (LIMA, 1999; Figura 2). Em um intervalo de até 50 m de profundidade, ocorrem os sedimentos das formações Barreiras e Marizal, discordantemente sobrepostos à formação São Sebastião (Grupo Massaracá) e, localmente, delgadas coberturas aluviais recentes, com menos de 10 m de profundidade (LIMA, & VILAS BOAS, 2000). A formação São Sebastião faz parte da supersequência da fase sin-rifte, enquanto a formação Marizal foi depositada na pós-rifte, e a formação Barreiras tem ocorrência subordinada, vinculada aos eventos pós rifte (DA SILVA et al., 2007). A parte superior da sequência sedimentar que preencheu o rifte possui mergulho regional suave para sudeste e é formada pelos depósitos flúvio-deltáicos da formação São Sebastião. As unidades supracitadas influenciam diretamente a composição físico-química dos solos, destacando a importância de compreender essas características para definir parâmetros de qualidade ambiental e gerenciar áreas potencialmente contaminadas.

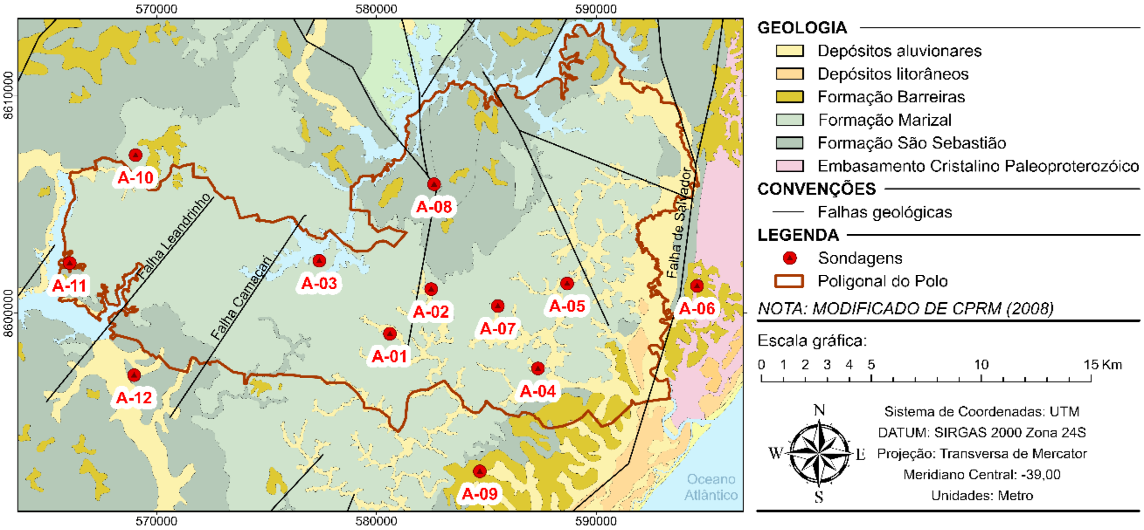


Figura 2. Mapa Geológico simplificado da Área de Estudo

Neste contexto, a determinação de valores de background para solos e sedimentos emerge como uma ferramenta essencial. Esses valores representam as concentrações naturais ou de referência, permitindo distinguir entre fontes de contaminação antropogênicas e condições naturais (ITRC, 2022). No Brasil, a Resolução CONAMA nº 420/2009 estabelece a necessidade de cada estado definir Valores de Referência de Qualidade (VRQs) para solos (BRASIL, 2009). Contudo, a ausência de valores definidos no estado da Bahia representa uma lacuna significativa para a gestão ambiental, especialmente considerando a densidade industrial do Polo Industrial de Camaçari.

O objetivo principal deste estudo é propor valores de background para compostos inorgânicos nos solos e sedimentos da zona não saturada do Polo Industrial de Camaçari. Especificamente, busca-se: (i) caracterizar as unidades geológicas da área de estudo e propor um modelo conceitual geológico para a área, (ii) avaliar a representatividade dos parâmetros inorgânicos em diferentes formações geológicas, (iii) determinar valores de *background* utilizando abordagens estatísticas robustas, fornecendo assim subsídios técnicos para a gestão ambiental de passivos industriais no PIC.

Este estudo se justifica por sua relevância técnica e prática. Tecnicamente, oferece uma base confiável para avaliações de qualidade ambiental, subsidiando processos de licenciamento, fiscalização e remediação de áreas contaminadas. Em termos práticos, fortalece a capacidade regulatória e de gestão ambiental no maior complexo industrial do hemisfério Sul, alinhando-se aos Objetivos de Desenvolvimento Sustentável da ONU, particularmente o ODS 15 – Vida Terrestre.

Como produto desta pesquisa, foi elaborado o artigo *"Background threshold values for soils and sedimentary deposits of the unsaturated zone in a large industrial complex"*, a ser submetido à revista *Environmental Science & Policy* (fator de impacto 4,9). Essa revista, dedicada à interface entre ciência ambiental, políticas públicas e sociedade, possui um escopo alinhado ao objetivo deste trabalho, que integra análises técnicas robustas com práticas de gestão ambiental sustentável.

Referências

COFIC Polo, 2021. Informações sobre o Polo Industrial de Camaçari. Disponível em: https://www.coficpolo.com.br/pagina.php?p=39. (Acessado em 18 de novembro de 2021).

Brasil, Ministério do Meio Ambiente, 2009. Resolução CONAMA Nº 420, de 28 de dezembro de 2009. Dispõe sobre critérios e valores orientadores de qualidade do solo quanto à presença de substâncias químicas e estabelece diretrizes para o gerenciamento ambiental de áreas contaminadas por essas substâncias em decorrência de atividades antrópicas.

Da Silva, B.O., Caixeta, J.M., Milhomem, P.S., Kosin, M.D., 2007. Bacia do Recôncavo. Boletim Geociências Petrobrás. 15(2), 423–431.

ITRC (Interstate Technology & Regulatory Council), 2022. Soil Background and Risk Assessment. Soil Background and Risk Team. Interstate Technology & Regulatory Council, Washington, DC. https://sbr-1.itrcweb.org/.

Lima, O.A.L., 1999. Caracterização hidráulica e padrões de poluição no Aquífero Recôncavo na região de Camaçari - Dias D'Ávila. Tese (Concurso para Professor Titular). Departamento de Geologia e Geofísica Aplicada, Universidade Federal da Bahia. Salvador, Brasil.

Lima, C.U., Vilas Boas, G.S., 2000. A arquitetura deposicional da Formação Marizal (Cretáceo Inferior) na Bacia do Recôncavo, Bahia. Revista Brasileira de Geociências. 30(4), 729–736.

CAPÍTULO 2

ARTIGO 1 – BACKGROUND THRESHOLD VALUES FOR SOILS AND SEDIMENTARY DEPOSITS OF THE UNSATURATED ZONE IN A LARGE INDUSTRIAL COMPLEX

Gabriela Santos Oliveira[1], Ricardo Galeno Fraga de Araújo Pereira[2], Harald Klammler[3]

[1] Núcleo de Estudos Hidrogeológicos e do Meio Ambiente – NEHMA. Programa de Pós-Graduação em Geologia, Instituto de Geociências – IGEO, Universidade Federal da Bahia - UFBA, Salvador, Brasil - gabrielasts.oliveira@gmail.com.

[2] Núcleo de Estudos Hidrogeológicos e do Meio Ambiente – NEHMA. Programa de Pós-Graduação em Geologia, Instituto de Geociências – IGEO, Universidade Federal da Bahia - UFBA, Salvador, Brasil - fraga.pereira@ufba.br

[3] Núcleo de Estudos Hidrogeológicos e do Meio Ambiente – NEHMA. Programa de Pós-Graduação em Geologia, Instituto de Geociências – IGEO, Universidade Federal da Bahia - UFBA, Salvador, Brasil - hklammler@ufba.br

Abstract

The long-term operation of industrial complexes often leads to soil contamination from multiple sources, yet the absence of established background values poses a critical challenge for assessing anthropogenic impacts, identifying contaminants of concern, and defining remediation goals. Therefore, this study establishes Background Threshold Values (BTV) for inorganic parameters in soils and sedimentary deposits of the unsaturated zone of the Camaçari Industrial Complex (CIC), Brazil. A geological conceptual model of the region was developed to support the sampling plan, which included soil and sediment samples from each lithological layer of the unsaturated zone within the Marizal and Barreiras formations. Samples were collected from reference areas selected to represent natural conditions. Following chemical and statistical analyses, parameters were categorized into three groups: (1) parameters with at least five detections, for which BTVs were calculated using the UTL95-95 method; (2) parameters with one to five detections, where BTVs were defined as the maximum values detected; and (3) undetected parameters, for which BTVs were set as below the detection limit. The BTVs for Group 1 are as follows: Al: 7308 mg/kg, As: 31.57 mg/kg, Ba: 2.47 mg/kg, Ca: 91 mg/kg, Cr: 10.9 mg/kg, Cu: 14 mg/kg, Fe: 78194 mg/kg, Hg: 0.11 mg/kg, Mg: 181 mg/kg, Mn: 26.76 mg/kg, Na: 31.83 mg/kg, Ti: 178.4 mg/kg, V: 67.38 mg/kg, Zn: 21.11 mg/kg, Bromide: 2.47 mg/kg, Sulfate: 18.83 mg/kg, Sulfite: 70 mg/kg. The methodological framework developed is adaptable to other industrial regions, advancing scientific approaches to BTV definition and improving contaminated site management worldwide.

Keywords: background threshold value; Camaçari Industrial Complex; management of contaminated areas.

1. Introduction

Industrial complexes that have been in operation for decades often present multiple sources of contamination, involving a wide range of substances of environmental concern (Nascimento et al., 2020; Bento et al., 2021; Fernandes et al., 2016). Over time, these contaminants may accumulate in the soil, leading to potential risks to human health and ecosystems (Souza, 2016; Berrocal et al., 2025) A major challenge in such areas is the lack of established background values for soil quality, which are essential for distinguishing anthropogenic impacts from natural conditions (ITRC, 2022; EPA, 2002). The absence of these reference values hinders the identification of contaminants of concern, the establishment of remediation goals, and the evaluation of soil quality in regulatory frameworks. Developing robust background values for industrial zones is therefore critical to support environmental assessments, risk management strategies, and decision-making processes related to soil contamination (ITRC, 2022; EPA, 2002).

The Camaçari Industrial Complex (CIC), established in 1978 in the municipality of Camaçari, Bahia, Brazil, is recognized as the largest integrated industrial complex in the Southern Hemisphere. With an installed production capacity exceeding twelve million tons per year, the CIC encompasses basic, intermediate, and final chemicals and petrochemicals (COFIC, 2021). Defined by State Decree No. 13,010 of July 11, 2011 (BAHIA, 2011), the CIC spans an area of 298.54 km², extending across the municipalities of Dias D'Ávila and Camaçari. This industrial hub houses more than ninety industries, including those in the chemical, petrochemical, oil, paper, cellulose, and metallurgical sectors (ALVES *et al*., 2020). However, such extensive industrial activity poses a significant potential for soil contamination, due to the diverse range of organic and inorganic chemical substances involved.

Contamination is defined by the Brazilian National Council for the Environment (CONAMA) Resolution No. 420, dated December 28, 2009, as the presence of chemical substances, resulting from anthropogenic activities, at concentrations that restrict the use of environmental resources for current or intended purposes. CONAMA is a regulatory body within Brazil's Ministry of the Environment, whose resolutions are binding normative instruments designed to implement and detail environmental legislation in Brazil, providing technical and legal standards for environmental management and protection. These concentrations, as defined in the resolution, are determined based on risk assessments to human health and environmental assets under standardized or site-specific exposure scenarios. Notably, Article 25 of the resolution establishes that areas will not be considered contaminated when the competent environmental authority recognizes the concentration of a chemical substance as naturally occurring (BRAZIL, 2009).

In Article 8, the resolution mandates that state environmental agencies establish Quality Reference Values (QRVs) for soils within their territories by December 2013. Defined in Article 6, paragraph XXII, QRVs represent the natural quality of soils, determined through statistical analyses of physicochemical properties across diverse soil types (BRAZIL, 2009). However, more than a decade after the stipulated deadline, the State of Bahia has yet to define QRVs for its territory. Although studies addressing soil quality have been performed in certain regions of Bahia (e.g., FADIGAS et al., 2006; FADIGAS et al., 2010; CARVALHO et al., 2013; PASSE, 2015; AQUINO, 2015; DOS SANTOS, 2016; DOS SANTOS et al., 2017; GLOAGUEN & PASSE, 2017; BARRETO

MASCARENHAS, 2018; OLIVEIRA et al., 2020BARRETO MASCARENHAS et al., 2022; CARDOSO et al., 2023), a data gap remains for the CIC region, where no such investigations have been undertaken.

Reference values, also referred to as background or geochemical background, are commonly defined as the natural concentrations of elements or substances present in soils, sediments, and groundwater (FADIGAS et al., 2006; RODRIGUES & NALINI JÚNIOR, 2009; SIMÃO *et al*., 2019). However, the USEPA (2002) offers a more comprehensive definition, characterizing backgrounds as concentrations of substances that are not influenced by activities conducted within the study area. These concentrations may be classified as either naturally occurring (resulting from natural environmental processes without human influence) or anthropogenic (resulting from human activities unrelated to those occurring within the study area). The USEPA (2002) definition was adopted for this study as it aligns more closely with the context of the CIC, considering the industrial density of the region, its location spanning two municipalities (Camaçari and Dias D'Ávila), irregular land use within its boundaries, and significant landscape alterations caused by its establishment and operations.

Background threshold values (BTV) are pivotal in human health and ecotoxicological risk assessments, serving as a tool to identify contaminants of potential concern (COPC) and distinguish between concentrations linked to anthropogenic activities and those attributed to natural soil conditions (ITRC, 2022). Comparing site-specific concentrations to background thresholds allows for the exclusion of chemicals as COPCs when their levels do not exceed natural background concentrations, as it is not reasonable to require remediation to achieve values below these thresholds (ITRC, 2022). Furthermore, BTVs are often instrumental in setting remediation goals, particularly when these thresholds exceed risk-based limits, thereby providing a robust technical and practical framework for environmental interventions (ITRC, 2022).

Given the critical importance of managing contaminated areas within such a large and diversified industrial hub, coupled with the absence of quality reference values for local soils, this study proposed background threshold values (BTVs) for inorganic parameters. These thresholds were established considering not only the surface soils, as recommended by CONAMA Resolution No. 420 (2009), but also the unsaturated sedimentary layers within the CIC.

2. Geological characterization of the Camaçari Industrial Complex

The CIC is situated within the Recôncavo Sedimentary Basin, a component of an asymmetric rift system infilled with continental clastic sediments of Jurassic to Cretaceous age (LIMA, 1999). Within the first fifty meters of depth, the Barreiras and Marizal formations are present, unconformably overlying the São Sebastião Formation (Massaracá Group). Locally, this sequence is covered by thin alluvial deposits less than 10 meters thick (LIMA & VILAS BOAS, 2000). These stratigraphic units, which are critical to understanding the geological framework of the study area, are further described in the following sections.

2.1. São Sebastião Formation

The São Sebastião Formation sediments comprise a range of lithologies, including coarse to fine-grained, reddish-yellow, friable feldspathic sandstones interbedded with variegated silty clays. In the middle portion of the unit, sandy intercalations become more pronounced, imparting a well-developed slope morphology. The upper portion is dominated by coarser clastic materials, occasionally conglomeratic, while the basal section is characterized by the Bebedouro Sandstone, a whitish-gray, fine- to medium-grained, feldspathic sandstone, typically massive, with subrounded grains (VIANA *et al.*, 1971).

With a thickness reaching up to 1,800 meters, the São Sebastião Formation exhibits significant lithological variability, reflecting complex sedimentary and mineralogical processes. The unit consists of sandstones with variable granulometry, ranging from fine to coarse, often feldspathic, micaceous, calciferous, and occasionally showing arkosic characteristics. Interbedded shales and siltstones display a diverse palette of colors, including gray, red, yellow, brown, and violet, enriched with mica, kaolinite, and iron oxides. Plastic clays, found in silty layers, range from gray to reddish hues. Additional features include calcareous nodules, iron oxide concretions, carbonaceous material layers, and fossiliferous sequences within black shales (VIANA *et al.*, 1971).

Two prominent gravitational faults with a N30ºE orientation, identified as the Camaçari and Leandrinho faults, have been mapped in the region, segmenting the study area into three distinct geological compartments and extend to the basin's basement (Lima, 1999). They represent the primary structural features of the complex, playing a critical role in the tectonic evolution of the region and influencing its geological and hydrogeological framework.

2.2. Marizal Formation

In the CIC, the Marizal Formation underlies approximately 80% of the area, with thicknesses ranging from 5 to 12 meters on average and a maximum thickness of up to thirty meters (LIMA & VILAS BOAS, 2000). First formalized by Viana *et al.* (1971), the Marizal Formation is lithologically diverse, comprising a basal conglomerate along with variegated sandstones, claystones, siltstones, shales, and limestones. The sandstones, which are a dominant lithology, display variegated colors ranging from light gray to yellow with reddish hues, with fine- to coarse-grained textures, poorly sorted, and grains varying from subangular to subrounded. These sandstones are quartz-rich, with feldspathic components, low mica content, kaolinitic clays, and occasional ferruginous materials, often featuring thin limonite intercalations and frequent cross-stratification.

The conglomerates within the Marizal Formation are polymictic, with colors ranging from light gray to yellowish. They consist of cobbles and pebbles of red sandstone, slightly metamorphosed black and gray limestone, pinkish limestone, quartz, and flint, all within a sandy matrix. The shales are light gray with pinkish hues to yellowish, typically silty, weakly calcareous, and occasionally contain thin laminations of gypsum and barite. Siltstones are pinkish to reddish-yellow, micaceous, clayey, and rarely ferruginous or calcareous. Finally, the formation also includes rare occurrences of gray to yellowish-gray limestones, which are finely crystalline and sometimes clayey (VIANA et al., 1971).

This lithological diversity and facies complexity reflect the dynamic depositional processes and paleoenvironmental conditions that characterize the Marizal Formation, underscoring its significance within the stratigraphy of the Recôncavo Basin.

2.3. Barreiras Formation

There is divergence regarding the hierarchical classification of such sediments, with some scholars classifying them as a Group (BIGARELLA & ANDRADE, 1964; BIGARELLA, 1975; VILAS BÔAS *et al*., 2001; ARAI, 2006; NUNES & SILVA, 2011; CORRÊA *et al*., 2008; STEIN *et al*., 2019), and other scholars in Formation (VIANA, 1971; SUGUIO & NOGUEIRA, 1999; OLIVEIRA *et al*., 2010; MOURA-FÉ, 2014; BALSAMO *et al.*, 2010; SOUZA *et al*., 2020; WEST & MELLO, 2020; MORAIS *et al.*, 2020; FREIRE *et al.*, 2022). In the present study, this geological unit will be referred to as the Barreiras Formation. Due to its wide distribution along the coast of Brazil, the Barreiras Formation exhibits significant facies variation (NUNES & SILVA, 2011). Locally, in the study region, its sediments consist of coarse sands, reddish-gray, purple and yellowish clays, as well as coarse and conglomeratic sandstones, poorly consolidated, poorly classified, whitish-gray, yellowish and reddish color, with cross-stratification, channel structure and abundant kaolinitic matrix (VIANA et al, 1971). Garcia (2015) conducted mineralogical analyses of lithofacies of the Barreiras Formation in the coastal tablelands of the northern coast of Bahia, including the characterization of light and heavy minerals. In the analysis of light minerals, only the mineral quartz was identified. On the other hand, the analysis of heavy minerals revealed a predominance of tourmaline, yellow garnet, red garnet, zircon, and ilmenite in all the profiles evaluated.

3. Pedological characterization of the Camaçari Industrial Complex

According to the New Soil Map of Brazil (IBGE, 2011), developed at a scale of 1:5,000,000 through updates, compilations, and digital integration of soil surveys conducted by the RADAMBRASIL Project (BRASIL, 1981), the northern portion of the CIC is predominantly characterized by Dystrophic Red-Yellow Ultisols, Eutrophic Red-Yellow Ultisols, and Dystrophic Yellow Latosols (PVAd43). In the southern portion, Hydromorphic Ferrihumilluvic Spodosols and Dystrophic Red-Yellow Ultisols (ESKg3) are predominant.

According to the Brazilian Soil Classification System (EMBRAPA, 2018), Ultisols are mineral soils characterized by a distinctive Bt clay-enriched horizon with low activity or high activity combined with low base saturation or aluminic properties. These soils exhibit a Bt horizon immediately below the surface horizon, except in histic profiles, and do not meet the criteria for classification as Luvisols, Planosols, Plinthosols, or Gleysols. Typically, Ultisols exhibit higher clay content in the Bt horizon compared to the surface horizon, with or without a decrease in the lower horizons. The transition between the A and Bt horizons is usually sharp, abrupt, or gradual. Their depth varies from well-drained to imperfectly drained profiles, displaying reddish, yellowish, brownish, or grayish colors. Textures range from sandy to clayey in the A horizon and medium to very clayey in the Bt horizon, always with an increase in clay content. These soils are kaolinitic, with high or low base saturation, and their molecular Ki ratio ranges from 1.0 to 3.3. Dystrophic Ultisols exhibit base saturation below 50% in most of the upper 100 cm of the B horizon, including the BA horizon (EMBRAPA, 2018).

Spodosols, on the other hand, are mineral soils distinguished by a spodic B horizon, which is characterized by the accumulation of illuvial organic compounds associated with aluminum and iron oxides and may display varying degrees of cementation (EMBRAPA, 2018). It is estimated that 90% of soluble aluminum in the eluvial horizon of podzolized soils is bound to organic compounds (OLIVEIRA, 2007). Spodosols typically have sandy textures throughout the profile, with drainage conditions varying according to depth, degree of development, and the hardness or cementation of the spodic B horizon. These soils are generally nutrient-poor, moderately to strongly acidic, and usually have low base saturation, with potentially elevated levels of extractable aluminum. They develop primarily in sandy-quartz materials under conditions of high humidity, in tropical and subtropical climates, and are commonly found in flat, gently undulating relief, seepage areas, and depressions. Hydromorphic Spodosols are characterized by water saturation in one or more horizons within the upper 100 cm of the soil profile for extended periods or artificial drainage. These soils exhibit at least one of the following characteristics: a histic H horizon; a gleyed Eg horizon or mottling; and/or iron or manganese oxide accumulations caused by reduction-oxidation processes within the E or spodic B horizon, within 100 cm of the soil surface (EMBRAPA, 2018).

The mobilization and immobilization of organic matter, along with iron and aluminum in the spodic B horizon, are attributed to processes involving low molecular weight organic acids as well as fulvic and humic acids (OLIVEIRA, 2007). These acids facilitate the dissolution of primary and secondary minerals and promote the mobilization of metal ions through complexation (TAN, 1986). They readily form stable complexes with aluminum and iron ions and are easily decomposed by soil microbiota, contributing to their dynamic behavior in the soil (BOUDOT, 1989).

Araújo Filho (2003) investigated the mineralogy of Ultisols and Spodosols in coastal tableland environments. According to the author, these soils are mineralogically simple, predominantly composed of kaolinite and quartz. The clay fraction showed an essentially kaolinitic composition, with minor proportions of anatase, rutile, and goethite. The results also indicated a slight excess of aluminum relative to silica in kaolinitic clays with amorphous or low-crystallinity phases. The sand and gravel fractions were dominated by quartz, accounting for more than 95% of the total, with minor occurrences (up to 3%) of muscovite, zircon, leucoxene, staurolite, tourmaline, kyanite, ilmenite, rutile, altered feldspar, and ferruginous crusts.

Additional studies by Silva *et al.* (1997) and Jacomine (1974) conducted in the same region also reported the presence of halloysite in the clay fraction. Similarly, Melo & Santos (1996), in studies of comparable soils and environments, identified the presence of lepidocrocite, cristobalite, and illite in the clay fraction. These findings highlight the mineralogical diversity and pedogenic processes that characterize these soils in the coastal tableland landscapes.

4. Materials and methods

The methodology employed in this study follows a structured, multi-step approach, as summarized in Figure 1. The following subsections provide a detailed description of each step.

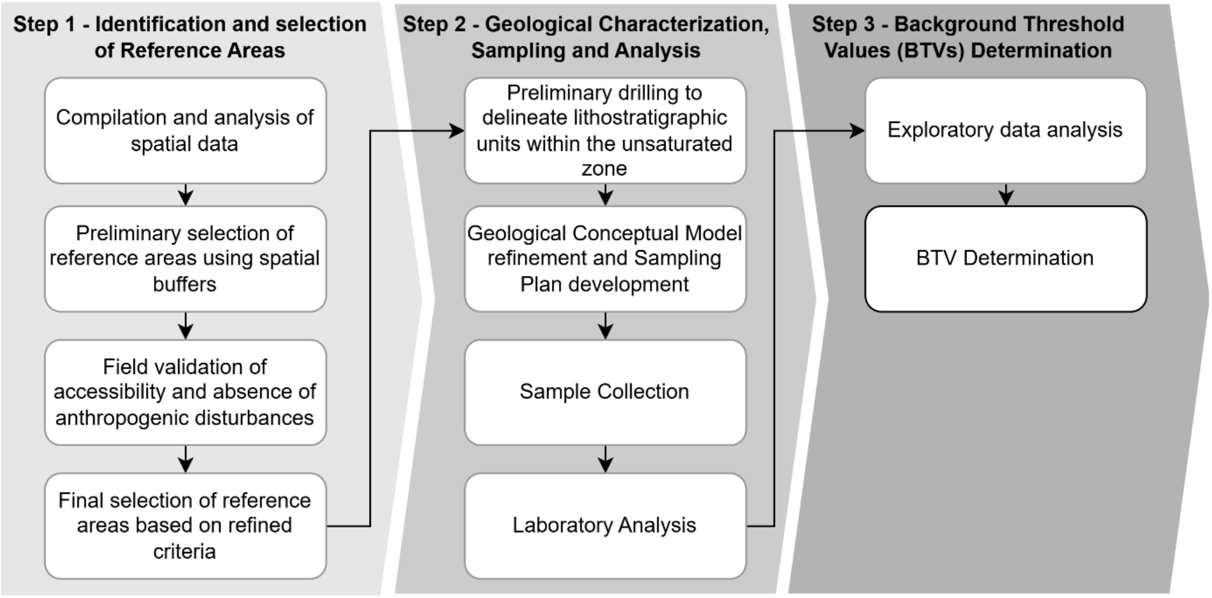


Figure 1. Schematic workflow of the methodology, outlining the sequential steps for reference area selection, geological characterization, sampling, and Background Threshold Value (BTV) determination

4.1. Step 1: Identification and selection of Reference Areas

For the selection of background samples, USEPA (2002) recommends identifying reference areas with physical, chemical, geological, and biological characteristics comparable to those of the study area, but free from the anthropogenic activities being evaluated. Specific criteria for defining reference areas have been highlighted in several studies, often incorporating minimum buffer distances to reduce potential contamination interference. For instance, Smith *et al*. (2013), in a study conducted by the United States Geological Survey (USGS), proposed minimum buffer distances for American soils as follows: 200 m from highways, 50 m from rural roads, 100 m from buildings or structures, and 5 km from major industrial activities such as power plants or smelters. Similarly, Stensvold (2012), in a USGS study examining arsenic distribution in Wisconsin surface soils, defined more stringent criteria: (i) the site must be located in a forest, permanent pasture, or other undisturbed area, at least 6 m away from a fence; (ii) it must be at least 1.6 km from any other study sample site; (iii) it must be no less than 8 km from another sample within the same soil group; (iv) it must be at least 30.5 m away from historic construction sites or disturbed areas, such as roads, dumps, wells, pipelines, or homes; and (v) it must maintain a minimum distance of 91.4 m from any potential contamination source.

These criteria emphasize the critical importance of methodological rigor in the selection of reference areas, ensuring that BTVs accurately represent the natural or diffuse conditions of the studied region. Such rigor minimizes the influence of contamination sources and strengthens the reliability of geochemical background assessments as tools for environmental management and risk evaluation.

Following the guidelines established by the USEPA (1995, 2002), reference areas were selected within and around the CIC to represent the physicochemical characteristics of soils in the industrial zones of the complex. These areas were selected based on the absence of evidence of anthropogenic impacts in the region, as determined through the analysis of both current and historical aerial photographs, as well as field inspections.

A detailed survey of digital data was conducted during the initial stage of the study, land use and occupation maps, zoning data, geology, pedology, and hydrography. To minimize the likelihood of reference areas being influenced by industrial or other anthropogenic activities, buffer zones (distancing criteria) were applied, following the recommendations of the ITRC (2022) and methodologies implemented in previous studies, such as those by Smith *et al.* (2013) and Stensvold (2012). The adopted buffer distances are as follows:

- Industrial facilities and industrial effluent network within the CIC (areas of interest): 1 km buffer
- Urban centers: 1 km buffer
- Asphalted highways: 200 m buffer
- Unpaved rural roads: 50 m buffer
- Other anthropogenic intervention areas (buildings, agricultural plantations, and degraded areas due to sand mining activities): 100 m buffer

Reference areas were selected based on these criteria, and field visits were conducted to verify their accessibility and confirm the absence of anthropogenic disturbances.

4.2. Step 2: Geological characterization, sampling and analysis

In each reference area, reconnaissance drilling was conducted to identify the lithological layers present within the unsaturated zone. Due to the remote locations of the study areas, access to mechanized equipment was unfeasible, and all drilling operations were performed manually using augers. To ensure operational safety and account for the technical limitations of the manual method, a maximum drilling depth of fifteen meters was established, except in cases where lithological layers impenetrable to manual augering were encountered at shallower depths. In locations where the saturated zone was reached, temporary piezometers with a filter section of up to two meters below the water table were installed, enabling precise measurements of hydraulic head.

Lithological assessments were conducted in the field using tactile-visual methods to characterize properties such as grain size, angularity, sorting, and color. These characteristics were correlated with corresponding geological units based on specialized literature reviews. Additionally, the collected information was integrated with supplementary data, including topographic elevation and geomorphology, to develop a Geological Conceptual Model of the area. Building upon the conceptual model and the acquired data, a comprehensive sampling plan was designed, incorporating a second drilling phase in each reference area to collect one soil or sediment sample from each identified lithostratigraphic layer within the unsaturated zone.

Soil and sediment samples were collected using stainless steel tools, including trays, spoons, and samplers, and were stored in glass containers. After collection, the samples were placed in refrigerated thermal boxes maintained at approximately 4°C and transported to the laboratory, accompanied by their respective chain-of-custody documentation. Table 1 summarizes the number of samples collected from each geological unit.

Table 1. Number of samples collected by Geological Unit.

Geological Unit	Reference Areas	Number of samples collected
Alluvial deposits	A-04	3
Barreiras Formation	A-06, A-08, A-09, and A-11	24
Marizal Formation	A-01, A2, A-03, A-05, and A-07	21
São Sebastião Formation	A-08 and A-12	8
Total		56

The target parameters of this study include both elemental inorganics (Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Pb, Co, Cu, Cr, S, Se, Sn, Sr, Fe, Li, Mg, Mn, Hg, Mo, Ni, K, Na, Ta, Te, Ti, V, and Zr) and ionic species (bromide, chloride, fluoride, nitrate-N, nitrite-N, sulfate, sulfide, hydrogen sulfide), as well as total phosphorus, encompassing all phosphorus fractions (inorganic phosphorus, orthophosphates, polyphosphates, and organically bound phosphates).

According to the ITRC (2022) guidelines, chemical analyses for determining BTVs must utilize analytical methods that are equivalent and comparable to those employed in site-specific environmental investigations. CONAMA Resolution 420/2009 stipulates that the determination of Reference Values for Soil Quality (RVQs) for the inorganic substances listed in its Annex II, excluding mercury, should be conducted using the USEPA 3050 or USEPA 3051 methodologies, which yield pseudo-total concentrations.

In alignment with ITRC (2022) and CONAMA Resolution 420/2009, elemental parameters were analyzed following sample extraction on a heating plate with nitric acid, based on the USEPA 3050B method to obtain pseudo-total concentrations. Analyses were performed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Exceptions include sulfur (S), which was quantified through stoichiometric calculations derived from sulfide analysis, and mercury (Hg), arsenic (As), selenium (Se), and antimony (Sb), which were analyzed using Cold Vapor Atomic Absorption Spectroscopy (CVAAS) following methodologies 3112 B and 3114 C from the 23rd edition of the Standard Methods for the Examination of Water and Wastewater (SMEWW) (APHA, 2017), adapted for soil matrices.

Ionic parameters were determined in a 1:10 aqueous extract using methodologies from the SMEWW adapted for soil matrices. Bromide, chloride, fluoride, nitrate-N, nitrite-N, and sulfate were analyzed by Ion Exchange Chromatography, following SMEWW, 21st ed., Part 4110B (APHA, 2005). Sulfite was determined by the Iodometric method (SMEWW, 22nd ed., Part 4500SO_3^2 B, APHA, 2012), while sulfide was analyzed by spectrophotometry (SMEWW, 23rd ed., Part 4500S^2 D, APHA, 2017). Hydrogen sulfide, like sulfur, was calculated stoichiometrically based on sulfide concentrations. Total phosphorus was analyzed by spectrophotometry, following SMEWW, 23rd ed., Part 4500-P C (APHA, 2017).

Granulometric analysis was also performed to refine the lithological descriptions previously conducted using tactile and visual observations and to enhance the Geological Conceptual Model. This analysis was conducted by sieving, in accordance with NBR 2181 (ABNT, 2025).

Soil samples were analyzed in batches of 20 samples, following rigorous quality assurance and quality control (QA/QC) procedures in accordance with ISO/IEC 17025 (ISO, 2025). Each batch included the analysis of an analytical blank to assess cross-contamination, a duplicate sample to verify analytical precision, a spiked sample to estimate analyte recovery, and two control standards (one at high and one at low concentration) to validate instrument calibration. In addition, the statistical monitoring of result stability was performed using control charts. To ensure metrological traceability and result accuracy, Certified Reference Materials (CRM) were employed, while the reliability of the analytical process was evaluated through the analysis of blind samples, whose concentrations were unknown to the analyst. The QA/QC results met the established criteria, ensuring the validity and reliability of the analytical data.

4.3. Step 3: Evaluation and interpretation of data and determination of background threshold values

In regions with multiple geological units, it may be necessary to establish distinct BTVs for each unit (USEPA, 2020) or differentiate between surface and subsurface soil/sediments. However, in practice, this approach can be challenging due to its complexity and data limitations. In such cases, a single BTV encompassing all geological units may be adopted to streamline its application (USEPA, 2020).

In this study, a unified BTV was determined for each parameter, regardless of geological variability, to enhance practical applicability. This approach facilitates comparisons of industrial site samples by industries, consultants, and researchers, ensuring consistency in environmental assessments. Nonetheless, an analysis of the data populations was conducted to assess the influence of geological units on the concentrations of inorganic parameters in the sediments of the unsaturated zone. This analysis also aimed to evaluate whether data from all geological units should be included in the BTV determination.

Descriptive statistics and cumulative distribution function, categorized by geological unit, were analyzed. For the treatment of non-detected values (below the detection limit, DL), the Kaplan-Meier (1958) method was employed. This method uses an estimated distribution function, like the sample distribution function, but adjusted for censored data.

For some parameters, data populations were found to be influenced by geological formations. Consequently, the study was restricted to the two predominant geological units in the unsaturated zone of the CIC, which also had the largest number of samples: the Marizal and Barreiras formations. The analytical results of the samples collected from these units constituted the final dataset.

An outlier evaluation was subsequently performed, recognizing that environmental datasets can include erroneous values arising from transcription errors, coding issues, or instrumental failures (USEPA, 2020). Such values can distort statistical calculations and compromise decisions regarding remediation and environmental protection (Rousseeuw & Leroy, 1987; Barnett & Lewis, 1994; Singh & Nocerino, 1995). Potential outliers were identified through graphical methods, including QQ-plots and boxplots (Johnson & Wichern, 2002; Hoaglin *et al.*, 1983). Statistical outlier tests, such as those proposed by Rosner (1975, 1983) and Dixon (1953), were deemed unsuitable due to their reliance on normality assumptions, which were not satisfied by most distributions in this study

(USEPA, 2020). Suspect values were individually reviewed for procedural errors. Data identified as erroneous were corrected, while valid extreme values were retained, reflecting the natural variability of the area, characterized by heterogeneous geological units and asymmetric distributions (USEPA, 2020).

A revised table of descriptive statistics was generated for the final dataset to provide a comprehensive summary of the data. The suitability of the dataset for primary statistical distributions was rigorously evaluated using robust and established methods, considering only detected values. The Shapiro-Wilk test was applied to assess normality at a 1% significance level, while adherence to the lognormal distribution was examined at a 10% significance level. The Anderson-Darling test, performed at a 5% significance level, was utilized to evaluate the gamma distribution. These significance levels are pre-configured in the ProUCL software (EPA, 2022) and adhere to the methodological standards outlined by USEPA (2020). When the statistical tests rejected the hypotheses of normality, lognormality, and gamma distribution, the dataset was classified as following a non-parametric distribution (i.e., using its empirical cumulative distribution function).

Background threshold values (BTVs) were determined and classified into three distinct groups based on the number of detections, data availability, and the recommendations of USEPA (2020), as follows:

- **Group 1:** Parameters with at least five detections, for which BTVs were estimated using Upper Tolerance Limit (UTL95-95) method.

- **Group 2:** Parameters with one to five detections, for which the proposed BTVs correspond to the highest detected value.

- **Group 3:** Parameters with no detections in the analyzed samples, for which the BTVs were considered below the detection limit (< DL) of the analytical methods employed.

For parameters with at least three detections, the Upper Tolerance Limit (UTL95-95) was calculated, as recommended by USEPA (2020). This threshold is appropriate for scenarios requiring comparisons of multiple observations to a reference value, such as at the CIC. UTL95-95 ensures that 95% of the observations from the population of interest (background and comparable data) are below or equal to the threshold, with 95% confidence. The Kaplan-Meier (1958) method was used to manage censored data.

UTL95-95 was adjusted based on the data distribution established through adherence tests. When data adhered to more than one distribution, the normal distribution was prioritized, followed by the gamma distribution. The lognormal distribution was only used when the other two were rejected, as per USEPA (2020) recommendations. For data following the gamma distribution, the Hawkins and Wixley (1986) method was applied for UTL calculation, given its suitability for highly skewed datasets, as observed in this study.

It is important to note that for datasets with low detection frequency (Group 2) or no detections (Group 3), the uncertainty in BTV estimates is heightened, and the statistical properties, such as bias, accuracy, and precision, remain indeterminate (USEPA, 2020).

All statistical analyses, calculations, and visualizations presented in this study were performed using ProUCL software version 5.2, developed by the U.S. Environmental Protection Agency (USEPA, 2022).

5. Results and discussions

5.1. Selection of Reference Areas

Twelve reference areas were identified in proximity to the industrial zones of the CIC using the criteria outlined in the methodology. These areas underwent field inspections to validate their suitability, and specific adjustments were made to ensure accessibility while maintaining the established minimum distances from anthropogenic intervention zones.

Figure 2 provides a consolidated visualization of the industrial zones, adjacent anthropogenic areas, buffer zones with the adopted minimum distances, and the final locations of the selected reference areas.

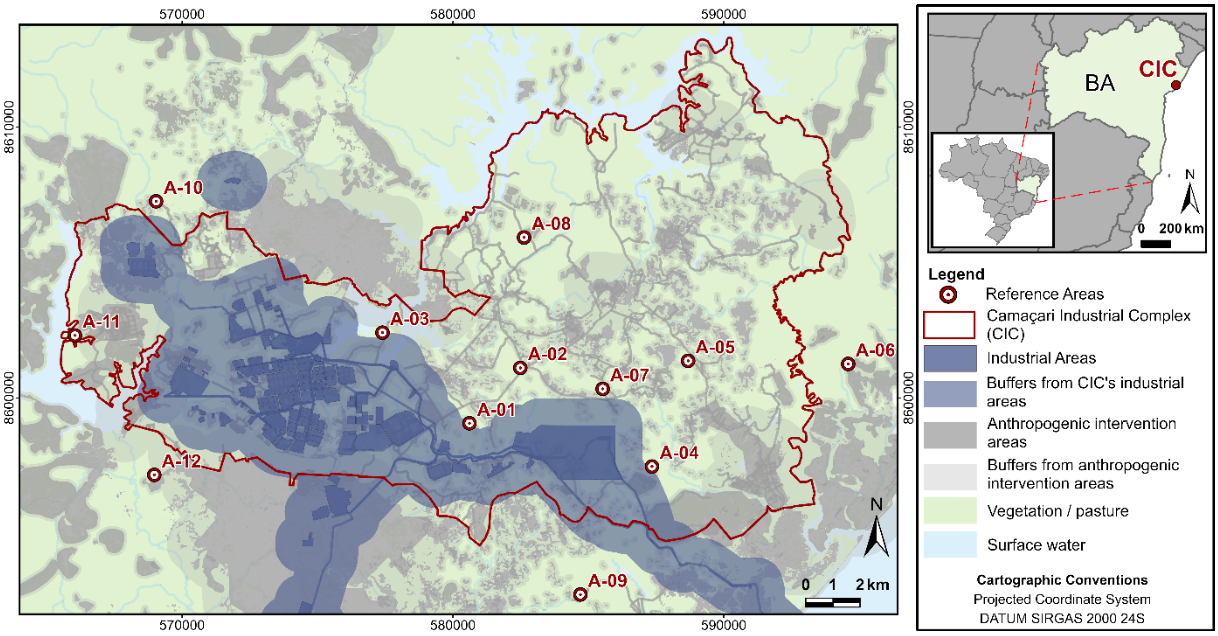


Figure 2. Background reference areas (A-01 to A-12) delineated based on the established minimum buffer distances.

5.2. Conceptual model of the area

Based on an integrated analysis of lithological and granulometric data, combined with geomorphological and geological information from the literature, the geological units outcropping in the study area were comprehensively characterized. Table A.1 (Appendix A) provides a detailed description of the lithostratigraphic layers identified in each reference area, along with the corresponding samples collected. Additionally, Table A.2 (Appendix A) summarizes the granulometric analysis results. The primary characteristics of the geological units outcropping in the investigated region are outlined below.

- **São Sebastião:** Sediments of this formation were identified in two Reference Areas (A-08 and A-12), characterized by steeper slopes within aquifer recharge zones. One borehole intercepted the water table at 6.8 m depth, while the other did not. In A-08, the sequence included shale layers overlying fine-grained sediments (clayey fine sand and silty clay) with pinkish, reddish, yellowish, and grayish tones. In A-12, the sequence comprised fine to medium clayey sands in light brown, strong brown, and yellowish-red hues, followed by well-sorted medium sand. In both boreholes, the sandy fraction exhibited subangular grains.
- **Marizal Formation:** Sediments from this formation were identified in six Reference Areas (A-01, A-02, A-03, A-05, A-07, and A-10), located in flatter terrains, with water table depths ranging from 1 m to 8.5 m. The granulometry was predominantly sandy, with poorly sorted sand packages varying from fine to medium sand, often clayey and occasionally silty, to medium to coarse clayey sand. Grain shapes ranged from subangular to subrounded, with some occurrences of quartz pebbles and/or laterite lenses. Sediment colors included yellowish, brownish, gray, and whitish tones, with rare occurrences of reddish or pinkish hues.
- **Barreiras Formation:** Sediments of this formation were identified in three Reference Areas (A-06, A-09, and A-11), situated in coastal tablelands within aquifer recharge zones. Only the sounding at A-11 intercepted the water table, recorded at 8.5 m depth. Lithological sequences predominantly consisted of poorly sorted sands with granulometry ranging from fine to coarse, often clayey, silty, or silty-clayey. Grain shapes varied from subangular to subrounded, with occasional rounded grains, and quartz pebbles and laterite lenses were observed. Predominant sediment colors included strong reddish and yellowish tones, with occasional brownish and grayish hues. Compared to the Marizal Formation, the Barreiras Formation exhibited greater intercalation of sediment packages, as well as increased variability in grain size and coloration.
- **Alluvial deposits:** Identified in Reference Area A-04, located within a floodplain with a shallow water table (approximately 2 m depth). Only one lithological layer was present in the unsaturated zone. Sediments of this unit exhibited predominantly fine to medium sandy granulometry, with minimal silt and clay content. The grains displayed variable selection, ranging from well-sorted to poorly sorted, and were subangular, with colors varying from very dark gray and reddish gray to light gray and light reddish brown.

From the detailed evaluation of lithologies and geological unit classification, a conceptual model of the study area was developed, as presented in Figure 3.

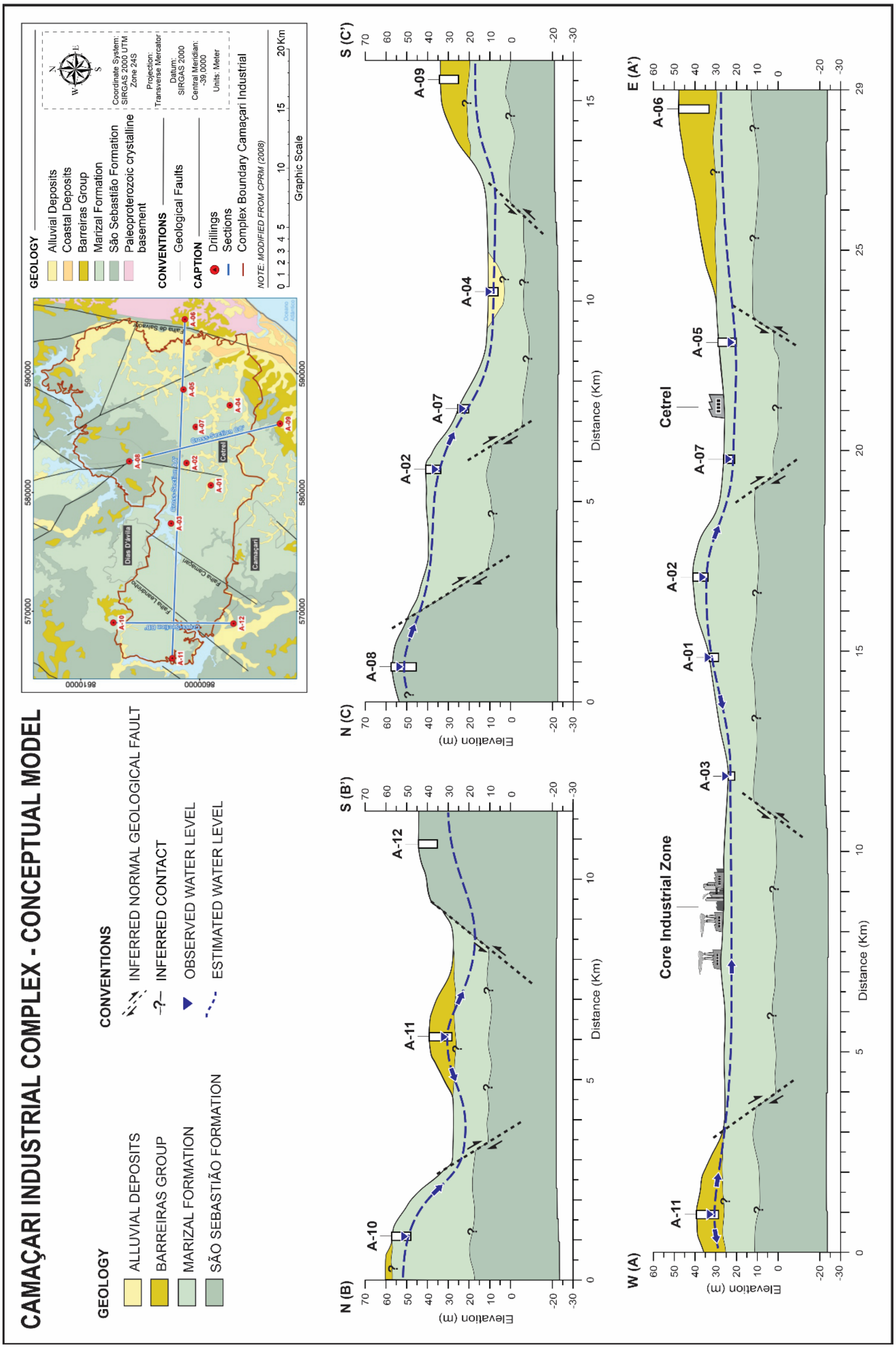


Figure 3. *Geological Conceptual Model of the Camaçari Industrial Complex*

5.3. Analytical results and proposition of background threshold values

5.3.1. Analysis of data distributions

Parameters such as antimony, bismuth, cadmium, sulfur, phosphorus, nitrite-N, silver, selenium, sulfide, hydrogen sulfide, thallium, and tellurium were not detected in any of the 56 analyzed samples and are therefore excluded from further analysis. This suggests that the BTVs for these elements are consistently below the detection limits of the analytical methods employed, indicating extremely low concentrations or an absence in the evaluated geological units. Table A.3 (Appendix A) provides the complete results of laboratory analyses for parameters with at least one detection. Table A.4 (Appendix A) presents descriptive statistics for physicochemical data, both aggregated and segmented by geological unit, and summarizes the statistical characterization of censored distributions using the Kaplan-Meier (1958) method. Appendix B includes graphs (Graph B.1 to Graph B.17) of cumulative distribution functions (cdf) of parameters classified by geological unit, restricted to those with more than five detections. The key findings from these analyses are summarized below:

- Aluminum and iron were detected in all samples, confirming their ubiquitous presence in the sediments of the geological units investigated. Titanium, magnesium, and chromium were also frequently detected, appearing in over 75% of the samples, reflecting their common distribution in local geological formations.

- Barreiras Formation: This formation was the sole source of detections for arsenic, boron, and molybdenum, and it also exhibited the highest average concentrations of chromium, tin, iron, nitrate, titanium, and vanadium. In contrast, beryllium, lead, strontium, fluoride, and lithium were not detected in Barreiras Formation samples, suggesting their absence or concentrations below detection limits.

- Marizal Formation: Lead was detected exclusively in this formation, but no detections were recorded for arsenic, beryllium, boron, chloride, cobalt, strontium, fluoride, lithium, molybdenum, nickel, or potassium.

- Alluvial Deposits: This unit exhibited the highest number of undetected elements, including arsenic, bromide, lead, chloride, cobalt, copper, tin, manganese, mercury, molybdenum, nickel, nitrate, potassium, and sulfate. It also recorded the lowest average concentrations for calcium, chromium, iron, magnesium, sodium, vanadium, and zinc. These findings reflect the low retention capacity of sandy sediments with minimal reactivity. However, this unit demonstrated the highest average concentrations of sulfite, aluminum, and the greatest cation exchange capacity (CEC) among all geological units.

- São Sebastião Formation: This formation exhibited the highest average concentrations of aluminum, barium, calcium, chloride, cobalt, copper, magnesium, manganese, nickel, potassium, sodium, sulfate, and zinc. Unique detections of beryllium, strontium, fluoride, and lithium were also attributed to this formation, specifically within the shale sample. This shale sample displayed elevated concentrations of several elements. appearing as outliers in graphical analyses, but their anomalous composition reflects natural shale characteristics, including high clay mineral content.

- General Observations: The São Sebastião Formation exhibited the highest concentrations for most parameters, while the Alluvial Deposits consistently recorded the lowest averages, contrasting with the Barreiras and Marizal Formations.

- Geological Influence: Evaluations of the cumulative distribution function for iron, titanium, chromium, and vanadium revealed population separations based on geological units, with higher concentrations in the Barreiras and São Sebastião Formations compared to the Marizal Formation and Alluvial Deposits. However, the small sample size for the Alluvial Deposits (n=3) limits its statistical representativeness.

- Distinct Patterns for Aluminum: Aluminum concentrations formed distinct populations according to the cumulative distribution function, with higher values in the Alluvial Deposits and São Sebastião Formation, while the Barreiras and Marizal Formations exhibited lower concentrations.

- Parameter-Specific Trends: Arsenic was exclusively detected in 10 samples from the Barreiras Formation, with no detection in other formations. Conversely, parameters such as sulfite, manganese, zinc, and magnesium showed no clear correlation with geological units.

The São Sebastião Formation (n=8) and Alluvial Deposits (n=3) exhibited insufficient statistical representativeness compared to the Barreiras (n=24) and Marizal (n=21) Formations. Additionally, the Alluvial Deposits had the highest number of undetected parameters and significantly lower concentrations for most analytes, except for sulfite, distinguishing it as an outlier formation. The São Sebastião Formation displayed high concentrations of most parameters, particularly in shale samples, further distinguishing it from other units.

Given the predominance of sediments from the Barreiras and Marizal Formations in the unsaturated zone of the CIC and their practical relevance for future studies in the region, the dataset was refined to include only these formations. This final dataset, totaling 45 samples, ensures greater consistency and representativeness for defining BTVs.

5.3.2. Proposition of background threshold values

Table 2 presents the descriptive statistics for parameters with at least one detection, considering only the detected values of the final dataset. Additionally, it includes the estimated percentiles, which account for censored data processed using the Kaplan-Meier (1958) method. A detailed statistical characterization of the censored distributions is presented in Table A.4 (Appendix A). Table 3 summarizes the results of goodness of fit tests evaluating the conformity of the data to normal, lognormal, and gamma distributions, considering only detected values.

Table 2 – Descriptive statistics for parameters with at least one detection of final dataset, including detected values only, alongside percentiles estimated using the Kaplan-Meier (1958) method to account for non-detected values.

Variable	Detected	%	General Statistics (detected data only)								Percentiles (detected and undetected)			
		Detected	Min	Max	Average	Median	VAR	SD	Skewness	CV	P 50%	P 75%	P 90%	P 95%
Aluminum (mg/kg)	45	100%	102	14958	1801	1092	5787842	2406	4,005	1,336	1092	2516	3764	4101
Iron (mg/kg)	45	100%	7	51342	12968	4320	244028281	15621	1,128	1,205	4320	18603	37312	43091
Arsenic (mg/kg)	10	22%	11	58	24,1	19,50	219,2	14,81	1,637	0,614	10	10	19,8	26,6
Barium (mg/kg)	6	13%	1	5	2,167	2	2,167	1,472	1,84	0,679	1	1	1	2
Boron (mg/kg)	1	2%	21	21	21	21	N/A	N/A	N/A	N/A	3	3	3	3
Bromide (mg/kg)	6	13%	1,3	2,8	1,833	1,4	0,507	0,712	0,964	0,388	1	1	1,36	1,4
Calcium (mg/kg)	30	67%	5	91	19,93	11,5	423	20,57	2,131	1,032	8	14	40	52,8
Lead (mg/kg)	2	4%	11	16	13,5	13,5	12,5	3,536	N/A	0,262	10	10	10	10
Chloride (mg/kg)	2	4%	13	20	16,5	16,5	24,5	4,95	N/A	0,3	10	10	10	10
Cobalt (mg/kg)	1	2%	2	2	2	2	N/A	N/A	N/A	N/A	2	2	2	2
Copper (mg/kg)	16	36%	1	14	4,625	2	21,18	4,603	1,26	0,995	1	1	5,6	10,2
Chromium (mg/kg)	34	76%	2	110	22,38	11	607,3	24,64	1,837	1,101	7	20	51,6	61,2
Tin (mg/kg)	2	4%	22	30	26	26	32	5,657	N/A	0,218	10	10	10	10
Magnesium (mg/kg)	41	91%	2	181	16,63	9	872,6	29,54	4,661	1,776	8	14	29,6	55,4
Manganese (mg/kg)	17	38%	2	224	22,24	7	2784	52,77	3,93	2,373	2	4	15,2	19,8
Mercury (mg/kg)	7	16%	0,07	0,16	0,104	0,1	0,00103	0,0321	0,857	0,308	0,1	0,1	0,1	0,108
Molybdenum (mg/kg)	3	7%	5	17	10	8	39	6,245	1,293	0,624	5	5	5	5
Nickel (mg/kg)	1	2%	7	7	7	7	N/A	N/A	N/A	N/A	5	5	5	5
Nitrate-N (mg/kg)	2	4%	1,9	3,3	2,6	2,6	0,98	0,99	N/A	0,381	1	1	1	1
Potassium (mg/kg)	1	2%	39	39	39	39	N/A	N/A	N/A	N/A	30	30	30	30
Sodium (mg/kg)	30	67%	8	40	19,03	17	54,86	7,407	1,055	0,389	13	18	27,8	30,6
Sulfate (mg/kg)	17	38%	10	25	14,94	15	15,18	3,897	1,149	0,261	10	13	15,6	18
Sulfite (mg/kg)	28	62%	6	70	14,61	10	149,5	12,23	3,708	0,837	8	10	19,6	20
Titanium (mg/kg)	40	89%	2	222	42,75	23,5	2761	52,54	2,092	1,229	20	37	99,2	165
Vanadium (mg/kg)	18	40%	12	104	38,78	27	754,8	27,47	1,069	0,708	10	22	51	73,6
Zinc (mg/kg)	27	60%	1	27	6,963	4	54,42	7,377	1,802	1,059	2	5	12,6	17,8

Table 3 – Results of adherence tests: Shapiro-Wilk test for assessing fit to normal and lognormal distributions, and Anderson-Darling test for evaluating fit to the gamma distribution.

Parameter	Shapiro Wilk test (normal distribution)			Shapiro Wilk test (lognormal distribution)			Anderson Darling test (gamma distribution)		
	Test Value	**Critical Value**	**Conclusion (1% significance level)**	**Test Value**	**Critical Value**	**Conclusion (5% significance level)**	**Test Value**	**Critical Value**	**Conclusion (10% significance level)**
Aluminum	0,610	0,926	Rejected	0,971	0,953	Not rejected	0,533	0,777	Not rejected
Arsenic	0,812	0,781	Not rejected	0,937	0,869	Not rejected	0,462	0,730	Not rejected
Barium	0,751	0,713	Not rejected	0,857	0,826	Not rejected	0,593	0,701	Not rejected
Bromide	0,698	0,713	Rejected	0,711	0,826	Rejected	1,039	0,698	Rejected
Calcium	0,696	0,900	Rejected	0,912	0,939	Rejected	1,738	0,762	Rejected
Chromium	0,768	0,908	Rejected	0,956	0,943	Not rejected	1,043	0,774	Rejected
Copper	0,774	0,844	Rejected	0,873	0,906	Rejected	0,883	0,759	Rejected
Iron	0,781	0,926	Rejected	0,929	0,953	Rejected	0,588	0,813	Not rejected
Magnesium	0,467	0,920	Rejected	0,938	0,95	Rejected	2,155	0,781	Rejected
Manganese	0,393	0,851	Rejected	0,893	0,91	Rejected	1,730	0,788	Rejected
Mercury	0,923	0,730	Not rejected	0,951	0,838	Not rejected	0,276	0,708	Not rejected
Molybdenum	0,923	0,753	Not rejected	0,982	0,789	Not rejected	0,293	0,637	Not rejected
Sodium	0,916	0,900	Not rejected	0,981	0,939	Not rejected	0,437	0,746	Not rejected
Sulfite	0,564	0,896	Rejected	0,845	0,936	Rejected	2,133	0,754	Rejected
Sulfate	0,906	0,851	Not rejected	0,955	0,91	Not rejected	0,385	0,738	Not rejected
Titanium	0,719	0,919	Rejected	0,974	0,949	Not rejected	0,603	0,783	Not rejected
Vanadium	0,862	0,858	Not rejected	0,939	0,814	Not rejected	0,548	0,750	Not rejected
Zinc	0,733	0,894	Rejected	0,944	0,935	Not rejected	0,881	0,768	Rejected

Table 4 presents the proposed BTVs for the analyzed parameters, categorized into three distinct groups based on the number of detections and data availability. It is important to note that for datasets with low detection frequency (Group 2) or no detection (Group 3), increased uncertainty in BTV estimates was observed, with statistical properties such as bias, accuracy, and precision remaining undefined.

For comparative purposes Table 4 includes the following reference concentrations for selected elements derived from relevant studies and applicable legislation:

- **Fadigas et al. (2006):** Proposed reference values for heavy metals in soils derived from sediments of the Barreiras Formation under natural conditions, predominantly Ultisols (27%) and Latosols (42%), formed mainly by Tertiary (54%) and Quaternary sediments (6%), along with other sedimentary or rocky materials. Metal extraction was conducted using aqua regia (pseudo-total concentration), and quantification performed via Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES). Reference values were defined as the upper quartile of groups based on dissimilarity measures.

- **Carvalho et al. (2013):** Proposed reference values for metals in natural soils classified as Oxisols from the coastal tablelands of Bahia (Barreiras Formation). Metal extraction involved acid digestion (pseudo-total concentration), and quantification was carried out using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Reference values corresponded to the upper quartile of groups determined through dissimilarity analysis.

- **Passe (2015):** Proposed reference values for metals in soils of the Recôncavo and Tucano Sul sedimentary basins. The reported values were based on averages for Yellow-Red Ultisols and the Marizal Formation. Metal extraction followed the USEPA 3050B method (pseudo-total concentration), and quantification was performed via ICP-OES.

- **CONAMA Resolution 420/2009 (BRASIL, 2009):** Brazilian legislation that established Prevention Values (PV), which are the maximum permissible concentrations of specific elements in soils to maintain their environmental functionality.

- **Kabata-Pendias (2010**): Provided global average concentrations of elements in soils.

Table 4. Final distribution fits with proposed background threshold values and reference concentrations for selected soil parameters for comparative purposes.

Group	**Parameter**	**Distribution fit**	**Background Threshold Value (mg/kg)**	**References for concentrations of certain parameters in soils (mg/kg)**					
				Fadigas et al. (2006)	**Carvalho et al. (2013)**	**Passe (2015) – Ultisols Red Yellow**	**Passe (2015) - Marizal**	**CONAMA Resolution 420/2009**	**Kabata-Pendias (2010)**
Group 1 (≥5 detects)	Aluminum	Gamma	7308	-	-	-	-	-	-
	Arsenic	Normal	31,57	-	-	-	-	15	0,1 - 67
	Barium	Normal	2,47	-	-	-	-	150	362 - 580
	Bromide	Nonparametric	2,8	-	-	-	-	-	-
	Calcium	Nonparametric	91	-	-	-	-	-	-
	Chromium	Lognormal	103,9	36	47	16,03	10,23	75	60
	Copper	Nonparametric	14	8	9	5,15	1,77	60	14 - 109
	Iron	Gamma	78194	-	-	27.000	21.000	-	35000
	Magnesium	Nonparametric	181	-	-	-	-	-	-
	Manganese	Lognormal	26,76	-	-	238	200	-	411 - 550
	Mercury	Normal	0,11	-	-	-	-	0,5	0,58 - 1,8
	Sodium	Normal	31,83	-	-	-	-	-	-
	Sulfite	Nonparametric	70	-	-	-	-	-	-
	Sulfate	Normal	18,83	-	-	-	-	-	-
	Titanium	Gamma	178,5	-	-	41.000	21.000	-	100 - 25000
	Vanadium	Normal	67,38	-	-	-	-	-	69 - 320
	Zinc	Lognormal	21,11	20	33	5,22	6,53	300	60 - 89
Group 2 (<5 detects)	Boron	NA	21	-	-	-	-	-	42
	Chloride	NA	20	-	-	-	-	-	-
	Cobalt	NA	2	5	9	-	-	25	10
	Fluoride	NA	4,7	-	-	-	-	-	-
	Lead	NA	16	-	14	6,35	3,35	72	27
	Molybdenum	Normal	17	-	-	-	-	30	0,9 - 1,8
	Nickel	NA	7	14	18	2,27	1,36	30	13 - 37
	Nitrate-N	NA	3,3	-	-	-	-	-	-
	Potassium	NA	39	-	-	-	-	-	-
	Tin	NA	30	-	-	-	-	-	<0,1 - 5

Group	Parameter	Distribution fit	Background Threshold Value (mg/kg)	References for concentrations of certain parameters in soils (mg/kg)					
				Fadigas et al. (2006)	Carvalho et al. (2013)	Passe (2015) – Ultisols Red Yellow	Passe (2015) - Marizal	CONAMA Resolution 420/2009	Kabata-Pendias (2010)
Group 3 (0 detects)	Antimony	NA	< 2	-	-	-	-	2	0,25 – 1,04
	Beryllium	NA	< 1	-		-	-	-	0,92 – 2
	Bismuth	NA	< 50	-	-	-	-	-	0,42
	Cadmium	NA	< 1	1	-	-	-	1,3	0,2 – 1,1
	Lithium	NA	< 2	-	-	-	-	-	13 - 28
	Total Phosphorus	NA	< 200	-	-	-	-	-	-
	nitrite-N	NA	< 1	-	-	-	-	-	-
	Silver	NA	< 2	-	-	-	-	2	0,05-0,13
	Selenium	NA	< 5	-	-	-	-	5	0,05 – 1,5
	Sulfide	NA	< 0.2	-	-	-	-	-	-
	Hydrogen Sulfide	NA	< 0.02	-	-	-	-	-	-
	Sulphur	NA	< 5	-	-	-	-	-	-
	Strontium	NA	< 2	-	-	-	-	-	130 - 240
	Thallium	NA	< 10	-	-	-	-	-	0,024 – 2,8
	Tellurium	NA	< 10	-	-	-	-	-	0,006 – 0,0,4

NA: Not applicable

As detailed in Section 4, the study area is predominantly composed of Ultisols and Spodosols, soil types recognized for their high concentrations of iron and aluminum (EMBRAPA, 2018; Araújo Filho, 2003). Additionally, sediments from the Marizal and Barreiras Formations are characterized by a predominantly kaolinitic matrix and the presence of minerals enriched with iron and aluminum oxides (VIANA *et al*., 1971). The analytical results corroborate this mineralogical composition, as iron and aluminum were detected in 100% of the analyzed samples, exhibiting concentrations significantly higher than other measured parameters. This geochemical profile explains the elevated background threshold value (BTV) for iron in the study area, which exceeds the global average for soils reported by Kabata-Pendias (2010).

The calculated BTV for iron (78,194 mg/kg) exceeded the maximum observed concentration (51,342 mg/kg), which can be attributed to the pronounced skewness and long-tailed nature inherent to the dataset, characteristics aligned with the Gamma distribution. The presence of several extreme values in the upper tail significantly influenced the distribution's parameters, leading to an elevated UTL95-95, which is designed to account for potential extreme values in the population beyond those observed in the sample.

The sediments of the Marizal Formation are characterized by the presence of minerals such as feldspar, mica, gypsum, barite, and limestone (Viana et al., 1971). In contrast, the sediments of the Barreiras Formation may contain minerals such as andradite, almandine, ilmenite, and tourmaline (Garcia, 2015). Additionally, Araújo Filho (2003) notes that Ultisols and Spodosols in coastal tablelands are enriched with minerals including muscovite, zircon, leucoxene, staurolite, tourmaline, kyanite, ilmenite, rutile, and altered feldspar, although these occur in very low proportions (up to 3%) within the sand and gravel fractions. Collectively, these minerals contribute to the presence of elements in the soil of the study area, including aluminum, iron, titanium, vanadium, manganese, magnesium, chromium, potassium, sodium, calcium, barium, and sulfate.

The BTV for chromium exceeded the Prevention Value (PV) set by CONAMA Resolution 420/2009, as well as reference values from prior studies and the global soil averages reported by Kabata-Pendias (2010). This occurred because the maximum chromium concentration (110 mg/kg) was significantly higher than the second-highest concentration (69 mg/kg), skewing the distribution upward. Given the lognormal distribution fit, the calculated UTL95-95 (103,9 mg/kg) closely approached the maximum value. The decision was made to retain this discrepant value after ruling out analytical errors through a thorough review of methods and procedures. It was concluded that the elevated concentration resulted from the presence of clay and lateritic lenses observed in the lithological layer where the sample was collected.

Arsenic BTV is above the PV established by CONAMA, but lacks regional reference values and falls within the global average reported by Kabata-Pendias (2010). Titanium BTV falls below regional references but aligns with global averages. For parameters such as aluminum, barium, bromide, calcium, magnesium, sodium, sulfite, sulfate, and chloride (Group 1), reference values were not available in the consulted bibliography. The remaining parameters in

Group 1 not explicitly mentioned or discussed above were found to be of the same order of magnitude or below the reference values from the compared bibliographies.

Parameters including molybdenum, chloride, lead, nitrate-N, tin, boron, cobalt, and nickel (Group 2) were detected in fewer than five of the 45 samples analyzed. Meanwhile, antimony, beryllium, bismuth, cadmium, sulfur, phosphorus, lithium, nitrite-N, silver, selenium, sulfide, hydrogen sulfide, thallium, and tellurium (Group 3) were not detected in any of the samples. These results indicate that the BTVs for these elements are consistently below the detection limits of the employed analytical methods.

6. Conclusions

This study proposed background threshold values for inorganic compounds in soils and sediments of the unsaturated zone within the Camaçari Industrial Complex (CIC), as presented in Table 4. These values provide a robust scientific foundation for the management and conservation of soils and sediments in the region. They serve as a reference for monitoring soil and sediment quality, facilitating the identification of potential chemical alterations resulting from industrial activities, and supporting impact assessments, monitoring programs, risk evaluations, and remediation efforts for contaminated areas.

The BTVs established in this study constitute a critical tool for decision-making processes, with significant potential to assist environmental agencies in the inspection and licensing of industrial operations within the CIC. Furthermore, the methodological approach employed contributes to the scientific advancement of BTV determination in industrial contexts and offers a replicable model for application in other industrial regions both in Brazil and globally.

By integrating BTVs into environmental management strategies, this study promotes the conservation and protection of natural resources, balancing economic development with environmental sustainability in industrial areas. Additionally, it aligns with the United Nations Sustainable Development Goals (SDGs), particularly Goal 15 – Life on Land, by fostering the sustainable use of terrestrial ecosystems and protecting soils as a vital resource for environmental equilibrium.

Future research should focus on establishing background threshold values for the São Sebastião Formation while also extending investigations to include sediments from the saturated zone and groundwater quality in the region.

7. References

ABNT NBR 7181:2025. Solo – Análise Granulométrica. Associação Brasileira de Normas Técnicas, Rio de Janeiro. ISBN: 978-85-07-06573-9.

Aquino, E.L., 2015. Teores naturais e valores de referência de qualidade de Cd, Co, Cr, Cu, Ni, Pb e Zn em solos derivados de rochas ígneas e metamórficas do território do Sisal, Bahia. Dissertação de Mestrado. Universidade Federal do Recôncavo da Bahia, Programa de Pós-Graduação em Solos e Qualidade de Ecossistemas, Cruz das Almas, Bahia

Alves, L.S., Santos, L.L., Couto, E.R., 2020. Distribuição das concentrações de ozônio (O_3) na área de influência do polo industrial de Camaçari – Bahia: prováveis impactos na saúde humana e no meio ambiente. Revista Brasileira do Meio Ambiente. 8(1), 113–130. ISSN: 2595-4431.

American Public Health Association (APHA), American Water Works Association, Water Environment Federation, 2005. Standard Methods for the Examination of Water and Wastewater, 21st ed. American Public Health Association Press, Washington, DC.

American Public Health Association (APHA), American Water Works Association, Water Environment Federation, 2012. Standard Methods for the Examination of Water and Wastewater, 22nd ed. American Public Health Association Press, Washington, DC.

American Public Health Association (APHA), American Water Works Association, Water Environment Federation, 2017. Standard Methods for the Examination of Water and Wastewater, 23rd ed. American Public Health Association Press, Washington, DC.

Arai, M., 2006. The great eustatic uplift of the Miocene and its influence on the origin of the Barreiras Group. Geology USP - Scientific Series 6, 1–13. https://doi.org/10.5327/S1519-874X2006000300002.

Araújo Filho, J.C., 2003. Horizontes cimentados em Argissolos e Espodossolos dos tabuleiros costeiros e em Neossolos Regolíticos e Planossolos da depressão sertaneja no Nordeste do Brasil. Tese de Doutorado, Instituto de Geociências, Universidade de São Paulo, São Paulo.

Bahia (State), 2011. Decreto nº 13.010, de 11 de julho de 2011. Declara de utilidade pública, para fins de desapropriação, as áreas de terra que indica. Diário Oficial do Estado da Bahia.

Balsamo, F., Rossetti, F., Berra, F., Storti, F., 2010. Structural and petrophysical evolution of extensional fault zones in low-porosity, poorly lithified sandstones of the Barreiras Formation, NE Brazil. Journal of Structural Geology 32, 1806–1826.

Barnett, V., Lewis, T., 1994. Outliers in Statistical Data, third ed. John Wiley & Sons Ltd, UK.

Barreto Mascarenhas, R.B., 2018. Valores de referência de qualidade para metais traços em Latossolos, Argissolos e Espodossolos do Baixo Sul da Bahia. Dissertação de Mestrado. Universidade Estadual de Feira de Santana, Programa de Pós-Graduação em Modelagem em Ciências da Terra e do Ambiente, Feira de Santana, Bahia.

Barreto Mascarenhas, R.B., de Jesus, T.B., Gloaguen, T.V., Costa, O.D.V., Wyzykowski, J., 2022. Quality reference values for trace metals in Podzols, Ferralsols, and Acrisols of Brazilian Atlantic rainforest. *Catena* 210, 105879. https://doi.org/10.1016/j.catena.2021.105879

Bento, S., Gramaglia, C., Erdlenbruch, K., Levasseur, P., Condesso de Melo, M.T., 2021. Contaminação de solos e água em Estarreja: que efeitos na vida dos habitantes? CAPTAR, 10, 16 p. https://doi.org/10.34624/captar.v10i0.23968.

Berrocal, R.A., Hypolito, R., Ezaki, S., 2013. Comportamento de íons de metais pesados (Pb e Ni) e de compostos nitrogenados em área industrial impactada no município de Cubatão - SP. Águas Subterrâneas 27(1). https://doi.org/10.14295/ras.v27i1.25566.

Bigarella, J.J., Andrade, G.O., 1964. Considerações sobre a estratigrafia dos sedimentos cenozóicos de Pernambuco (Grupo Barreiras). Instituto de Arqueologia 2, 2–14.

Bigarella, J.J., Andrade-Lima, D., Riehs, P.J., 1975. Considerações a respeito das mudanças paleoambientais na distribuição de algumas espécies vegetais e animais no Brasil. Anais da Academia Brasileira de Ciências (Suplemento) 47, 411–464.

Boudot, J.P., Bel Hadj Brahim, A., Steiman, R., Seigle-Murandi, F., 1989. Biodegradation of synthetic organo-metallic complexes of iron and aluminum with selected metal to carbon ratios. Soil Biology and Biochemistry, 21, 961–966.

Brasil, Ministério de Minas e Energia, Secretaria Geral, 1981. Projeto RADAMBRASIL: Folha SD. 24 Salvador; geologia, geomorfologia, pedologia, vegetação e uso potencial da terra. Levantamento de Recursos Naturais, vol. 24. Rio de Janeiro. 624 p.

Brasil, Ministério do Meio Ambiente, 2009. Resolução CONAMA Nº 420, de 28 de dezembro de 2009. Dispõe sobre critérios e valores orientadores de qualidade do solo quanto à presença de substâncias químicas e estabelece diretrizes para o gerenciamento ambiental de áreas contaminadas por essas substâncias em decorrência de atividades antrópicas.

Cardoso, K.M., Boechat, C.L., Nascimento, C.W.A., Escobar, M.E.O., Silva, D.G., Lins, S.A.S., Oliveira, R.L., Morais, P.G.C., 2023. Watershed-scale assessment of environmental background values of soil potential toxic elements from the Caatinga and Atlantic Forest ecotone in Brazil. Chemosphere 338. https://doi.org/10.1016/j.chemosphere.2023.139394.

Carvalho, S.R., Vilas Bôas, G.S., Fadigas, F.S., 2013. Concentrações naturais de metais pesados em solos derivados de sedimentos do Grupo Barreiras. Cadernos de Geociências 10(2), 97–107. https://periodicos.ufba.br/index.php/cadgeoc/article/view/7066.

COFIC Polo, 2021. Informações sobre o Complexo Industrial de Camaçari. Disponível em: https://www.coficpolo.com.br/pagina.php?p=39.

Corrêa, M.M., Ker, J.C., Barrón, V., Torrent, J., Curi, N., Torres, T.C.P., 2008. Caracterização física, química, mineralógica e micromorfológica de horizontes coesos e fragipãs de solos vermelhos e amarelos do ambiente de tabuleiros costeiros. Revista Brasileira de Ciência do Solo 32(1), 297–313. https://doi.org/10.1590/S0100-06832008000100028.

Da Silva, B.O., Caixeta, J.M., Milhomem, P.S., Kosin, M.D., 2007. Bacia do Recôncavo. Boletim de Geociências da Petrobras. 15(2), 423–431.

Dos Santos, L.M.R., 2016. Teores naturais de metais e valores de referência de qualidade para solos do Greenstone Belt Rio Itapicuru. Dissertação de Mestrado. Universidade Federal do Recôncavo da Bahia, Programa de Pós-Graduação em Solos e Qualidade de Ecossistemas, Cruz das Almas, Bahia

Dos Santos, L.M.R., Gloaguen, T.V., Fadigas, F.S., Chaves, J.M., Martins, T.M.O., 2017. Acumulação de metais em solos derivados de rochas vulcano-sedimentares, Cinturão Greenstone do Rio Itapicuru, nordeste do Brasil. Science of the Total Environment 601–602, 1762–1774. http://dx.doi.org/10.1016/j.scitotenv.2017.06.035.

Dixon, W.J., 1953. Processing data for outliers. Biometrics. 9, 74–89. https://doi.org/10.2307/3001634

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária., 2018. Sistema Brasileiro de Classificação de Solos, quinta edição revisada e ampliada. EMBRAPA, Brasília, DF, 356 p. ISBN 978-85-7035-800-4.

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. Revista Brasileira de Engenharia Agrícola e Ambiental. 10(3), 699–705. https://doi.org/10.1590/S1415-43662006000300024.

Fadigas, F.S., Amaral Sobrinho, N.M.B., Anjos, L.H.C., Mazur, N., 2010. Background levels of some trace elements in weathered soils from the Brazilian Northern region. Scientia Agricola 67, 53–59.

Fernandes, L.O., Nunes, J.A., Porto, M.F.S., 2016. Contaminação química: respostas das instituições responsáveis e ações das populações atingidas no Brasil e em Portugal. Saúde e Sociedade, 25(1), 218–232. https://doi.org/10.1590/S0104-12902016145753.

Freire, L.V., Santos Júnior, O.F., Ingunza, M.D.P.D., Chaves, L.F.M., Freitas Neto, O.D., 2022. Caracterização química, mineralógica e geotécnica de sedimentos das formações Barreiras e Pós-Barreiras - Litoral Sul do Rio Grande do Norte, Brasil. Revista de Geociências do Nordeste. 8(2), 76–90.

Garcia, M.F.S., 2015. Mineralogia de solos e sedimentos do Grupo Barreiras no Litoral Norte da Bahia. Dissertação (mestrado). Universidade Federal da Bahia, Instituto de Geociências, Salvador, 85 p.

Gloaguen, T.V., Passe, J.J., 2017. Importance of lithology in defining natural background concentrations of Cr, Cu, Ni, Pb and Zn in sedimentary soils, northeastern Brazil. Chemosphere 186, 31–42. https://doi.org/10.1016/j.chemosphere.2017.07.134.

Hawkins, D.M., Wixley, R.A.J., 1986. A note on the transformation of chi-squared variables to normality. The American Statistician 40, 296–298.

Hoaglin, D.C., Mosteller, F., Tukey, J.W., 1983. Understanding Robust and Exploratory Data Analysis. John Wiley, New York.

IBGE - Instituto Brasileiro de Geografia e Estatística, 2011. Mapa de Solos do Brasil. Escala 1:5.000.000. Base cartográfica elaborada pelo Departamento de Cartografia; mapa temático elaborado pelo Departamento de Recursos Naturais e Estudos Ambientais e pelas Divisões de Geociências (Sul, 1º Nordeste, Norte e Centro-Oeste). Em colaboração com a EMBRAPA - Centro Nacional de Pesquisa de Solos. IBGE, Rio de Janeiro.

Interstate Technology & Regulatory Council (ITRC), 2022. Soil Background and Risk Assessment. Soil Background and Risk Team. Interstate Technology & Regulatory Council, Washington, DC. https://sbr-1.itrcweb.org/.

ISO - International Organization for Standardization. ISO/IEC 17025:2017 – General requirements for the competence of testing and calibration laboratories. Geneva: ISO, 2017.

Jacomine, P.K.T., 1974. Fragipãs em solos de "tabuleiros": características, gênese e implicações no uso agrícola. Tese de Livre-Docência, Universidade Federal Rural de Pernambuco, Recife, 83 pp.

Johnson, R.A., Wichern, D., 2002. Applied Multivariate Statistical Analysis, 6th ed. Prentice Hall.

Kabata-Pendias, A., 2010. Trace Elements in Soils and Plants, fourth ed. CRC Press, Boca Raton, FL, 548 p. eBook ISBN 9780429192036. https://doi.org/10.1201/b10158.

Kaplan, E.L., Meier, P., 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53, 457–481.

Lima, O.A.L., 1999. Caracterização hidráulica e padrões de poluição no Aqüífero Recôncavo na região de Camaçari - Dias D'Ávila. Tese (Concurso para Professor Titular). Departamento de Geologia e Geofísica Aplicada, Universidade Federal da Bahia. Salvador, Brasil.

Lima, C.U., Vilas Boas, G.S., 2000. A arquitetura deposicional da Formação Marizal (Cretáceo Inferior) na Bacia do Recôncavo, Bahia. Revista Brasileira de Geociências. 30(4), 729–736.

Melo, F.R.R., Santos, M.C., 1996. Micromorfologia e mineralogia de dois solos de tabuleiro costeiro de Pernambuco. Revista Brasileira de Ciência do Solo 20, 99–108.

Morais, A.D., Santos Júnior, O.F., Freitas Neto, O., 2020. Propriedades geotécnicas de sedimentos da Formação Barreiras nas falésias de Barra de Tabatinga, Litoral Oriental do Rio Grande do Norte/Brasil. Holos 7, 1–20. https://doi.org/10.15628/holos.2020.9560.

Moura-Fé, M.M., 2014. Barreiras: grau, grupo ou formação? Revista Brasileira de Geografia Física 7, 1055–1061. https://www.ufpe.br/rbgfe.

Nascimento, C.A.S., Ramos, D.A.L., Paula, T.A.S., Villela, L.E., 2020. Contaminação, assoreamento, gentrificação e “chuva de prata”: impactos socioambientais do complexo industrial de Santa Cruz-RJ. Espaço e Economia, 19. https://doi.org/10.4000/espacoeconomia.16878.

Nunes, F.C., Silva, E.F., 2011. Grupo Barreiras: características, gênese e evidências de neotectonismo. Dados Eletrônicos. EMBRAPA Solos, Rio de Janeiro. 31 p. (Boletim de Pesquisa e Desenvolvimento / EMBRAPA Solos, ISSN 1678-0892; 194).

Oliveira, A.P. de, 2007. Pedogênese de Espodossolos em Ambientes da Formação Barreiras e de Restinga no Sul da Bahia. Dissertação (Mestrado), Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brasil.

Oliveira, A.P., Ker, J.C., Silva, I.R., Fontes, M.P.F., Oliveira, A.P., Neves, A.T.G., 2010. Pedogênese de Espodossolos em Ambientes da Formação Barreiras e de Restinga no Sul da Bahia. Revista Brasileira de Ciência do Solo 34, 847–860. https://doi.org/10.1590/S0100-06832010000300026.

Oliveira, A.S., Fadigas, F.S., Gloaguen, T.V., Nóbrega, J.C.A., 2020. Metais pesados em solos da Bahia: teores naturais no distrito de Santiago do Iguape, Cachoeira-BA. https://doi.org/10.46420/9786599120848.

Passe, J.J., 2015. Teores naturais de metais nos solos das bacias sedimentares do Recôncavo e do Tucano Sul, como subsídio ao estabelecimento de valores de referência de qualidade. Dissertação de Mestrado. Universidade Federal do Recôncavo da Bahia, Programa de Pós-Graduação em Solos e Qualidade de Ecossistemas, Cruz das Almas, Bahia. https://doi.org/10.13140/RG.2.2.12661.47847.

Rodrigues, A.S.L., Nalini Júnior, H.A., 2009. Valores de referência para concentração de fundo geoquímico e suas implicações em estudos ambientais. Revista Escola de Minas 62, 249–255. https://doi.org/10.1590/S0370-44672009000200006.

Rosner, B., 1975. On the detection of many outliers. Technometrics. 17, 221–227.

Rosner, B., 1983. Percentage points for a generalized ESD many-outlier procedure. Technometrics. 25, 165–172.

Rousseeuw, P.J., Leroy, A.M., 1987. Robust Regression and Outlier Detection. John Wiley & Sons, New York, ISBN:978047172538. https://doi.org/10.1002/0471725382.

Silva, F.B.R., Leprun, J.C., Boulet, R., 1997. Duripãs in soils of the coastal tablelands of Northeast Brazil: mineralogy, micromorphology, and genesis, in: Brazilian Congress of Soil Science, 26. Brazilian Society of Soil Science, Rio de Janeiro.

Simão, G., Pereira, J.L., Alexandre, N.Z., Galatto, S.L., Viero, A.P., 2019. Estabelecimento de valores de referência de fundo geoquímico de parâmetros relacionados à contaminação por carvão. Revista Águas Subterrâneas 33(2), 29207. https://doi.org/10.14295/ras.v33i2.29207.

Singh, A., Nocerino, J.M., 1995. Robust procedures for the identification of multiple outliers. Handbook of Environmental Chemistry, Statistical Methods. 2(G), 229–277. Springer Verlag, Germany.

Smith, D.B., Cannon, W.F., Woodruff, L.G., Solano, F., Kilburn, J.E., Fey, D.L., 2013. Geochemical and mineralogical data for soils of the conterminous United States. U.S. Geological Survey Data Series 801, 19 p. https://pubs.usgs.gov/ds/801/.

Souza, J., 2016. Reparação de Danos Causados por Contaminação de Organoclorados: O Caso Rhodia Cubatão-SP. Conpedi Law Review 2, 104. https://doi.org/10.26668/2448-3931_conpedilawreview/2016.v2i4.3656.

Souza, C.M.P., Costa, L.M., Firmino, F.H.T., Lima, C.C.U., Moreau, A.M.S.S., Leite, M.E., 2020. Associação de Estratos da Formação Pós-Barreiras e Formação Barreiras e Influência na Gênese dos Solos, Sul da Bahia – Brasil. Revista Brasileira de Ciência do Solo 44, e0200015. https://doi.org/10.36783/18069657rbcs20200015.

Stein, P., Cabral, N.M.T., Filho, J.M., Lucena, L.R.F., 2019. Efeito da descontinuidade estrutural na hidrogeoquímica do Aquífero Barreiras no nordeste do Brasil. Revista Águas Subterrâneas 33(1), 45–57. https://doi.org/10.14295/ras.v33i1.29591.

Stensvold, K.A., 2012. Distribution and variation of arsenic in Wisconsin surface soils, with data on other trace elements. U.S. Geological Survey Scientific Investigations Report 2011–5202, 41 p.

Suguio, K., Nogueira, A.C.R., 1999. Revisão crítica do conhecimento geológico sobre a Formação (ou Grupo?) Barreiras Neogênica e seu possível significado como testemunho de alguns eventos geológicos mundiais. Geociências 18, 461–479. https://repositorio.usp.br/directbitstream/57d2a582-7ae1-4642-a928-269ce9c6c19a/1189413.pdf

Tan, K.H., 1986. Degradation of soil minerals by organic acids, in: Huang, P.M., Schnitzer, M. (eds.), Interactions of Soil Minerals with Natural Organics and Microbes. Soil Science Society of America, Madison, pp. 606.

U.S. Environmental Protection Agency (USEPA), 1995. Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites. EPA/540/S-96/500. Office of Research and Development, Office of Solid Waste and Emergency Response, Washington, DC.

U.S. Environmental Protection Agency (USEPA), 2002. Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C. (EPA 540-R-01-003; OSWER 9285.7-41). https://www.epa.gov/sites/production/files/2015-11/documents/background.pdf.

U.S. Environmental Protection Agency (USEPA), 2020. ProUCL Version 5.2.0 Technical Guide: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. Office of Research and Development (ORD), Center for Environmental Solutions and Emergency Response (CESER), Technical Support Coordination Division (TSCD), Site Characterization and Monitoring Technical Support Center (SCMTSC). Prepared by Neptune and Company, Inc., Lakewood, CO. https://www.epa.gov/land-research/proucl-software.

U.S. Environmental Protection Agency (USEPA), 2022. ProUCL: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. Version 5.2. https://www.epa.gov/land-research/proucl-software.

Viana, C.F., Gama Júnior, E.G., Simões, I.A., Moura, J.A., Fonseca, J.R., Alves, R.J., 1971. Revisão estratigráfica da Bacia do Recôncavo/Tucano. Boletim Técnico da Petrobras, 14(3-4), 157-192.

Vilas Bôas, G.S., Sampaio, F.J., Pereira, A.M.S., 2001. O Grupo Barreiras no litoral nordeste do Estado da Bahia, Brasil: mecanismos e processos deposicionais. Anais da Academia Brasileira de Ciências, 73, 417–427. https://doi.org/10.1590/S0001-37652001000300010.

West, D.C., Mello, C.L., 2020. Distribuição da Formação Barreiras na região sul do Espírito Santo e sua relação com a deformação neotectônica. Revista Brasileira de Geociências 21, 1–15. https://doi.org/10.20502/rbg.v21i1.1667.

CAPÍTULO 3

CONCLUSÕES

Este trabalho de mestrado propôs valores de *background* para compostos inorgânicos em solos e sedimentos da zona não saturada do Polo Industrial de Camaçari (PIC), preenchendo uma lacuna científica e regulatória crucial para a gestão ambiental no estado da Bahia. Em um cenário onde a ausência de Valores de Referência de Qualidade (VRQs) regionais, conforme a Resolução CONAMA 420/2009, limita o avanço de políticas ambientais, este estudo emerge como uma contribuição técnica valiosa, capaz de orientar a avaliação de impactos ambientais e o gerenciamento de áreas potencialmente contaminadas no maior complexo industrial integrado do hemisfério Sul.

A definição dos valores de *background* foi conduzida com base em diretrizes metodológicas alinhadas às recomendações de EPA e do ITRC, organizações amplamente reconhecidas por sua expertise no campo da gestão ambiental. O estudo incorporou as especificidades geológicas e geoquímicas da região, garantindo que os valores estabelecidos reflitam com precisão as condições naturais locais. Esses valores configuram um ponto de referência confiável para a avaliação da qualidade ambiental, com aplicações diretas no monitoramento de alterações químicas em solos e sedimentos, na identificação de impactos associados às atividades industriais e no suporte a estudos de diagnóstico ambiental, avaliações de risco e planos de intervenção em áreas contaminadas.

Os resultados obtidos possuem grande potencial para subsidiar o órgão ambiental do estado da Bahia em processos de fiscalização, licenciamento e formulação de políticas públicas, fortalecendo a capacidade regulatória para enfrentar desafios ambientais e industriais da região. A abordagem metodológica aqui desenvolvida não apenas fortalece a gestão regional, mas também se apresenta como um modelo replicável, capaz de impulsionar avanços científicos e melhorias na gestão ambiental em outros contextos industriais ao redor do mundo.

Integrar os valores de *background* propostos em estratégias de gestão ambiental é abrir caminho para instrumentos mais eficazes na conservação dos recursos naturais e no manejo sustentável dos ecossistemas terrestres. Ao se alinhar aos Objetivos de Desenvolvimento Sustentável (ODS), especialmente ao ODS 15 – Vida Terrestre, este estudo contribui para a proteção do solo como recurso essencial e promove práticas industriais mais responsáveis, reforçando a conexão entre ciência, sustentabilidade e a preservação da vida no planeta.

APÊNDICE A – TABELAS DE DADOS

Table A.1 - Lithological Information of Reference Areas and Collected Samples

Reference Area	**UTM Coordinates Zone 24S (DATUM SIRGAS, 2000)**		**Drilling depth (m)**	**Terrain elevation (m)**	**Water level (m)**	**Lithological layer**	**Layer depth (m)**	**Granulometry**	**Angularity**	**Selection Degree**	**Color (Munsell scale)**	**Layer saturation**	**Observation**	**Geologycal Unit**	**Samples Collected for Granulometric**	**Samples Collected for Chemical Analysis**
	Latitude	**Longitude**														
A-01	580614,2405	8599059,0682	4,8	33,106	1	Layer 1	0 - 0,5	Fine to medium sand	Subangular	Poorly sorted	5YR_6-1 Grey	wet	No observations	Marizal formation	ST-167/196-SO2022T31001	ST-167/196-SO2022T31004
						Layer 2	0,5 - 2,8	Fine to medium clayey sand	Subangular	Poorly sorted	5YR_7-2 pinkish-grey	wet	No observations	Marizal formation	ST-167/196-SO2022T31002	ST-167/196-SO2022T31005
						Layer 3	2,8 - 4,8	Fine silty sand	Subrounded	Well sorted	5YR_8-1 White	saturated	No observations	Marizal formation	-	-
A-02	582490,3076	8601107,2397	7,3	40,895	6,37	Layer 1	0 - 4	Fine clayey sand	Subrounded	Poorly sorted	10YR_6-8 yellowish brown	wet	Laterite (iron oxide) lenses between 1.6 and 2.0m	Marizal formation	ST-167/197-SO2022T31009	ST-167/197-SO2022T31013
						Layer 2	4 - 4,3	Medium clayey-silty sand	Subrounded	Poorly sorted	7.5YR_7-2 pinkish-grey	dry	No observations	Marizal formation	ST-167/197-SO2022T31010	ST-167/197-SO2022T31014
						Layer 3	4,3 - 5	Medium clayey-silty sand	Subangular	Poorly sorted	7.5YR_6-8 reddish-yellow	wet	Presence of quartz pebbles and iron oxides (laterite)	Marizal formation	ST-167/197-SO2022T31011	ST-167/197-SO2022T31015
						Layer 4	5 - 6,4	Medium to coarse clayey-silty sand	Subangular	Poorly sorted	10YR_8-1 White	wet	Presence of quartz pebbles and ferruginous concretions (laterite)	Marizal formation	ST-167/197-SO2022T31008	ST-167/197-SO2022T31016
						Layer 5	6,4 - 7,3	fine sand	Subrounded	Poorly sorted	10YR_8-1 White	saturated	With silt and clay content (kaolinite)	Marizal formation	-	-
A-03	577402,5282	8602409,5454	3,3	24,195	0,85	Layer 1	0 - 0,8	Medium sand	Subangular	Well sorted	7.5YR_6-3 light brown	wet	With organic matter and roots	Marizal formation	ST-167/198-SO2022T31017	ST-167/198-SO2022T31020
						Layer 2	0,8 - 2	Medium to coarse sand	Subangular	Poorly sorted	7.5YR_4-6 strong brown	saturated	With laterite pebbles (iron oxide)	Marizal formation	-	-
						Layer 3	2 - 3,3	Fine to medium silty sand	Subrounded	Moderately to well sorted	7.5YR_4-6 strong brown	saturated	No observations	Marizal formation	-	-
A-04	587353,1226	8597463,8124	4,8	10,746	2	Layer 1	0 - 0,7	Fine to medium sand	Subangular	Well sorted	5YR_3-1 Very Dark Grey	wet	With organic matter and roots	Alluvial deposits	ST-167/199-SO2022T31026	ST-167/199-SO2022T31030
						Layer 2	0,7 - 1,2	Medium sand	Subangular	Well sorted	5YR_3-4 light reddish brown	wet	With organic matter and roots	Alluvial deposits	ST-167/199-SO2022T31027	ST-167/199-SO2022T31031
						Layer 3	1,2 - 2,3	Medium clayey sand	Subangular	Poorly sorted	5YR_5-2 reddish-grey	wet	No observations	Alluvial deposits	ST-167/199-SO2022T31028	ST-167/199-SO2022T31032
						Layer 4	2,3 - 3,8	Fine silty sand	Subrounded	Well sorted	5YR_5-2 reddish-grey	saturated	No observations	Alluvial deposits	-	-
						Layer 5	3,8 - 4,8	Fine silty-clayey sand	Rounded	Poorly sorted	5YR_7-1 light grey	saturated	No observations	Alluvial deposits	-	-
A-05	588680,1457	8601365,6824	8,9	29,05	8,5	Layer	0 - 2,5	Fine to medium sand	Subrounded	Moderately to well sorted	7.5YR_5-6 strong brown	wet	With organic matter and roots	Marizal formation	ST-167/200-SO2022T31037	ST-167/200-SO2022T31040
						Layer	2,5 - 4,2	Fine to medium sand	Subrounded	Moderately to well sorted	7.5YR_5-6 strong brown	wet	No observations	Marizal formation	ST-167/200-SO2022T31038	ST-167/200-SO2022T31041
						Layer	4,2 - 6,5	Medium to coarse sand	Subangular	Moderately to well sorted	10YR_8-6 yellow	dry	With quartz pebbles	Marizal formation	ST-167/200-SO2022T31039	ST-167/200-SO2022T31042
						Layer	6,5 - 8,5	Medium to coarse sand	Subrounded	Moderately to well sorted	10YR_7-4 very light grayish brown	wet	No observations	Marizal formation	ST-167/200-SO2022T31150	ST-167/200-SO2022T31044
						Layer	8,5 - 8,9	Fine to medium clayey sand	Subrounded	Poorly sorted	10YR_6-2 light	saturated	No observations	Marizal formation	-	-

Reference Area	UTM Coordinates Zone 24S (DATUM SIRGAS, 2000)		Drilling depth (m)	Terrain elevation (m)	Water level (m)	Lithological layer	Layer depth (m)	Granulometry	Angularity	Selection Degree	Color (Munsell scale)	Layer saturation	Observation	Geologycal Unit	Samples Collected for Granulometric	Samples Collected for Chemical Analysis
	Latitude	Longitude														
											brownish gray					
A-06	594592,5777	8601253,0570	15	47,852	Não atingiu	Layer 1	0 - 0,7	Fine clayey-silty sand	Subrounded	Poorly sorted	7.5YR_5-8 strong brown	wet	With organic matter	Barreiras formation	ST-167/201-SO2022T31046	ST-167/201-SO2022T31055
						Layer 2	0,7 - 1,4	Fine clayey-silty sand	Subangular	Poorly sorted	2.5YR_3-4 dark reddish brown	wet	With organic matter and roots. Presence of laterite pebbles (iron oxide)	Barreiras formation	-	ST-167/201-SO2022T31056
						Layer 3	1,4 - 2,2	Medium to coarse laterite	Subangular	Poorly sorted	2.5YR_3-6 dark red	dry	No observations	Barreiras formation	ST-167/201-SO2022T31047	ST-167/201-SO2022T31057
						Layer 4	2,2 - 6,8	Fine sand	Subrounded	Well sorted	2.5Y_7-8 yellow	dry	No observations	Barreiras formation	ST-167/201-SO2022T31051	ST-167/201-SO2022T31062
						Layer 5	6,8 - 8,8	Fine sand	Subrounded	Well sorted	7.5R_3-8 dark red	dry	No observations	Barreiras formation	-	ST-167/201-SO2022T31063
						Layer 6	8,8 - 9,6	Medium to coarse sand	Subrounded	Moderately to well sorted	7.5R_3-6 dark red	dry	No observations	Barreiras formation	ST-167/201-SO2022T31052	ST-167/201-SO2022T31064
						Layer 7	9,6 - 10	Fine to medium clayey sand	Subangular	Poorly sorted	2.5YR_7-6 light red	dry	No observations	Barreiras formation	ST-167/201-SO2022T31053	ST-167/201-SO2022T31066
						Layer 8	10 - 10,9	Medium to coarse sand	Subangular	Poorly sorted	7.5R_3-6 dark red	dry	With laterite pebbles (iron oxide)	Barreiras formation	ST-167/201-SO2022T31054	ST-167/201-SO2022T31065
						Layer 9	10,9 - 12,2	Medium to coarse sand	Subrounded	Poorly sorted	10R_4-8 red	dry	Variegated colors of yellow and red (predominance)	Barreiras formation	ST-167/201-SO2022T31048	ST-167/201-SO2022T31058
						Layer 10	12,2 - 13,2	Fine to medium clayey sand	Subangular	Poorly sorted	10R_5-3 grayish red	dry	With lenses of lilac silty sand	Barreiras formation	-	ST-167/201-SO2022T31059
						Layer 11	13,2 - 14,3	Very fine silty-clayey sand	Subrounded	Poorly sorted	2.5Y_8-8 yellow	dry	Presence of yellow silt lenses	Barreiras formation	ST-167/201-SO2022T31049	ST-167/201-SO2022T31060
						Layer 12	14,3 - 15	Very fine clayey-silty sand	Subangular	Poorly sorted	10YR_6-6 yellowish brown	dry	No observations	Barreiras formation	ST-167/201-SO2022T31050	ST-167/201-SO2022T31061
A-07	585527,3311	8600330,4507	5,5	26,205	3,7	Layer 1	0 - 3	Fine to medium clayey sand	Subangular	Poorly sorted	7.5YR_6-8 reddish yellow	wet	With organic matter	Marizal formation	ST-167/202-SO2022T31067	ST-167/202-SO2022T31070
						Layer 2	3 - 4,2	Fine to medium sand	Subrounded	Poorly sorted	10YR_6-6 yellowish brown	wet	With laterite pebbles (iron oxide)	Marizal formation	ST-167/202-SO2022T31068	ST-167/202-SO2022T31071
						Layer 3	4,2 - 5,5	Medium silty sand	Subrounded	Well sorted	2.5Y_8-4 very light grayish brown	saturated	CWith rounded quartz pebbles	Marizal formation	-	-
A-08	582628,4728	8605921,7174	12,4	58,102	6,8	Layer 1	0 - 0,8	Fine clayey-silty sand	Subangular	Poorly sorted	7.5YR_7-4 pinkish	wet	With organic matter and roots. Iron oxide (laterite) in coarse sand fraction and pebbles	São Sebastião formation	ST-167/203-SO2022T31075	ST-167/203-SO2022T31080
						Layer 2	0,8 - 2,7	Fine sandy clay	Subangular	Poorly sorted	5YR_5-8 yellowish red	wet	With organic matter and roots. Iron oxide (laterite) in medium to coarse sand fraction	São Sebastião formation	ST-167/203-SO2022T31076	ST-167/203-SO2022T31081
						Layer 3	2,7 - 8,4	Very fine clayey silt	Not applicable	Moderately to well sorted	7.5YR_6-6 reddish yellow	dry	No observations	São Sebastião formation	ST-167/203-SO2022T31077	ST-167/203-SO2022T31082
						Layer 4	8,4 - 12,4	Very fine shale	Not applicable	Moderately to well sorted	7.5YR_5-1 grayish	dry	Confined layer	São Sebastião formation	ST-167/203-SO2022T31078	ST-167/203-SO2022T31083

Reference Area	UTM Coordinates Zone 24S (DATUM SIRGAS, 2000)		Drilling depth (m)	Terrain elevation (m)	Water level (m)	Lithological layer	Layer depth (m)	Granulometry	Angularity	Selection Degree	Color (Munsell scale)	Layer saturation	Observation	Geologycal Unit	Samples Collected for Granulometric	Samples Collected for Chemical Analysis
	Latitude	Longitude														
A-09	584599,1925	8592690,5820	9,5	34,762	Não atingiu	Layer 1	0 - 0,6	Fine to medium silty sand	Subrounded	Poorly sorted	10YR_5-4 yellowish brown	wet	With organic matter and roots	Barreiras formation	ST-167/208-SO2022T32159	ST-167/208-SO2022T32149
						Layer 2	0,6 - 1,9	Fine sandy-silty clay	Subrounded	Poorly sorted	.5YR_4-3 dark reddish gray	wet	Variegated colors in red and beige. Iron oxide (laterite) in medium sand fraction	Barreiras formation	ST-167/208-SO2022T32160	ST-167/208-SO2022T32150
						Layer 3	1,9 - 3,2	Fine to medium clayey-silty sand	Subrounded	Poorly sorted	7.5YR_6-6 reddish yellow	wet	No observations	Barreiras formation	ST-167/208-SO2022T32161	ST-167/208-SO2022T32151
						Layer 4	3,2 - 4,1	Medium to coarse clayey sand	Subrounded	Poorly sorted	7.5YR_6-6 reddish yellow	dry	No observations	Barreiras formation	ST-167/208-SO2022T32162	ST-167/208-SO2022T32152
						Layer 5	4,1 - 6,5	Medium to coarse sand	Rounded	Poorly sorted	7.5YR_6-8 reddish yellow	dry	With silt and quartz pebbles	Barreiras formation	ST-167/208-SO2022T32164	ST-167/208-SO2022T32153
						Layer 6	6,5 - 9	Fine clayey sand	Subangular	Poorly sorted	10R_7-2 light grayish red	dry	Medium sand lenses throughout the layer, about 5 cm thick	Barreiras formation	ST-167/208-SO2022T32163	ST-167/208-SO2022T32154
						Layer 7	9 - 9,3	Fine to medium clayey-silty sand	Subrounded	Poorly sorted	5YR_7-8 reddish yellow	dry	With quartz pebbles and iron oxide (laterite) in coarse sand and pebbles fraction	Barreiras formation	ST-167/208-SO2022T32165	ST-167/208-SO2022T32155
						Layer 8	9,3 - 9,5	laterite	Not applicable	Not applicable	Not applicable	dry	Impenetrable (samples could not be collected)	Barreiras formation	-	-
A-10	569040,0054	8607259,2913	9,5	56,69	8,2	Layer 1	0 - 0,5	Fine to medium silty sand	Subangular	Poorly sorted	5YR_4-6 yellowish red	wet	With organic matter and roots	Marizal formation	ST-167/205-SO2022T31108	ST-167/205-SO2022T31114
						Layer 2	0,5 - 0,7	Medium to coarse laterite	Angular	Poorly sorted	5YR_4-6 yellowish red	dry	Laterite (iron oxide) in a fine sand matrix (top of the layer) and sandy clay (base of the layer)	Marizal formation	ST-167/205-SO2022T31109	ST-167/205-SO2022T31115
						Layer 3	0,7 - 2,2	Fine to medium clayey sand	Subrounded	Poorly sorted	7.5YR_4-6 strong brown	dry	No observations	Marizal formation	ST-167/205-SO2022T31110	ST-167/205-SO2022T31116
						Layer 4	2,2 - 4,6	Fine to medium clayey sand	Subangular	Poorly sorted	7.5YR_7-4 pinkish	dry	No observations	Marizal formation	ST-167/205-SO2022T31111	ST-167/205-SO2022T31117
						Layer 5	4,6 - 6,8	Medium sand	Subangular	Well sorted	7.5YR_7-1 light grayish	dry	No observations	Marizal formation	ST-167/205-SO2022T31112	ST-167/205-SO2022T31118 ST-167/205-SO2022T31119
						Layer 6	6,8 - 8,5	Medium to coarse sand	Subrounded	Poorly sorted	7.5YR_7-6 reddish yellow	wet	No observations	Marizal formation	ST-167/205-SO2022T31113	ST-167/205-SO2022T31120 ST-167/205-SO2022T31121
						Layer 7	8,5 - 9	Medium to Coarse silty sand	Subangular	Poorly sorted	10R_7-6 light red	saturated	No observations	Marizal formation	-	-
						Layer 8	9 - 9,5	Fine silty sand	Subrounded	Well sorted	10R_8-1 white	saturated	No observations	Marizal formation	-	-
A-11	566046,3580	8602308,7076	11	39,302	8,5	Layer 1	0 - 0,6	Fine to medium sand	Subangular	Well sorted	10R_7-1 light grayish	wet	No observations	Barreiras formation	ST-167/206-SO2022T31124	ST-167/206-SO2022T31130
						Layer 2	0,6 - 5	Medium to coarse clayey-silty sand	Subangular	Poorly sorted	7.5YR_6-6 reddish yellow	wet	With organic matter. Quartz pebbles starting at 1.8m, transition to laterite (iron oxide) between 3.8 and 4m	Barreiras formation	ST-167/206-SO2022T31125	ST-167/206-SO2022T31131

Reference Area	**UTM Coordinates Zone 24S (DATUM SIRGAS, 2000)**		**Drilling depth (m)**	**Terrain elevation (m)**	**Water level (m)**	**Lithological layer**	**Layer depth (m)**	**Granulometry**	**Angularity**	**Selection Degree**	**Color (Munsell scale)**	**Layer saturation**	**Observation**	**Geologycal Unit**	**Samples Collected for Granulometric**	**Samples Collected for Chemical Analysis**
	Latitude	**Longitude**														
						Layer 3	5 - 5,9	Medium clayey-silty sand	Subrounded	Poorly sorted	2.5YR_5-6 red	dry	Laterite pebbles (iron oxide). White lenses of clay	Barreiras formation	ST-167/206-SO2022T31126	ST-167/206-SO2022T31132
						Layer 4	5,9 - 7,1	Medium clayey-silty sand	Subangular	Poorly sorted	7.5YR_5-6 strong brown	dry	With intercalations of clay lenses (mostly red, but variegated) and quartz pebbles	Barreiras formation	ST-167/206-SO2022T31127	ST-167/206-SO2022T31133
						Layer 5	7,1 - 11	Medium to coarse clayey sand	Subangular	Poorly sorted	10YR_8-6 yellow	dry	With quartz pebbles	Barreiras formation	ST-167/206-SO2022T31128	ST-167/206-SO2022T31134
A-12	568972,9570	8597157,7596	9,3	44,449	Não atingiu	Layer 1	0 - 1,4	Fine to medium clayey sand	Subangular	Poorly sorted	7.5YR_6-4 light brown	wet	No observations	São Sebastião formation	ST-167/207-SO2022T31141	ST-167/207-SO2022T31144
						Layer 2	1,4 - 5,6	Fine to medium clayey sand	Subangular	Poorly sorted	7.5YR_4-6 strong brown	wet	No observations	São Sebastião formation	ST-167/207-SO2022T31142	ST-167/207-SO2022T31145
						Layer 3	5,6 - 8,3	Fine to medium clayey sand	Subangular	Poorly sorted	5YR_4-6 yellowish red	dry	No observations	São Sebastião formation	-	ST-167/207-SO2022T31146
						Layer 4	8,3 - 9,3	Medium sand	Subangular	Well sorted	2.5YR_5-8 red	wet	No observations	São Sebastião formation	ST-167/207-SO2022T31143	ST-167/207-SO2022T31147

Table A.2 – Results of the granulometric analysis of soil and sediment samples

Samples by Reference Area	**Sample Depth (m)**	**Granulometric Analysis**							**Granulometric Description**	**Sorting**
		Clay (0,0002 a 0,00394 mm)	**Silt (0,00394 a 0,062 mm)**	**Very fine sand (0,062 a 0,125 mm)**	**Fine sand (0,125 a 0,25 mm)**	**Medium sand (0,25 a 0,5 mm)**	**Coarse sand (0,5 a 1 mm)**	**Very Coarse sand (1 a 2 mm)**		
A-01										
ST-167/196-SO2022T31001	0,40	7,4%	8,1%	18,0%	34,3%	25,6%	5,6%	1,0%	Fine to medium sand	Poorly sorted
ST-167/196-SO2022T31002	1,00	10,2%	3,3%	7,3%	22,4%	48,0%	7,5%	1,2%	Fine to medium clayey sand	Poorly sorted
A-02										
ST-167/197-SO2022T31009	1,8	13,8%	2,6%	17,2%	50,6%	6,8%	8,9%	0,1%	Fine clayey sand	Poorly sorted
ST-167/197-SO2022T31010	4,3	12,5%	3,6%	3,4%	12,7%	56,8%	11,0%	0,1%	Fine to medium clayey sand	Poorly sorted
ST-167/197-SO2022T31011	4,6	20,9%	17,3%	8,0%	12,9%	31,6%	6,9%	2,4%	Medium clayey-silty sand	Poorly sorted
ST-167/197-SO2022T31008	5,3	21,3%	14,1%	3,1%	8,9%	28,1%	23,0%	1,6%	Medium to coarse clayey-silty sand	Poorly sorted
A-03										
ST-167/198-SO2022T31017	0,4	1,5%	4,9%	6,7%	14,8%	62,6%	9,3%	0,2%	Medium sand	Well sorted
A-04										
ST-167/199-SO2022T31026	0,6	3,4%	8,4%	10,8%	28,0%	42,2%	7,0%	0,1%	Fine to medium sand	Well sorted
ST-167/199-SO2022T31027	1,1	3,2%	4,0%	7,9%	16,0%	58,0%	10,2%	0,6%	Medium sand	Well sorted
ST-167/199-SO2022T31028	1,8	11,4%	7,9%	11,8%	16,2%	42,1%	10,4%	0,1%	Medium clayey sand	Poorly sorted
A-05										
ST-167/200-SO2022T31037	0,9	3,8%	3,9%	4,7%	8,8%	51,1%	26,4%	1,3%	Medium to coarse sand	Moderately to well sorted
ST-167/200-SO2022T31038	3,4	18,5%	1,8%	7,3%	13,1%	43,1%	16,1%	0,1%	Medium to coarse clayey sand	Poorly sorted
ST-167/200-SO2022T31039	5,4	1,7%	0,8%	4,0%	8,7%	34,9%	47,0%	2,9%	Medium to coarse sand	Moderately sorted
ST-167/200-SO2022T31150	8,1	9,9%	1,9%	3,4%	8,3%	47,5%	28,4%	0,6%	Medium to coarse sand	Moderately to well sorted
ST-167/200-SO2022T31149	8,6	11,3%	2,0%	3,8%	9,1%	26,8%	46,5%	0,5%	Medium to coarse clayey sand	Poorly sorted
A-06										
ST-167/201-SO2022T31046	0,3	31,2%	12,6%	17,9%	15,7%	11,7%	8,7%	2,1%	Fine clayey-silty sand	Poorly sorted
ST-167/201-SO2022T31047	1,8	10,8%	4,8%	12,6%	11,8%	22,2%	15,0%	22,9%	Medium to coarse laterite	Poorly sorted
ST-167/201-SO2022T31051	4,0	7,0%	1,9%	23,5%	53,4%	11,6%	2,0%	0,4%	Fine sand	Well sorted
ST-167/201-SO2022T31052	9,1	4,3%	3,2%	2,7%	5,1%	45,5%	38,5%	0,7%	Medium to coarse sand	Moderately to well sorted
ST-167/201-SO2022T31053	10	15,8%	6,7%	6,8%	43,0%	25,4%	1,8%	0,5%	Fine to medium clayey sand	Poorly sorted
ST-167/201-SO2022T31054	10,7	6,9%	2,7%	3,8%	15,2%	49,8%	21,4%	0,1%	Medium to coarse sand	Poorly sorted
ST-167/201-SO2022T31048	12,4	12,7%	6,0%	19,9%	17,6%	32,9%	10,7%	0,1%	Fine to medium clayey sand	Poorly sorted
ST-167/201-SO2022T31049	13,5	10,0%	15,2%	59,1%	11,2%	3,4%	1,0%	0,1%	Very fine silty-clayey sand	Poorly sorted
ST-167/201-SO2022T31050	15	21,9%	14,1%	39,5%	2,5%	8,9%	12,5%	0,6%	Very fine clayey-silty sand	Poorly sorted
A-07										
ST-167/202-SO2022T31067	1,6	11,3%	3,8%	20,7%	19,5%	36,1%	8,3%	0,3%	Fine to medium clayey sand	Poorly sorted
ST-167/202-SO2022T31068	3,4	8,2%	8,4%	20,8%	18,5%	34,6%	9,4%	0,1%	Fine to medium sand	Poorly sorted
A-08										
ST-167/203-SO2022T31075	0,5	19,0%	13,7%	26,1%	27,3%	10,5%	3,2%	0,3%	Fine clayey-silty sand	Poorly sorted
ST-167/203-SO2022T31076	2,1	39,4%	8,3%	20,0%	16,4%	7,8%	5,3%	2,7%	Fine sandy clay	Poorly sorted
ST-167/203-SO2022T31077	5,5	17,8%	77,5%	1,8%	1,8%	0,9%	0,1%	0,1%	Clayey silt	Moderately to well sorted

Samples by Reference Area	Sample Depth (m)	Granulometric Analysis							Granulometric Description	Sorting
		Clay (0,0002 a 0,00394 mm)	Silt (0,00394 a 0,062 mm)	Very fine sand (0,062 a 0,125 mm)	Fine sand (0,125 a 0,25 mm)	Medium sand (0,25 a 0,5 mm)	Coarse sand (0,5 a 1 mm)	Very Coarse sand (1 a 2 mm)		
ST-167/203-SO2022T31078	9,7	49,0%	44,4%	1,7%	0,9%	0,9%	2,2%	1,0%	Shale	Moderately to well sorted
A-09-1	**1**									
ST-167/208-SO2022T32159	0,4	5,2%	24,4%	35,7%	12,1%	14,5%	7,0%	1,1%	Fine to medium silty sand	Poorly sorted
ST-167/208-SO2022T32160	1,0	43,4%	17,2%	22,0%	4,7%	7,0%	4,4%	1,4%	Fine sandy-silty clay	Poorly sorted
ST-167/208-SO2022T32161	2,5	21,5%	11,8%	27,8%	11,5%	15,7%	10,2%	1,6%	Fine to medium clayey-silty sand	Poorly sorted
ST-167/208-SO2022T32162	3,6	15,8%	2,7%	5,6%	12,1%	37,8%	24,1%	2,0%	Medium to coarse clayey sand	Poorly sorted
ST-167/208-SO2022T32164	4,6	8,6%	2,3%	3,0%	9,6%	45,3%	30,2%	1,0%	Medium to coarse sand	Poorly sorted
ST-167/208-SO2022T32163	6,9	15,7%	4,4%	12,8%	45,8%	13,9%	6,1%	1,2%	Fine clayey sand	Poorly sorted
ST-167/208-SO2022T32165	9,3	22,8%	13,7%	17,3%	10,0%	20,6%	11,2%	4,5%	Fine to medium clayey-silty sand	Poorly sorted
A-10										
ST-167/205-SO2022T31108	0,3	9,6%	12,7%	9,6%	24,4%	35,0%	7,8%	0,9%	Fine to medium silty sand	Poorly sorted
ST-167/205-SO2022T31109	0,7	13,4%	8,9%	2,5%	9,0%	31,2%	19,1%	15,9%	Medium to coarse laterite	Poorly sorted
ST-167/205-SO2022T31110	1,9	27,7%	4,7%	8,6%	22,5%	29,8%	6,5%	0,3%	Fine to medium clayey sand	Poorly sorted
ST-167/205-SO2022T31111	4,6	11,5%	8,2%	10,2%	17,2%	36,6%	15,5%	0,8%	Fine to medium clayey sand	Poorly sorted
ST-167/205-SO2022T31112	5,0	9,5%	6,7%	3,6%	14,3%	62,6%	3,1%	0,1%	Medium sand	Well sorted
ST-167/205-SO2022T31113	7,5	9,6%	8,3%	4,1%	5,8%	47,0%	24,7%	0,4%	Medium to coarse sand	Poorly sorted
A-11										
ST-167/206-SO2022T31124	0,5	8,0%	9,9%	8,0%	20,0%	46,1%	7,5%	0,6%	Fine to medium sand	Well sorted
ST-167/206-SO2022T31125	2,0	17,2%	13,4%	5,7%	12,1%	35,3%	14,8%	1,6%	Medium to coarse clayey-silty sand	Poorly sorted
ST-167/206-SO2022T31126	5,4	26,6%	24,1%	4,8%	7,6%	24,3%	5,5%	7,0%	Medium clayey-silty sand	Poorly sorted
ST-167/206-SO2022T31127	6,5	16,3%	12,3%	5,9%	10,1%	38,3%	9,7%	7,4%	Medium clayey-silty sand	Poorly sorted
ST-167/206-SO2022T31128	7,9	11,4%	8,7%	5,3%	11,0%	37,2%	11,7%	14,8%	Medium to coarse clayey sand	Poorly sorted
A-12										
ST-167/207-SO2022T31141	0,8	14,9%	4,8%	9,1%	21,3%	47,1%	2,6%	0,2%	Fine to medium clayey sand	Poorly sorted
ST-167/207-SO2022T31142	2,9	17,3%	3,2%	14,0%	28,8%	34,6%	2,1%	0,1%	Fine to medium clayey sand	Poorly sorted
ST-167/207-SO2022T31143	9,3	7,8%	2,0%	4,2%	13,0%	72,8%	0,1%	0,1%	Medium sand	Well sorted
Colors used for ranking:	lower percentages	🟩	🟨	🟧	higher percentages					

Table A.3 – Analytical results of soil and sediment samples for parameters with at least one detected value (part 1)

Reference Area	Sample ID	Sample Name	Geological Unit	Sample Depth	Aluminum	Arsenic	Barium	Beryllium	Boro	Bromide	Calcium	Chloride	Cobalt	Copper	Chromium	Fluoride	Iron	Lead	Lithium
A-01	ST-167/196-SO2022T31004	A-01_0,3m	Marizal	0,3	1510	<10	<1	<1	<3	<1	14	<10	<2	<1	3	<1	222	<10	<2
A-01	ST-167/196-SO2022T31005	A-01_0,9m	Marizal	0,9	2611	<10	<1	<1	<3	<1	7	<10	<2	<1	7	<1	838	<10	<2
A-02	ST-167/197-SO2022T31013	A-02_1,5m	Marizal	1,5	6042	<10	5	<1	<3	<1	<5	<10	<2	<1	4	<1	1057	<10	<2
A-02	ST-167/197-SO2022T31015	A-02_4,3m	Marizal	4,3	2004	<10	2	<1	<3	<1	<5	<10	<2	<1	<2	<1	298	<10	<2
A-02	ST-167/197-SO2022T31014	A-02_4m	Marizal	4	1147	<10	1	<1	<3	<1	<5	<10	<2	<1	<2	<1	326	16	<2
A-02	ST-167/197-SO2022T31016	A-02_5m	Marizal	5	789	<10	1	<1	<3	<1	7	<10	<2	<1	<2	<1	934	11	<2
A-03	ST-167/198-SO2022T31020	A-03_0,3m	Marizal	0,3	147	<10	<1	<1	<3	<1	12	<10	<2	<1	<2	<1	7	<10	<2
A-04	ST-167/199-SO2022T31030	A-04_0,4m	Alluvial Deposits	0,4	632	<10	3	<1	<3	<1	17	<10	<2	<1	<2	<1	103	<10	<2
A-04	ST-167/199-SO2022T31031	A-04_0,9m	Alluvial Deposits	0,9	4170	<10	<1	<1	<3	<1	7	<10	<2	<1	3	<1	206	<10	<2
A-04	ST-167/199-SO2022T31032	A-04_1,5m	Alluvial Deposits	1,5	6873	<10	<1	<1	<3	<1	5	<10	<2	<1	7	<1	697	<10	<2
A-05	ST-167/200-SO2022T31040	A-05_0,8m	Marizal	0,8	765	<10	<1	<1	<3	<1	<5	<10	<2	<1	<2	<1	1807	<10	<2
A-05	ST-167/200-SO2022T31041	A-05_3,2m	Marizal	3,2	1389	<10	<1	<1	<3	2,7	10	<10	<2	1	4	<1	2118	<10	<2
A-05	ST-167/200-SO2022T31042	A-05_5,2m	Marizal	5,2	271	<10	<1	<1	<3	<1	<5	<10	<2	<1	<2	<1	487	<10	<2
A-05	ST-167/200-SO2022T31044	A-05_7,2m	Marizal	7,2	279	<10	<1	<1	<3	<1	14	<10	<2	<1	<2	<1	141	<10	<2
A-06	ST-167/201-SO2022T31055	A-06_0,2m	Barreiras	0,2	14958	<10	<1	<1	<3	<1	48	20	<2	<1	63	<1	51342	<10	<2
A-06	ST-167/201-SO2022T31056	A-06_0,7m	Barreiras	0,7	3720	<10	<1	<1	<3	<1	54	<10	<2	<1	69	<1	33444	<10	<2
A-06	ST-167/201-SO2022T31057	A-06_1,5m	Barreiras	1,5	3793	18	<1	<1	<3	<1	31	<10	<2	<1	54	<1	48148	<10	<2
A-06	ST-167/201-SO2022T31062	A-06_10,5m	Barreiras	10,5	317	<10	<1	<1	<3	2,8	12	<10	<2	<1	8	<1	10806	<10	<2
A-06	ST-167/201-SO2022T31063	A-06_10,9m	Barreiras	10,9	636	<10	<1	<1	<3	<1	5	<10	<2	<1	3	<1	3589	<10	<2
A-06	ST-167/201-SO2022T31064	A-06_12,2m	Barreiras	12,2	1366	28	<1	<1	<3	<1	11	<10	<2	2	19	<1	34577	<10	<2
A-06	ST-167/201-SO2022T31066	A-06_13,5m	Barreiras	13,5	731	16	<1	<1	<3	<1	8	<10	<2	1	20	<1	29488	<10	<2
A-06	ST-167/201-SO2022T31065	A-06_14,6m	Barreiras	14,6	1099	12	<1	<1	<3	1,3	20	<10	<2	1	22	<1	12743	<10	<2
A-06	ST-167/201-SO2022T31058	A-06_3,5m	Barreiras	3,5	999	<10	<1	<1	<3	<1	11	<10	<2	<1	11	<1	14368	<10	<2
A-06	ST-167/201-SO2022T31059	A-06_7,1m	Barreiras	7,1	1384	41	<1	<1	<3	<1	16	<10	<2	1	36	<1	43109	<10	<2
A-06	ST-167/201-SO2022T31060	A-06_8,9m	Barreiras	8,9	710	11	<1	<1	<3	<1	8	<10	<2	<1	11	<1	27867	<10	<2
A-06	ST-167/201-SO2022T31061	A-06_9,6m	Barreiras	9,6	627	<10	<1	<1	<3	<1	22	<10	<2	<1	7	<1	10719	<10	<2
A-07	ST-167/202-SO2022T31070	A-07_1,5m	Marizal	1,5	1092	<10	<1	<1	<3	<1	<5	<10	<2	<1	4	<1	937	<10	<2
A-07	ST-167/202-SO2022T31071	A-07_3,3m	Marizal	3,3	4070	<10	<1	<1	<3	<1	<5	<10	<2	<1	7	<1	1300	<10	<2
A-08	ST-167/203-SO2022T31080	A-08_0,3m	São Sebastião	0,3	2070	<10	2	<1	<3	<1	7	<10	<2	<1	8	<1	6048	<10	<2
A-08	ST-167/203-SO2022T31081	A-08_1,8m	São Sebastião	1,8	4753	<10	2	<1	<3	<1	<5	27	<2	<1	24	<1	13193	<10	<2
A-08	ST-167/203-SO2022T31082	A-08_4,7m	São Sebastião	4,7	7253	<10	11	<1	<3	<1	43	53	8	39	27	<1	33670	<10	<2
A-08	ST-167/203-SO2022T31083	A-08_9m	São Sebastião	9	11203	<10	101	3	<3	<1	818	11	37	56	28	4,7	23816	<10	13
A-09	ST-167/208-SO2022T32149	A-09_0,2m	Barreiras	0,2	1025	<10	<1	<1	<3	1,4	18	<10	<2	1	8	<1	4320	<10	<2
A-09	ST-167/208-SO2022T32150	A-09_0,6m	Barreiras	0,6	4109	<10	<1	<1	21	<1	91	<10	<2	<1	52	<1	34066	<10	<2
A-09	ST-167/208-SO2022T32151	A-09_2,2m	Barreiras	2,2	2623	21	<1	<1	<3	<1	<5	<10	<2	<1	28	<1	18603	<10	<2
A-09	ST-167/208-SO2022T32152	A-09_3,3m	Barreiras	3,3	2516	58	<1	<1	<3	<1	<5	<10	<2	2	51	<1	33899	<10	<2
A-09	ST-167/208-SO2022T32153	A-09_4,3m	Barreiras	4,3	1085	15	<1	<1	<3	<1	5	<10	<2	14	<2	<1	11111	<10	<2
A-09	ST-167/208-SO2022T32154	A-09_6,7m	Barreiras	6,7	668	<10	<1	<1	<3	<1	<5	13	<2	<1	12	<1	7526	<10	<2
A-09	ST-167/208-SO2022T32155	A-09_9,1m	Barreiras	9,1	2893	21	<1	<1	<3	<1	5	<10	<2	7	44	<1	39135	<10	<2
A-10	ST-167/205-SO2022T31114	A-10_0,2m	Marizal	0,2	2680	<10	<1	<1	<3	<1	65	<10	<2	6	6	<1	3361	<10	<2
A-10	ST-167/205-SO2022T31115	A-10_0,5m	Marizal	0,5	3114	<10	<1	<1	<3	<1	11	<10	<2	2	20	<1	18338	<10	<2
A-10	ST-167/205-SO2022T31116	A-10_1,5m	Marizal	1,5	1162	<10	<1	<1	<3	<1	6	<10	<2	<1	8	<1	3333	<10	<2
A-10	ST-167/205-SO2022T31118	A-10_4,7m	Marizal	4,7	128	<10	<1	<1	<3	<1	<5	<10	<2	<1	<2	<1	261	<10	<2
A-10	ST-167/205-SO2022T31117	A-10_4m	Marizal	4	173	<10	<1	<1	<3	<1	46	<10	<2	<1	2	<1	786	<10	<2
A-10	ST-167/205-SO2022T31119	A-10_6,5m	Marizal	6,5	142	<10	<1	<1	<3	<1	<5	<10	<2	<1	<2	<1	62	<10	<2
A-10	ST-167/205-SO2022T31121	A-10_7,8m	Marizal	7,8	287	<10	<1	<1	<3	<1	<5	<10	<2	<1	5	<1	2791	<10	<2
A-10	ST-167/205-SO2022T31120	A-10_7m	Marizal	7	102	<10	<1	<1	<3	<1	<5	<10	<2	<1	<2	<1	794	<10	<2
A-11	ST-167/206-SO2022T31130	A-11_0,2m	Barreiras	0,2	1730	<10	2	<1	<3	1,4	9	<10	<2	14	7	<1	6047	<10	<2
A-11	ST-167/206-SO2022T31131	A-11_1,5m	Barreiras	1,5	846	<10	<1	<1	<3	<1	10	<10	<2	4	13	<1	8325	<10	<2
A-11	ST-167/206-SO2022T31132	A-11_5,1m	Barreiras	5,1	2165	<10	2	<1	<3	1,4	14	<10	2	11	110	<1	43020	<10	<2
A-11	ST-167/206-SO2022T31133	A-11_6,2m	Barreiras	6,2	832	<10	<1	<1	<3	<1	8	<10	<2	5	35	<1	13453	<10	<2
A-11	ST-167/206-SO2022T31134	A-11_7,6m	Barreiras	7,6	301	<10	<1	<1	<3	<1	<5	<10	<2	2	8	<1	3635	<10	<2
A-12	ST-167/207-SO2022T31144	A-12_0,7m	São Sebastião	0,7	2603	<10	<1	<1	<3	<1	<5	<10	<2	<1	8	<1	5159	<10	<2
A-12	ST-167/207-SO2022T31145	A-12_2,8m	São Sebastião	2,8	4330	<10	1	<1	<3	<1	<5	<10	<2	<1	13	<1	9382	<10	<2
A-12	ST-167/207-SO2022T31146	A-12_6m	São Sebastião	6	2484	<10	<1	<1	<3	<1	7	<10	<2	1	8	<1	6933	<10	<2
A-12	ST-167/207-SO2022T31147	A-12_9m	São Sebastião	9	370	<10	<1	<1	<3	<1	<5	<10	<2	<1	4	<1	3137	<10	<2

Table A.3 – Analytical results of soil and sediment samples for parameters with at least one detected value (part 2)

Reference Area	Sample ID	Sample Name	Geological Unit	Sample Depth	Magnesium	Manganese	Mercury	Molybdenum	Nickel	N-nitrate	Potassium	Sodium	Strontium	Sulfate	Sulfite	Tin	Titanium	Vanadium	Zinc
A-01	ST-167/196-SO2022T31004	A-01_0,3m	Marizal	0,3	5	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	10	<10	10	<10	27
A-01	ST-167/196-SO2022T31005	A-01_0,9m	Marizal	0,9	3	<2	<0,1	<5	<5	<1	<30	8	<2	<10	10	<10	20	<10	2
A-02	ST-167/197-SO2022T31013	A-02_1,5m	Marizal	1,5	6	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	19	<10	22	<10	<1
A-02	ST-167/197-SO2022T31015	A-02_4,3m	Marizal	4,3	15	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	10	<10	4	<10	<1
A-02	ST-167/197-SO2022T31014	A-02_4m	Marizal	4	14	<2	0,1	<5	<5	<1	<30	11	<2	<10	29	<10	3	<10	<1
A-02	ST-167/197-SO2022T31016	A-02_5m	Marizal	5	12	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	70	<10	4	<10	<1
A-03	ST-167/198-SO2022T31020	A-03_0,3m	Marizal	0,3	<2	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	<5	<10	<2	<10	<1
A-04	ST-167/199-SO2022T31030	A-04_0,4m	Alluvial Deposits	0,4	6	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	19	<10	7	<10	<1
A-04	ST-167/199-SO2022T31031	A-04_0,9m	Alluvial Deposits	0,9	3	<2	<0,1	<5	<5	<1	<30	9	<2	<10	39	<10	10	<10	1
A-04	ST-167/199-SO2022T31032	A-04_1,5m	Alluvial Deposits	1,5	4	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	19	<10	26	10	<1
A-05	ST-167/200-SO2022T31040	A-05_0,8m	Marizal	0,8	5	<2	<0,05	<5	<5	<1	<30	11	<2	<10	10	<10	11	<10	<1
A-05	ST-167/200-SO2022T31041	A-05_3,2m	Marizal	3,2	8	<2	<0,1	<5	<5	<1	<30	17	<2	<10	10	<10	8	<10	1
A-05	ST-167/200-SO2022T31042	A-05_5,2m	Marizal	5,2	2	<2	<0,05	<5	<5	<1	<30	<8	<2	<10	19	<10	2	<10	<1
A-05	ST-167/200-SO2022T31044	A-05_7,2m	Marizal	7,2	13	18	<0,05	<5	<5	<1	<30	15	<2	<10	19	<10	<2	<10	8
A-06	ST-167/201-SO2022T31055	A-06_0,2m	Barreiras	0,2	59	19	0,13	5	<5	<1	<30	29	<2	10	14	<10	186	76	9
A-06	ST-167/201-SO2022T31056	A-06_0,7m	Barreiras	0,7	41	7	<0,1	<5	<5	<1	<30	31	<2	18	8	<10	110	64	5
A-06	ST-167/201-SO2022T31057	A-06_1,5m	Barreiras	1,5	14	224	<0,1	<5	<5	<1	<30	32	<2	11	20	<10	113	51	18
A-06	ST-167/201-SO2022T31062	A-06_10,5m	Barreiras	10,5	3	4	<0,05	<5	<5	<1	<30	17	<2	<10	8	<10	27	<10	<1
A-06	ST-167/201-SO2022T31063	A-06_10,9m	Barreiras	10,9	4	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	8	<10	18	<10	<1
A-06	ST-167/201-SO2022T31064	A-06_12,2m	Barreiras	12,2	4	2	<0,1	<5	<5	<1	<30	15	<2	12	6	<10	79	<10	4
A-06	ST-167/201-SO2022T31066	A-06_13,5m	Barreiras	13,5	3	<2	<0,05	<5	<5	<1	<30	13	<2	<10	18	<10	69	16	4
A-06	ST-167/201-SO2022T31065	A-06_14,6m	Barreiras	14,6	9	4	<0,05	<5	<5	<1	<30	23	<2	15	8	<10	45	19	3
A-06	ST-167/201-SO2022T31058	A-06_3,5m	Barreiras	3,5	4	<2	<0,05	<5	<5	<1	<30	15	<2	21	7	<10	31	<10	4
A-06	ST-167/201-SO2022T31059	A-06_7,1m	Barreiras	7,1	6	<2	<0,1	8	<5	<1	<30	26	<2	15	8	<10	75	22	6
A-06	ST-167/201-SO2022T31060	A-06_8,9m	Barreiras	8,9	3	3	<0,1	<5	<5	<1	<30	13	<2	<10	9	30	37	<10	3
A-06	ST-167/201-SO2022T31061	A-06_9,6m	Barreiras	9,6	13	<2	<0,1	<5	<5	<1	<30	16	<2	25	9	<10	27	<10	1
A-07	ST-167/202-SO2022T31070	A-07_1,5m	Marizal	1,5	<2	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	10	<10	<2	<10	<1
A-07	ST-167/202-SO2022T31071	A-07_3,3m	Marizal	3,3	4	2	<0,1	<5	<5	<1	<30	<8	<2	<10	20	<10	9	<10	<1
A-08	ST-167/203-SO2022T31080	A-08_0,3m	São Sebastião	0,3	13	5	<0,05	<5	<5	<1	<30	19	<2	<10	20	<10	12	13	<1
A-08	ST-167/203-SO2022T31081	A-08_1,8m	São Sebastião	1,8	18	3	<0,05	<5	<5	<1	33	23	<2	<10	<5	<10	22	28	2
A-08	ST-167/203-SO2022T31082	A-08_4,7m	São Sebastião	4,7	772	107	<0,1	<5	21	<1	787	185	<2	20	10	<10	46	41	30
A-08	ST-167/203-SO2022T31083	A-08_9m	São Sebastião	9	8497	228	<0,05	<5	87	<1	1314	299	9	81	20	<10	176	33	115
A-09	ST-167/208-SO2022T32149	A-09_0,2m	Barreiras	0,2	18	<2	0,08	<5	<5	3,3	<30	18	<2	<10	<5	<10	16	<10	<1
A-09	ST-167/208-SO2022T32150	A-09_0,6m	Barreiras	0,6	181	3	0,11	<5	<5	<1	<30	40	<2	14	<5	<10	33	82	7
A-09	ST-167/208-SO2022T32151	A-09_2,2m	Barreiras	2,2	23	<2	0,08	<5	<5	<1	<30	18	<2	15	<5	<10	36	29	1
A-09	ST-167/208-SO2022T32152	A-09_3,3m	Barreiras	3,3	8	<2	0,07	<5	<5	<1	<30	12	<2	14	<5	<10	52	51	5
A-09	ST-167/208-SO2022T32153	A-09_4,3m	Barreiras	4,3	5	<2	<0,05	<5	<5	<1	<30	16	<2	11	<5	<10	16	18	1
A-09	ST-167/208-SO2022T32154	A-09_6,7m	Barreiras	6,7	16	<2	<0,05	<5	<5	<1	<30	18	<2	11	<5	<10	25	<10	<1
A-09	ST-167/208-SO2022T32155	A-09_9,1m	Barreiras	9,1	11	<2	0,16	17	<5	<1	<30	29	<2	<10	<5	<10	222	25	3
A-10	ST-167/205-SO2022T31114	A-10_0,2m	Marizal	0,2	59	11	<0,1	<5	<5	1,9	<30	23	<2	<10	<5	<10	13	<10	27
A-10	ST-167/205-SO2022T31115	A-10_0,5m	Marizal	0,5	10	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	<5	<10	35	32	2
A-10	ST-167/205-SO2022T31116	A-10_1,5m	Marizal	1,5	4	<2	<0,1	<5	<5	<1	<30	<8	<2	16	<5	<10	10	12	<1
A-10	ST-167/205-SO2022T31118	A-10_4,7m	Marizal	4,7	<2	<2	<0,05	<5	<5	<1	<30	<8	<2	<10	<5	<10	2	<10	<1
A-10	ST-167/205-SO2022T31117	A-10_4m	Marizal	4	34	20	<0,1	<5	<5	<1	<30	21	<2	<10	<5	<10	5	<10	15
A-10	ST-167/205-SO2022T31119	A-10_6,5m	Marizal	6,5	2	<2	<0,05	<5	<5	<1	<30	<8	<2	<10	<5	<10	<2	<10	<1
A-10	ST-167/205-SO2022T31121	A-10_7,8m	Marizal	7,8	3	<2	<0,1	<5	<5	<1	<30	<8	<2	<10	<5	22	6	<10	<1
A-10	ST-167/205-SO2022T31120	A-10_7m	Marizal	7	<2	<2	<0,05	<5	<5	<1	<30	<8	<2	<10	<5	<10	<2	<10	<1
A-11	ST-167/206-SO2022T31130	A-11_0,2m	Barreiras	0,2	14	5	<0,05	<5	<5	<1	<30	17	<2	<10	10	<10	20	14	4
A-11	ST-167/206-SO2022T31131	A-11_1,5m	Barreiras	1,5	10	4	<0,05	<5	<5	<1	<30	12	<2	15	<5	<10	29	22	5
A-11	ST-167/206-SO2022T31132	A-11_5,1m	Barreiras	5,1	17	36	<0,1	<5	7	<1	39	23	<2	<10	10	<10	178	104	17
A-11	ST-167/206-SO2022T31133	A-11_6,2m	Barreiras	6,2	13	9	<0,05	<5	<5	<1	<30	19	<2	13	20	<10	83	49	4
A-11	ST-167/206-SO2022T31134	A-11_7,6m	Barreiras	7,6	4	7	<0,05	<5	<5	<1	<30	13	<2	18	10	<10	19	12	2
A-12	ST-167/207-SO2022T31144	A-12_0,7m	São Sebastião	0,7	6	5	<0,1	<5	<5	<1	<30	<8	<2	<10	10	<10	18	<10	<1
A-12	ST-167/207-SO2022T31145	A-12_2,8m	São Sebastião	2,8	11	4	<0,1	<5	<5	<1	<30	<8	<2	15	10	<10	34	18	2
A-12	ST-167/207-SO2022T31146	A-12_6m	São Sebastião	6	11	3	<0,1	<5	<5	<1	<30	<8	<2	<10	20	<10	28	11	2
A-12	ST-167/207-SO2022T31147	A-12_9m	São Sebastião	9	6	3	<0,1	<5	<5	<1	<30	<8	<2	<10	10	<10	18	<10	<1

Table A.4 - General statistics for censored data set using Kaplan Meier method for treatment of censored data and calculation of the 95-percentile

Variable	Geologic Unit	Num Obs	Num Ds	Num NDs	% NDs	Detection Limit	Minimum	Maximum	Mean	Median	Percentil 95%	Var	SD	Skewness	CV	KM Mean	KM Var	KM SD	KM CV
Aluminum (mg/kg)	Total	56	56	0	0%	2	102	14958	2282	1264	6968	7470692	2733	2,697	1,198	N/A	N/A	N/A	N/A
	Barreiras	24	24	0	0%	2	301	14958	2131	1092	4062	8750707	2958	3,829	1,388	N/A	N/A	N/A	N/A
	Alluvial Deposits	3	3	0	0%	2	632	6873	3892	4170	6603	9795622	3130	-0,397	0,804	N/A	N/A	N/A	N/A
	Marizal	21	21	0	0%	2	102	6042	1424	1092	4070	2390386	1546	1,644	1,086	N/A	N/A	N/A	N/A
	São Sebastião	8	8	0	0%	2	370	11203	4383	3466,5	9821	11873964	3446	1,17	0,786	N/A	N/A	N/A	N/A
Arsenic (mg/kg)	Total	56	10	46	82%	10	11	58	24,1	19,5	22,75	219,2	14,81	1,637	0,614	12,52	64,39	8,024	0,641
	Barreiras	24	10	14	58%	10	11	58	24,1	19,5	39,05	219,2	14,81	1,637	0,614	15,88	130,5	11,42	0,72
Barium (mg/kg)	Total	56	12	44	79%	1	1	101	11,08	2	3,5	809,5	28,45	3,407	2,567	3,161	176,1	13,27	4,199
	Barreiras	24	2	22	92%	1	2	2	2	2	1,85	0	0	N/A	N/A	1,083	0,0764	0,276	0,255
	Alluvial Deposits	3	1	2	67%	1	3	3	3	3	2,8	N/A	N/A	N/A	N/A	1,667	0,889	0,943	0,566
	Marizal	21	4	17	81%	1	1	5	2,25	1,5	2	3,583	1,893	1,659	0,841	1,238	0,753	0,868	0,701
	São Sebastião	8	5	3	38%	1	1	101	23,4	2	69,5	1898	43,57	2,189	1,862	15	1067	32,66	2,177
Beryllium (mg/kg)	Total	56	1	55	98%	1	3	3	3	3	1	N/A	N/A	N/A	N/A	1,036	0,0702	0,265	0,256
	São Sebastião	8	1	7	88%	1	3	3	3	3	2,3	N/A	N/A	N/A	N/A	1,25	0,438	0,661	0,529
Boro (mg/kg)	Total	56	1	55	98%	3	21	21	21	21	3	N/A	N/A	N/A	N/A	3,321	5,682	2,384	0,718
	Barreiras	24	1	23	96%	3	21	21	21	21	3	N/A	N/A	N/A	N/A	3,75	12,94	3,597	0,959
Bromide (mg/kg)	Total	56	6	50	89%	1	1,3	2,8	1,833	1,4	1,4	0,507	0,712	0,964	0,388	1,089	0,112	0,334	0,307
	Barreiras	24	5	19	79%	1	1,3	2,8	1,66	1,4	1,4	0,408	0,639	2,21	0,385	1,138	0,14	0,374	0,329
	Marizal	21	1	20	95%	1	2,7	2,7	2,7	2,7	1	N/A	N/A	N/A	N/A	1,081	0,131	0,362	0,335
Calcium (mg/kg)	Total	56	37	19	34%	5	5	818	40,59	11	56,75	17629	132,8	5,886	3,271	28,52	11617	107,8	3,779
	Barreiras	24	20	4	17%	5	5	91	20,3	11,5	53,1	458,6	21,42	2,338	1,055	17,75	395,6	19,89	1,121
	Alluvial Deposits	3	3	0	0%	N/A	5	17	9,667	7	16	41,33	6,429	1,545	0,665	9,667	41,33	6,429	0,665
	Marizal	21	10	11	52%	5	6	65	19,2	11,5	46	394	19,85	1,908	1,034	11,76	219,1	14,8	1,259
	São Sebastião	8	4	4	50%	5	7	818	218,8	25	546,8	159888	399,9	1,989	1,828	111,9	71380	267,2	2,388
Chloride (mg/kg)	Total	56	5	51	91%	10	11	53	24,8	20	14,75	288,2	16,98	1,538	0,685	11,32	38,4	6,197	0,547
	Barreiras	24	2	22	92%	10	13	20	16,5	16,5	12,55	24,5	4,95	N/A	0,3	10,54	4,248	2,061	0,196
	São Sebastião	8	3	5	63%	10	11	53	30,33	27	43,9	449,3	21,2	0,69	0,699	17,63	209,2	14,46	0,821
Chromium (mg/kg)	Total	56	44	12	21%	2	2	110	20,25	9,5	56,25	501,3	22,39	2,096	1,106	16,34	441	21	1,285
	Barreiras	24	23	1	4%	2	3	110	30,04	20	68,1	710,5	26,66	1,416	0,887	28,88	682,7	26,13	0,905
	Alluvial Deposits	3	2	1	33%	2	3	7	5	5	6,6	8	2,828	N/A	0,566	4	4,667	2,16	0,54
	Marizal	21	11	10	48%	2	2	20	6,364	5	8	23,85	4,884	2,494	0,768	4,286	16,11	4,014	0,937
	São Sebastião	8	8	0	0%	N/A	4	28	15	10,5	27,65	95,14	9,754	0,469	0,65	15	95,14	9,754	0,65
Cobalt (mg/kg)	Total	56	3	53	95%	2	2	37	15,67	8	2	350,3	18,72	1,534	1,195	2,732	21,98	4,688	1,716
	Barreiras	24	1	23	96%	2	2	2	2	2	2	N/A	N/A	N/A	N/A	2	0	0	N/A
	São Sebastião	8	2	6	75%	2	8	37	22,5	22,5	26,85	420,5	20,51	N/A	0,911	7,125	131,4	11,46	1,609
Copper (mg/kg)	Total	56	19	37	66%	1	1	56	8,947	2	14	210,9	14,52	2,574	1,623	3,696	81,96	9,053	2,449
	Barreiras	24	13	11	46%	1	1	14	5	2	13,55	24,5	4,95	1,091	0,99	3,167	16,22	4,028	1,272
	Marizal	21	3	18	86%	1	1	6	3	2	2	7	2,646	1,458	0,882	1,286	1,156	1,075	0,836
	São Sebastião	8	3	5	63%	1	1	56	32	39	50,05	793	28,16	-1,049	0,88	12,63	423,5	20,58	1,63
Fluoride (mg/kg)	Total	56	1	55	98%	1	4,7	4,7	4,7	4,7	1	N/A	N/A	N/A	N/A	1,066	0,24	0,49	0,46
	São Sebastião	8	1	7	88%	1	4,7	4,7	4,7	4,7	3,405	N/A	N/A	N/A	N/A	1,463	1,497	1,224	0,837
Iron (mg/kg)	Total	56	56	0	0%	2	7	51342	12248	5603	14764	217968332	14764	1,223	1,205	N/A	N/A	N/A	N/A
	Barreiras	24	24	0	0%	2	3589	51342	22639	16485,5	47392	244443708	15635	0,372	0,691	N/A	N/A	N/A	N/A
	Alluvial Deposits	3	3	0	0%	2	103	697	335,3	206	647,9	100754,3	317,4	1,529	0,947	N/A	N/A	N/A	N/A
	Marizal	21	21	0	0%	2	7	18338	1914	838	3361	15218158	3901	4,087	2,038	N/A	N/A	N/A	N/A
	São Sebastião	8	8	0	0%	2	3137	33670	12667	8157,5	30221	114339285	10693	1,378	0,844	N/A	N/A	N/A	N/A
Lead (mg/kg)	Total	56	2	54	96%	10	11	16	13,5	13,5	10	12,5	3,536	N/A	0,262	10,13	0,645	0,803	0,0793
	Marizal	21	2	19	90%	10	11	16	13,5	13,5	11	12,5	3,536	N/A	0,262	10,33	1,651	1,285	0,124
Lithium (mg/kg)	Total	56	1	55	98%	2	13	13	13	13	2	N/A	N/A	N/A	N/A	2,196	2,122	1,457	0,663
	São Sebastião	8	1	7	88%	2	13	13	13	13	9,15	N/A	N/A	N/A	N/A	3,375	13,23	3,638	1,078
Magnesium (mg/kg)	Total	56	52	4	7%	2	2	8497	192,9	9,5	89,5	1390350	1179	7,122	6,114	179,2	1268628	1126	6,284
	Barreiras	24	24	0	0%	N/A	3	181	20,13	10,5	56,3	1341	36,62	4,043	1,82	20,13	1341	36,62	1,82
	Alluvial Deposits	3	3	0	0%	N/A	3	6	4,333	4	5,8	2,333	1,528	0,935	0,353	4,333	2,333	1,528	0,353

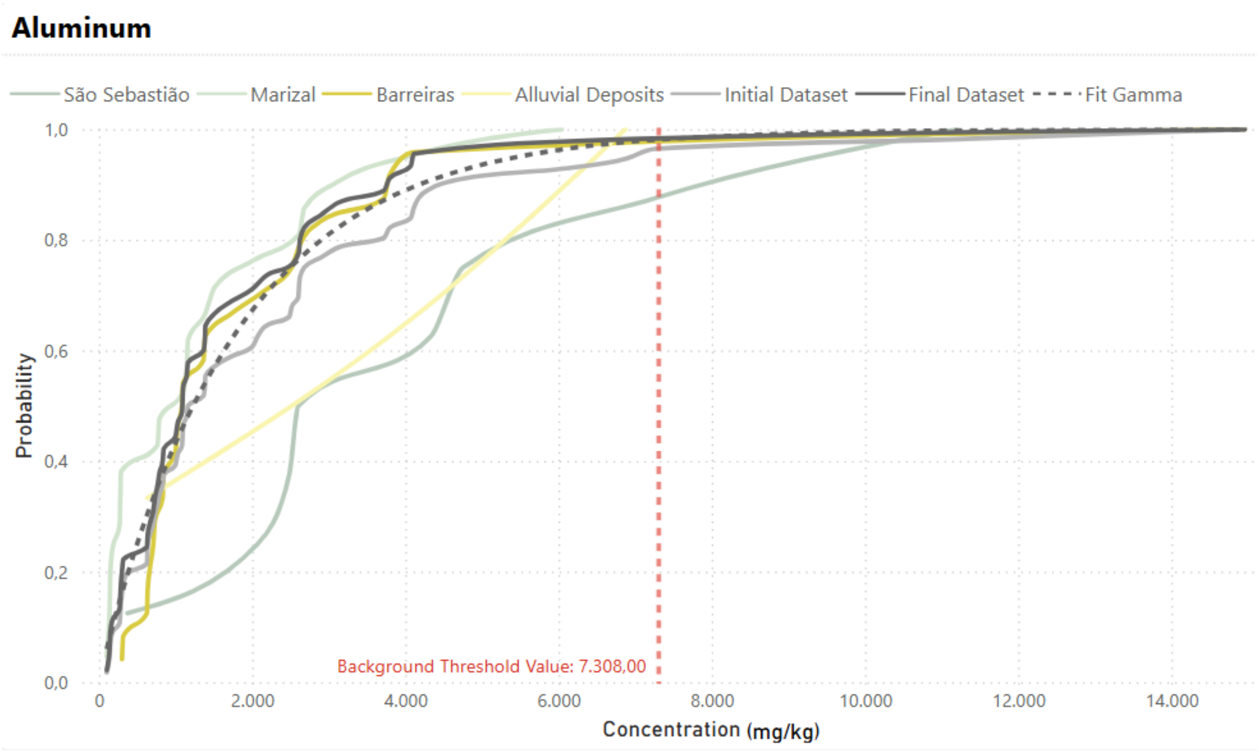
Variable	Geologic Unit	Num Obs	Num Ds	Num NDs	% NDs	Detection Limit	Minimum	Maximum	Mean	Median	Percentil 95%	Var	SD	Skewness	CV	KM Mean	KM Var	KM SD	KM CV
	Marizal	21	17	4	19%	2	2	59	11,71	6	34	209,3	14,47	2,619	1,236	9,875	174	13,19	1,338
	São Sebastião	8	8	0	0%	N/A	6	8497	1167	12	5793	9000000	2974	2,785	2,549	1167	8843622	2974	2,549
Manganese (mg/kg)	Total	56	25	31	55%	2	2	228	29,44	5	53,75	3951	62,85	2,804	2,135	14,25	1879	43,35	3,042
	Barreiras	24	13	11	46%	2	2	224	25,15	5	33,45	3657	60,47	3,463	2,404	14,54	1961	44,29	3,046
	Marizal	21	4	17	81%	2	2	20	12,75	14,5	18	66,25	8,139	-0,892	0,638	4,048	27,28	5,223	1,29
	São Sebastião	8	8	0	0%	N/A	3	228	44,75	4,5	185,7	6787	82,38	2,038	1,841	44,75	6787	82,38	1,841
Mercury (mg/kg)	Total	56	7	49	88%	0,05 and 0,1	0,07	0,16	0,104	0,1	0,103	0,001	0,0321	0,857	0,308	0,0587	0,00045586	0,0214	0,364
	Barreiras	24	6	18	75%	0,05 and 0,1	0,07	0,16	0,105	0,095	0,127	0,0012	0,0351	0,751	0,334	0,0658	0,00081923	0,0286	0,435
	Marizal	21	1	20	95%	0,05 and 0,1	0,1	0,1	0,1	0,1	0,1	N/A	N/A	N/A	N/A	0,0524	0,00011338	0,0106	0,203
Molybdenum (mg/kg)	Total	56	3	53	95%	5	5	17	10	8	5	39	6,245	1,293	0,624	5,268	2,66	1,631	0,31
	Barreiras	24	3	21	88%	5	5	17	10	8	7,55	39	6,245	1,293	0,624	5,625	5,984	2,446	0,435
Nickel (mg/kg)	Total	56	3	53	95%	5	7	87	38,33	21	5,5	1825	42,72	1,525	1,115	6,786	121,5	11,02	1,625
	Barreiras	24	1	23	96%	5	7	7	7	7	5	N/A	N/A	N/A	N/A	5,083	0,16	0,4	0,0786
	São Sebastião	8	2	6	75%	5	21	87	54	54	63,9	2178	46,67	N/A	0,864	17,25	722,4	26,88	1,558
N-nitrate (mg/kg)	Total	56	2	54	96%	1	1,9	3,3	2,6	2,6	1	0,98	0,99	N/A	0,381	1,057	0,106	0,325	0,307
	Barreiras	24	1	23	96%	1	3,3	3,3	3,3	3,3	1	N/A	N/A	N/A	N/A	1,096	0,211	0,46	0,419
	Marizal	21	1	20	95%	1	1,9	1,9	1,9	1,9	1	N/A	N/A	N/A	N/A	1,043	0,0367	0,192	0,184
Potassium (mg/kg)	Total	56	4	52	93%	30	33	1314	543,3	413	34,5	389364	624	0,58	1,149	66,66	38331	195,8	2,937
	Barreiras	24	1	23	96%	30	39	39	39	39	30	N/A	N/A	N/A	N/A	30,38	3,234	1,798	0,0592
	São Sebastião	8	3	5	63%	30	33	1314	711,3	787	1130	414534	643,8	-0,522	0,905	285,5	212434	460,9	1,614
Sodium (mg/kg)	Total	56	35	21	38%	8	8	299	31,6	18	34	3003	54,8	4,285	1,734	22,75	1954	44,2	1,943
	Barreiras	24	23	1	4%	8	12	40	20,22	18	31,85	57,63	7,592	1,075	0,375	19,71	58,79	7,667	0,389
	Alluvial Deposits	3	1	2	67%	8	9	9	9	9	8,9	N/A	N/A	N/A	N/A	8,333	0,222	0,471	0,0566
	Marizal	21	7	14	67%	8	8	23	15,14	15	21	30,81	5,551	0,253	0,367	10,38	20,14	4,488	0,432
	São Sebastião	8	4	4	50%	8	19	299	131,5	104	259,1	18449	135,8	0,572	1,033	69,75	10731	103,6	1,485
Sulfite (mg/kg)	Total	56	38	18	32%	5	6	70	15,42	10	22,25	130,2	11,41	3,321	0,74	12,07	109,7	10,47	0,868
	Barreiras	24	16	8	33%	5	6	20	10,81	9	19,7	21,1	4,593	1,308	0,425	8,875	20,69	4,549	0,513
	Alluvial Deposits	3	3	0	0%	N/A	19	39	25,67	19	37	133,3	11,55	1,732	0,45	25,67	133,3	11,55	0,45
	Marizal	21	12	9	43%	5	10	70	19,67	14,5	29	289,3	17,01	2,724	0,865	13,38	204,2	14,29	1,068
	São Sebastião	8	7	1	13%	5	10	20	14,29	10	20	28,57	5,345	0,374	0,374	13,13	30,86	5,555	0,423
Sulfate (mg/kg)	Total	56	20	36	64%	10	10	81	18,5	15	20,25	230,5	15,18	4,04	0,821	13,04	94,78	9,736	0,747
	Barreiras	24	16	8	33%	10	10	25	14,88	14,5	20,55	16,12	4,015	1,185	0,27	13,25	15,35	3,918	0,296
	Marizal	21	1	20	95%	10	16	16	16	16	10	N/A	N/A	N/A	N/A	10,29	1,633	1,278	0,124
	São Sebastião	8	3	5	63%	10	15	81	38,67	20	59,65	1350	36,75	1,696	0,95	20,75	530,2	23,03	1,11
Strontium (mg/kg)	Total	56	1	55	98%	2	9	9	9	9	2	N/A	N/A	N/A	N/A	2,125	0,859	0,927	0,436
	São Sebastião	8	1	7	88%	2	9	9	9	9	6,55	N/A	N/A	N/A	N/A	2,875	5,359	2,315	0,805
Tin (mg/kg)	Total	56	2	54	96%	10	22	30	26	26	10	32	5,657	N/A	0,218	10,57	9,388	3,064	0,29
	Barreiras	24	1	23	96%	10	30	30	30	30	10	N/A	N/A	N/A	N/A	10,83	15,97	3,997	0,369
	Marizal	21	1	20	95%	10	22	22	22	22	10	N/A	N/A	N/A	N/A	10,57	6,531	2,556	0,242
Titanium (mg/kg)	Total	56	51	5	9%	2	2	222	41,31	22	176,5	2617	51,16	2,179	1,238	37,8	2462	49,62	1,313
	Barreiras	24	24	0	0%	N/A	16	222	64,42	36,5	184,8	3405	58,36	1,565	0,906	64,42	3405	58,36	0,906
	Alluvial Deposits	3	3	0	0%	N/A	7	26	14,33	10	24,4	104,3	10,21	1,565	0,713	14,33	104,3	10,21	0,713
	Marizal	21	16	5	24%	2	2	35	10,25	8,5	22	78,2	8,843	1,708	0,863	8,286	68,2	8,259	0,997
	São Sebastião	8	8	0	0%	N/A	12	176	44,25	25	130,5	2949	54,31	2,618	1,227	44,25	2949	54,31	1,227
Vanadium (mg/kg)	Total	56	25	31	55%	10	10	104	34,08	25	67	630,4	25,11	1,368	0,737	20,75	413,5	20,33	0,98
	Barreiras	24	16	8	33%	10	12	104	40,88	27	81,1	799,9	28,28	0,94	0,692	30,58	711,7	26,68	0,872
	Alluvial Deposits	3	1	2	67%	10	10	10	10	10	10	N/A	N/A	N/A	N/A	10	0	0	N/A
	Marizal	21	2	19	90%	10	12	32	22	22	12	200	14,14	N/A	0,643	11,14	21,93	4,683	0,42
	São Sebastião	8	6	2	25%	10	11	41	24	23	38,2	142,4	11,93	0,346	0,497	20,5	125,8	11,21	0,547
Zinc (mg/kg)	Total	56	33	23	41%	1	1	115	10,3	4	27	417,5	20,43	4,504	1,983	6,482	259,5	16,11	2,485
	Barreiras	24	20	4	17%	1	1	18	5,3	4	15,8	21,38	4,624	2,002	0,872	4,583	19,49	4,415	0,963
	Alluvial Deposits	3	1	2	67%	1	1	1	1	1	1	N/A	N/A	N/A	N/A	1	0	0	N/A
	Marizal	21	7	14	67%	1	1	27	11,71	8	27	132,6	11,51	0,621	0,983	4,571	63,39	7,962	1,742
	São Sebastião	8	5	3	38%	1	2	115	30,2	2	85,25	2394	48,93	1,93	1,62	19,25	1397	37,38	1,942

N/A: Not applicable due to the number of non-detects.

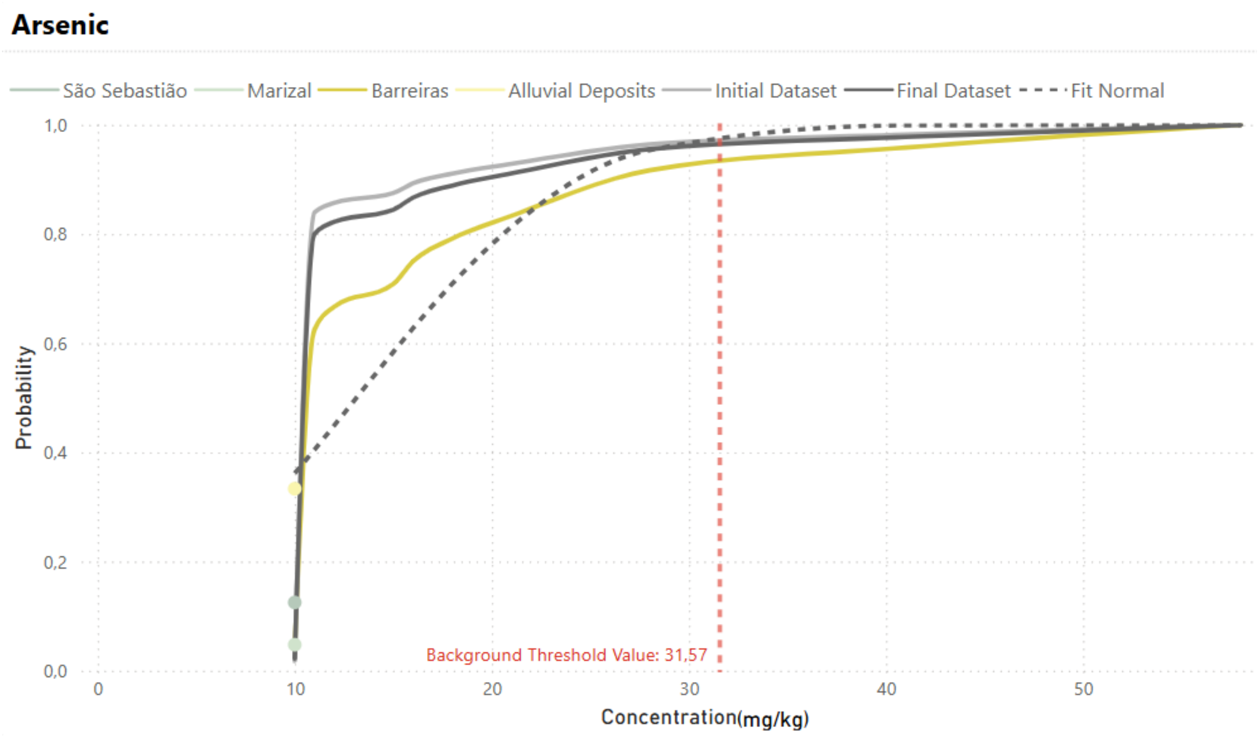
Table A.5 - General statistics for censored data using Kaplan Meier Method on the final dataset

Variable	Num Obs	Num Ds	Num NDs	% NDs	Detection Limit	KM Mean	KM Var	KM SD	KM CV
Arsenic (mg/kg)	45	10	35	77,78%	10	13,13	78,2	8,843	0,673
Barium (mg/kg)	45	6	39	86,67%	1	1,156	0,398	0,631	0,546
Boro (mg/kg)	45	1	44	97,78%	3	3,4	7,04	2,653	0,78
Bromide (mg/kg)	45	6	39	86,67%	1	1,111	0,137	0,37	0,333
Calcium (mg/kg)	45	30	15	33,33%	5	14,96	322,2	17,95	1,2
Lead (mg/kg)	45	2	43	95,56%	10	10,16	0,798	0,893	0,088
Chloride (mg/kg)	45	2	43	95,56%	10	10,29	2,339	1,529	0,149
Cobalt (mg/kg)	45	1	44	97,78%	2	2	0	0	N/A
Copper (mg/kg)	45	16	29	64,44%	1	2,289	10,07	3,174	1,387
Chromium (mg/kg)	45	34	11	24,44%	2	17,4	522,1	22,85	1,313
Tin (mg/kg)	45	2	43	95,56%	10	10,71	11,58	3,403	0,318
Magnesium (mg/kg)	45	41	4	8,89%	2	15,33	793	28,16	1,837
Manganese (mg/kg)	45	17	28	62,22%	2	9,644	1086	32,96	3,417
Mercury (mg/kg)	45	7	38	84,44%	0,05 and 0,1	0,0605	5,42E-04	0,0233	0,385
Molybdenum (mg/kg)	45	3	42	93,33%	5	5,333	3,289	1,814	0,34
Nickel (mg/kg)	45	1	44	97,78%	5	5,044	0,0869	0,295	0,0584
N-nitrate (mg/kg)	45	2	43	95,56%	1	1,071	0,13	0,361	0,337
Potassium (mg/kg)	45	1	44	97,78%	30	30,2	1,76	1,327	0,0439
Sodium (mg/kg)	45	30	15	33,33%	8	15,36	62,41	7,9	0,514
Sulfate (mg/kg)	45	17	28	62,22%	10	11,87	11,14	3,337	0,281
Sulfite (mg/kg)	45	28	17	37,78%	5	10,98	111,4	10,55	0,961
Titanium (mg/kg)	45	40	5	11,11%	2	38,22	2557	50,56	1,323
Vanadium (mg/kg)	45	18	27	60,00%	10	21,51	483,9	22	1,023
Zinc (mg/kg)	45	27	18	40,00%	1	4,578	39,98	6,323	1,381

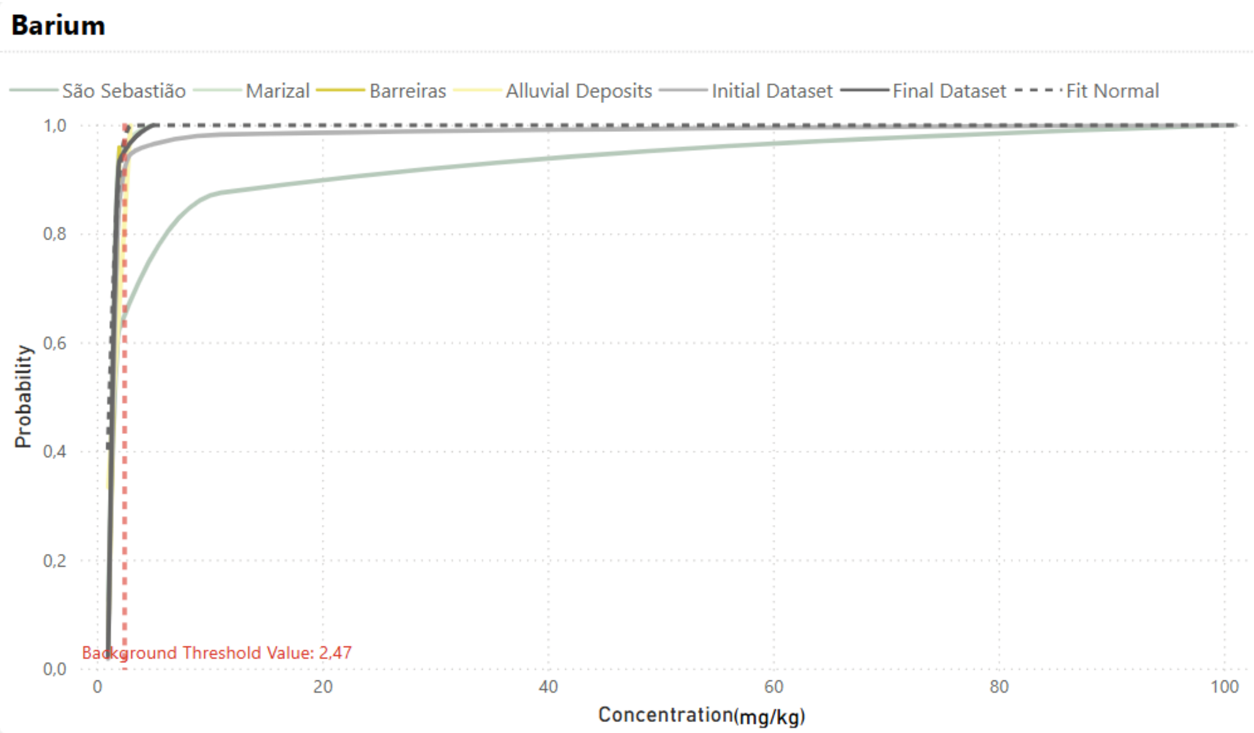
APÊNDICE B - GRÁFICOS



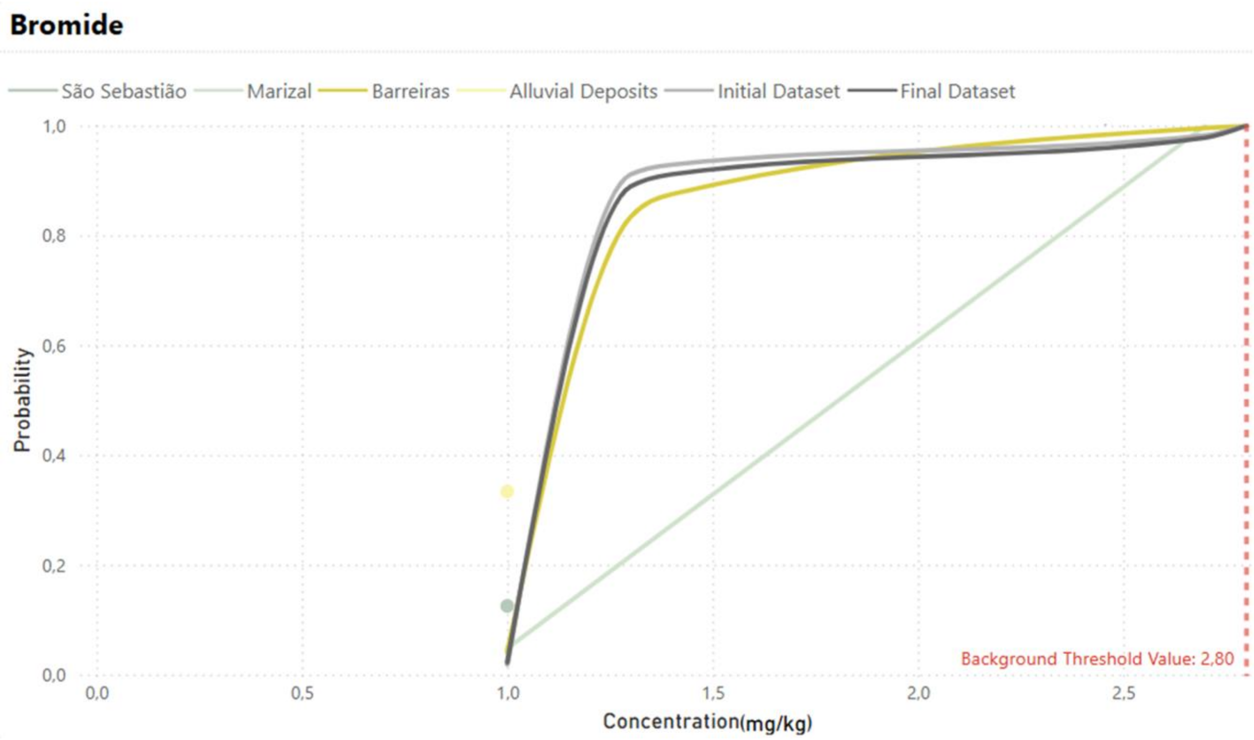
Graph B.1 – Cumulative distribution functions (cdf) and estimated BTV for Aluminum



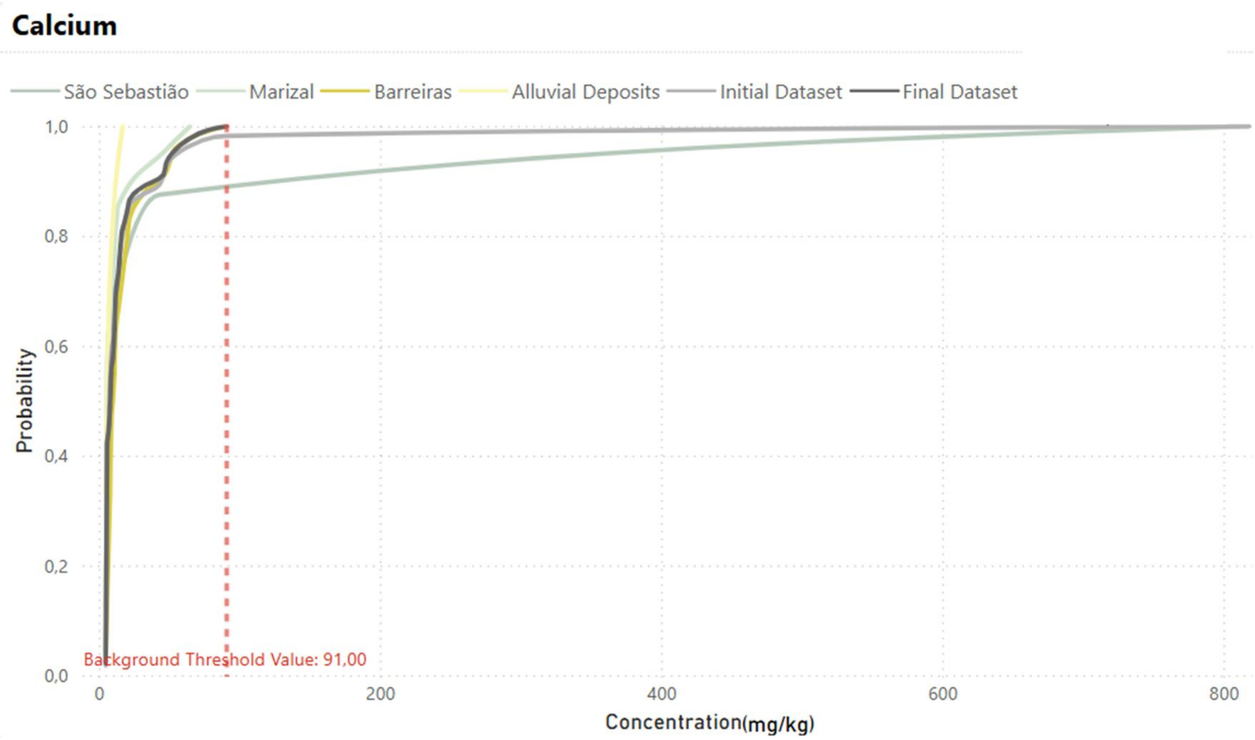
Graph B.2 – Cumulative distribution functions (cdf) and estimated BTV for Arsenic



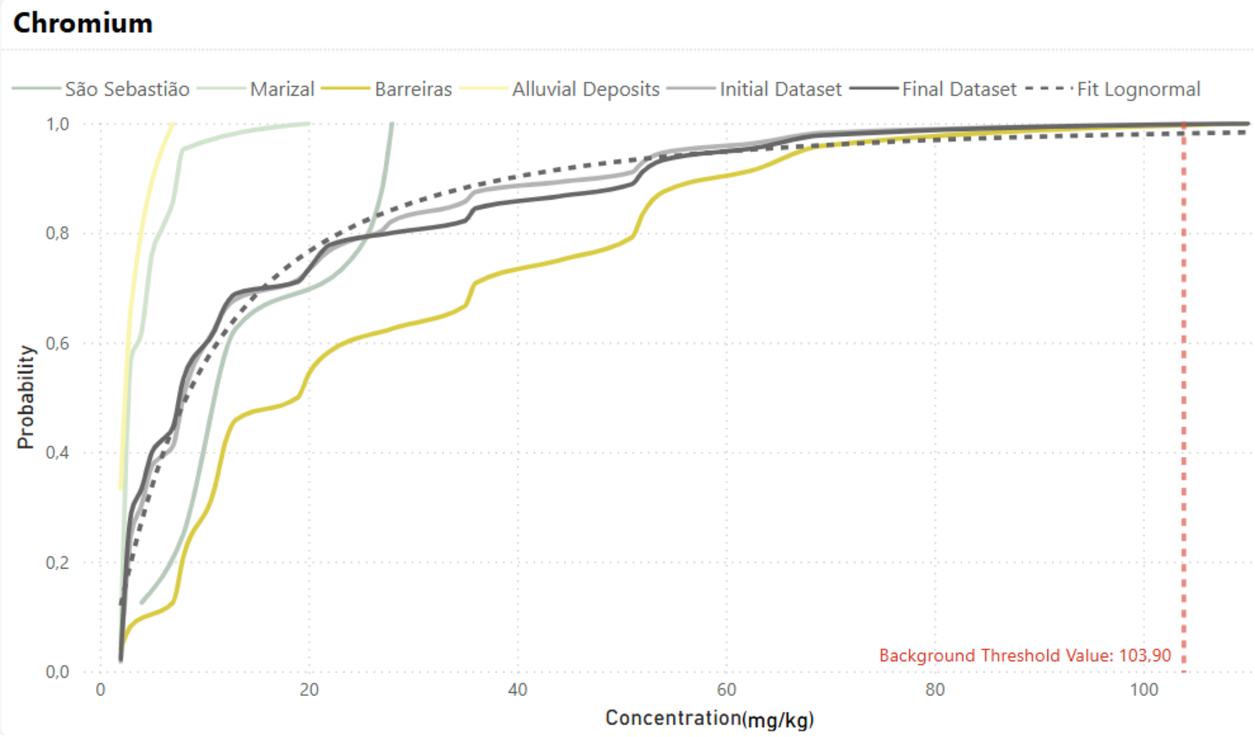
Graph B.3 - Cumulative distribution functions (cdf) and estimated BTV for Barium



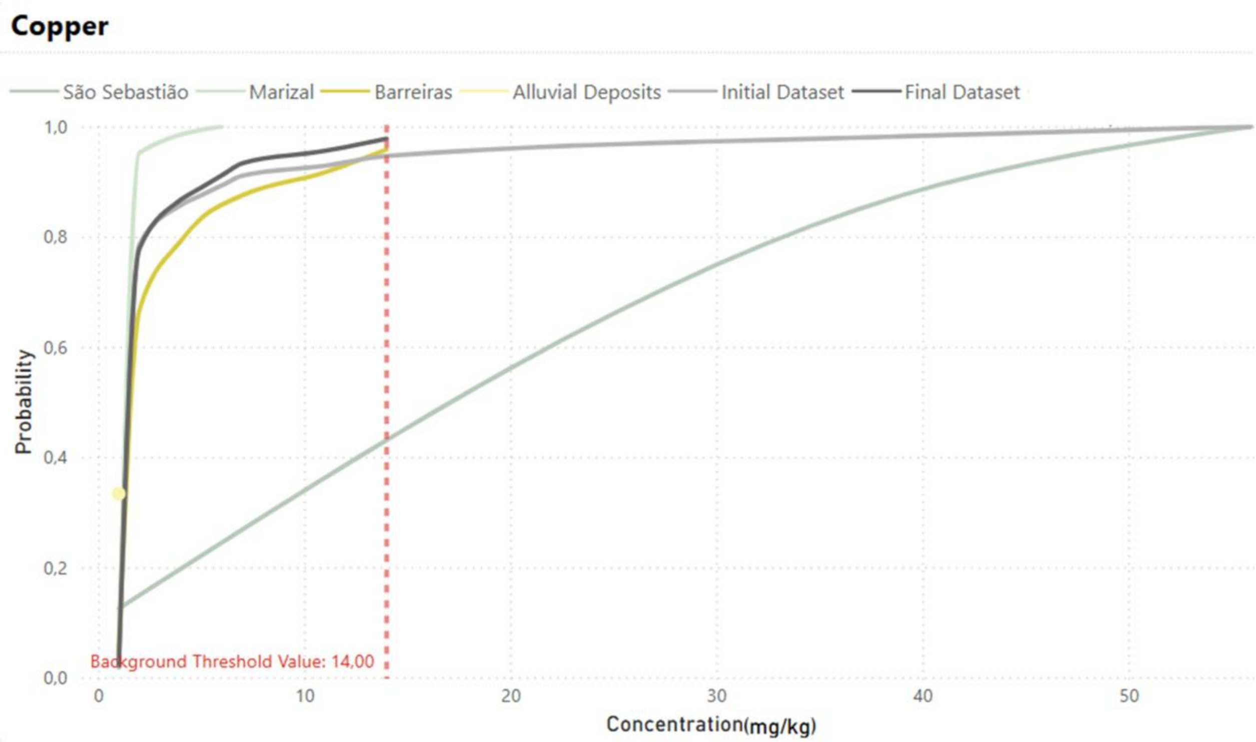
Graph B.4 - Cumulative distribution functions (cdf) and estimated BTV for Bromide



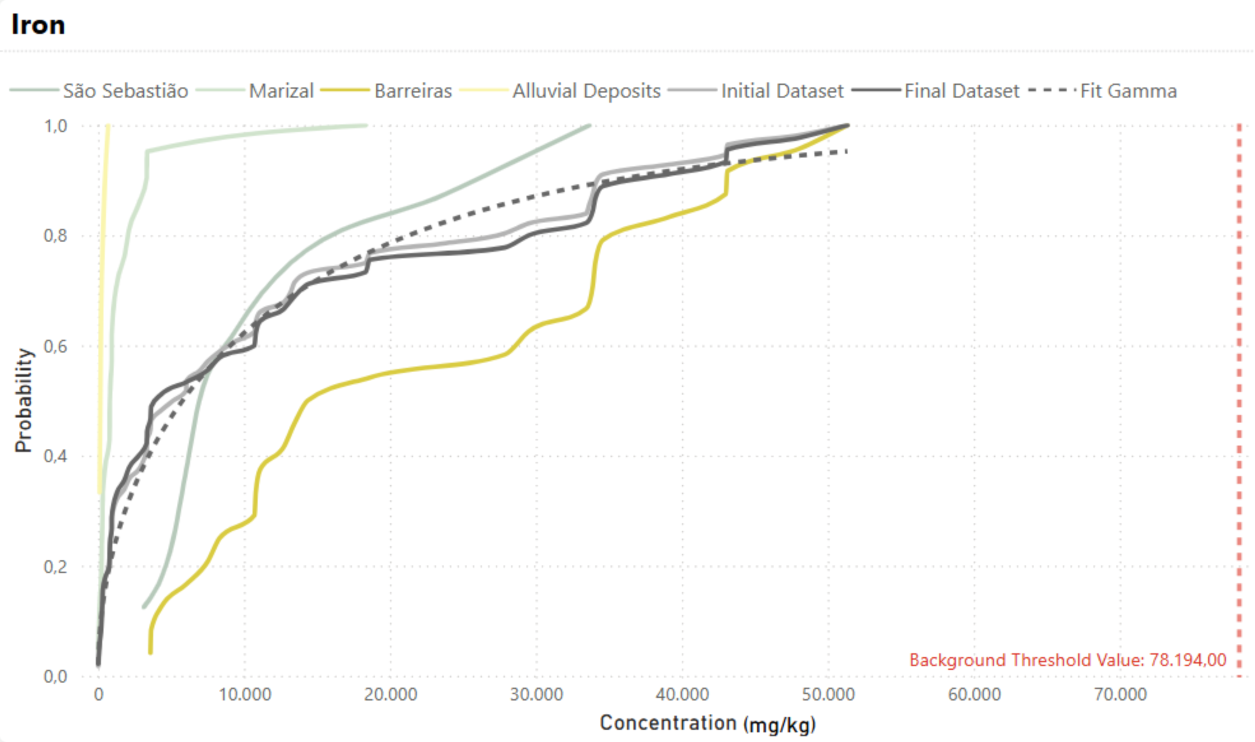
Graph B.5 – Cumulative distribution functions (cdf) and estimated BTV for Calcium



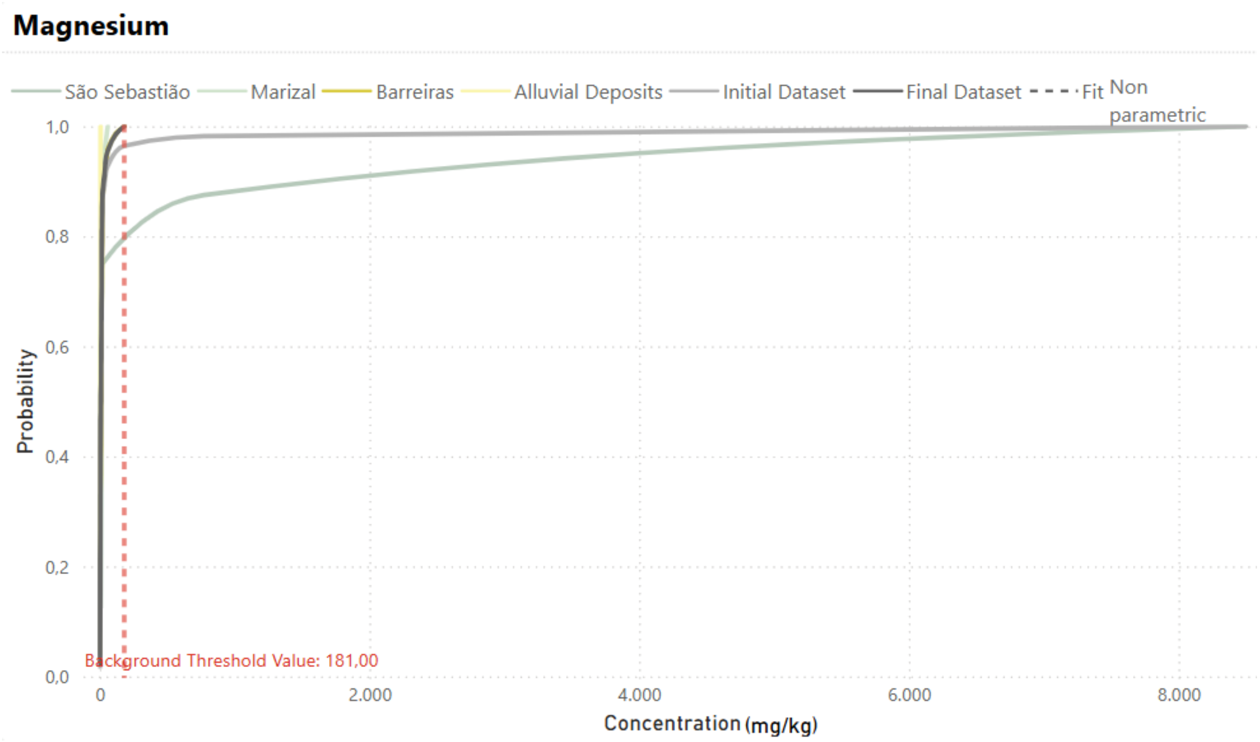
Graph B.6 – Cumulative distribution functions (cdf) and estimated BTV for Chromium



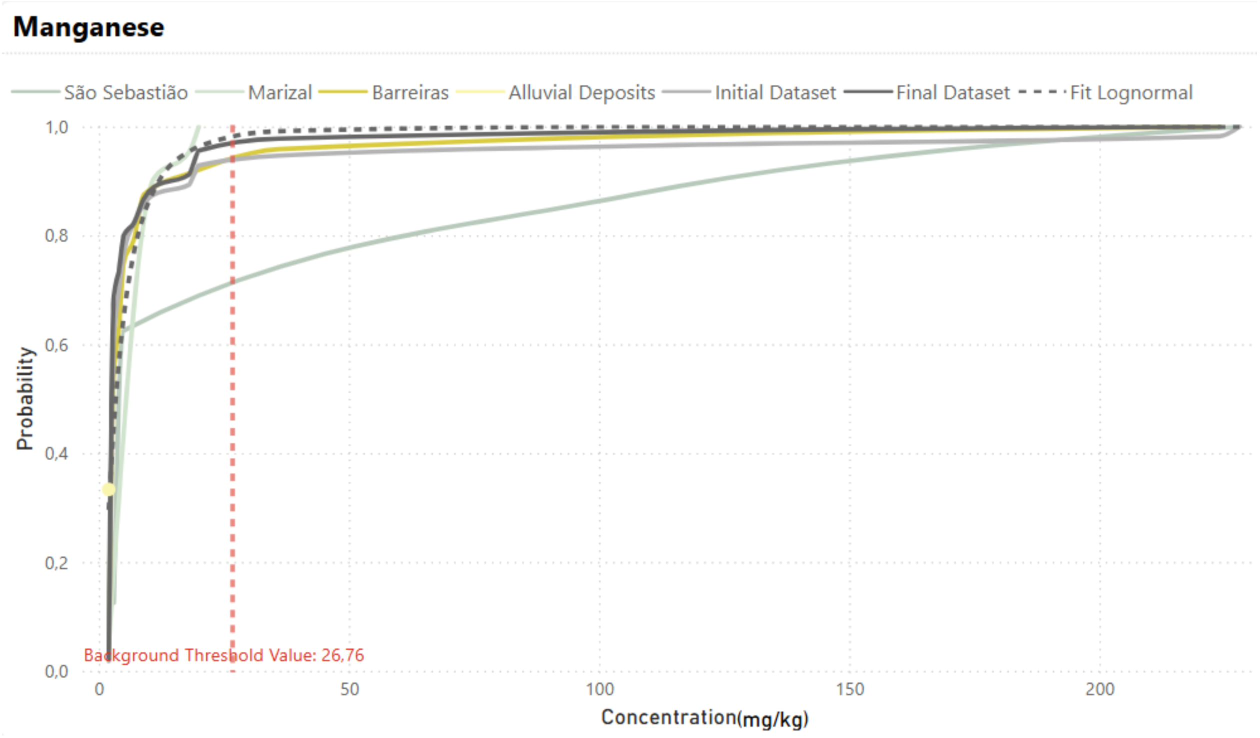
Graph B.7 – Cumulative distribution functions (cdf) and estimated BTV for Copper



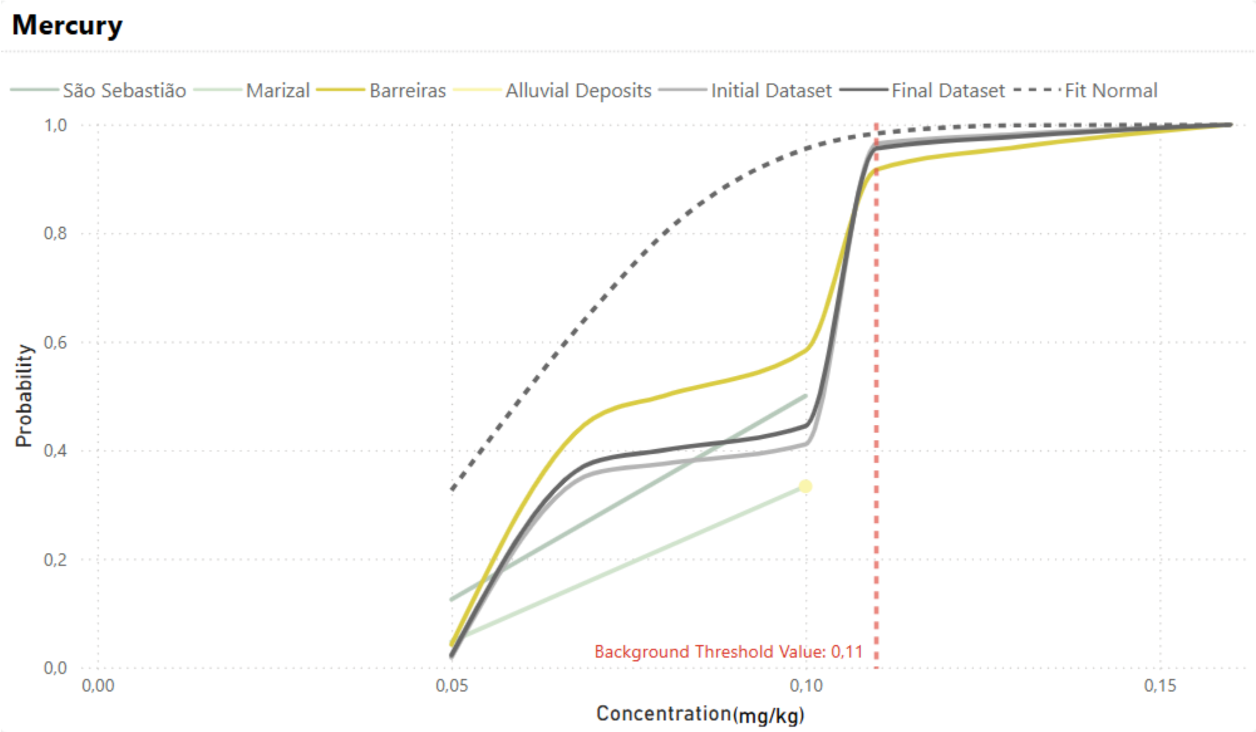
Graph B.8 – Cumulative distribution functions (cdf) and estimated BTV for Iron



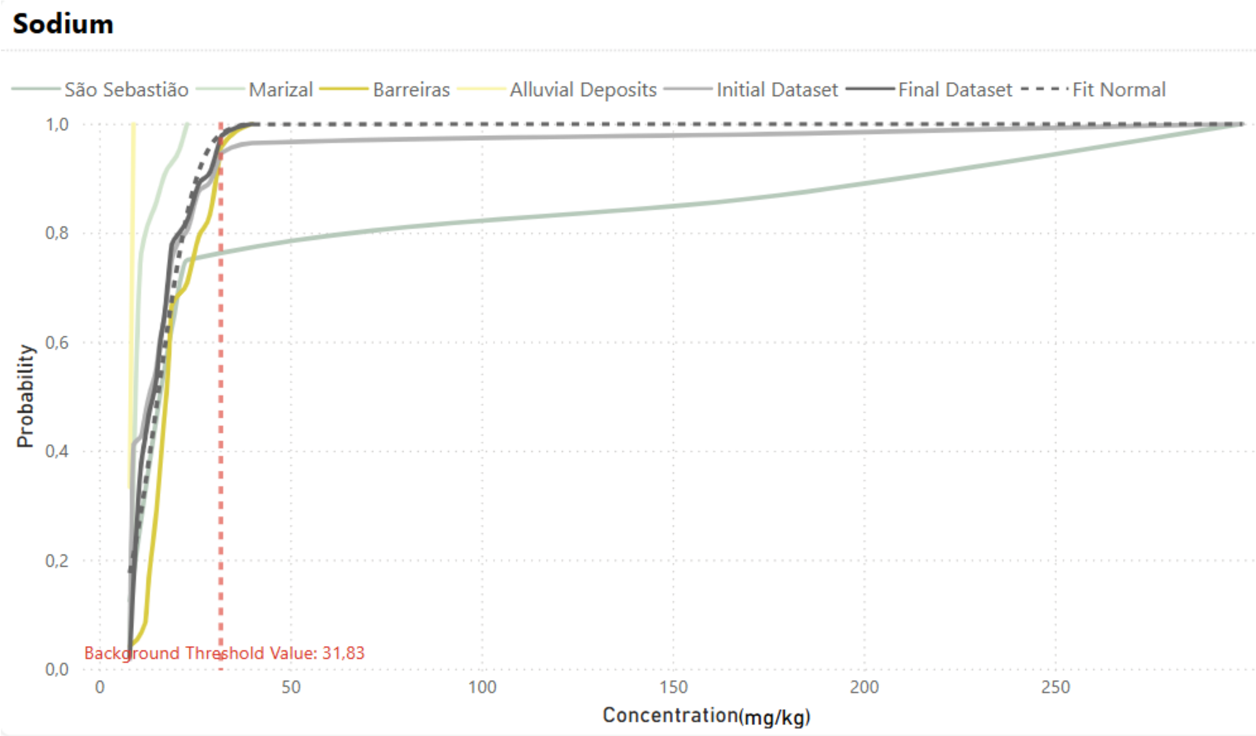
Graph B.9 – Cumulative distribution functions (cdf) and estimated BTV for Magnesium



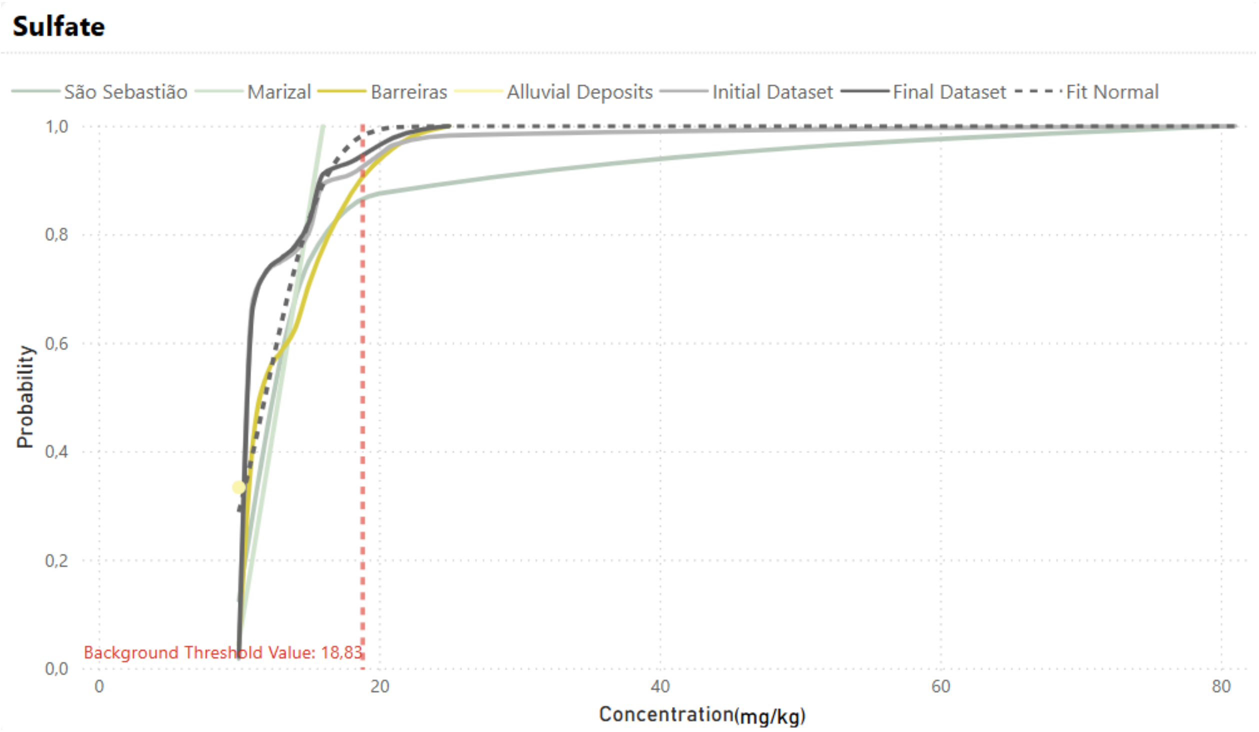
Graph B.10 – Cumulative distribution functions (cdf) and estimated BTV for Manganese



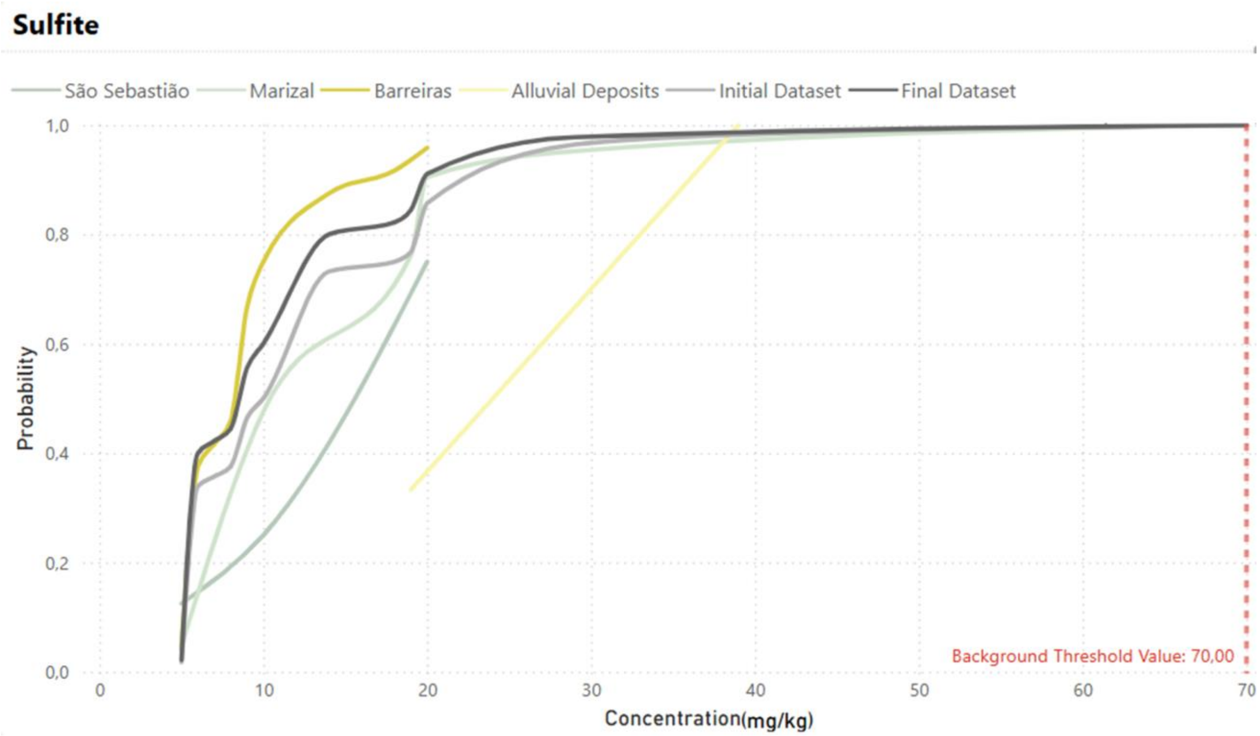
Graph B.11 – Cumulative distribution functions (cdf) and estimated BTV for Mercury



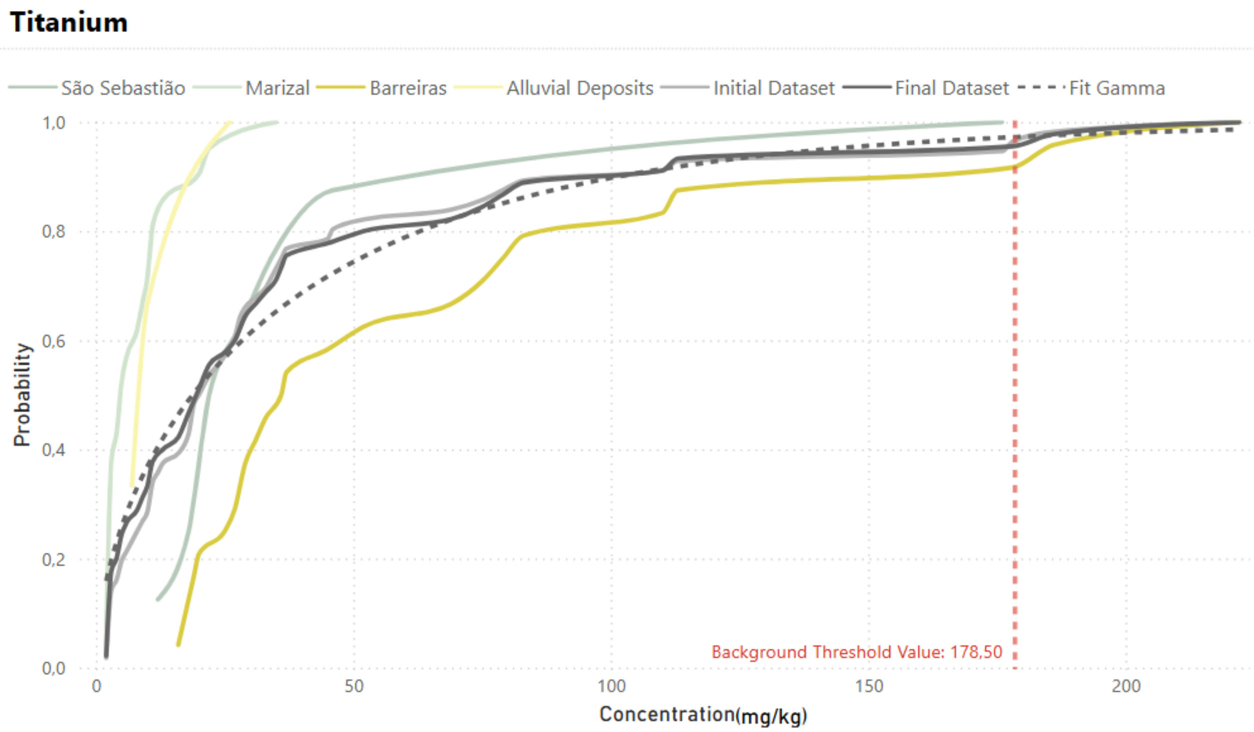
Graph B.12 – Cumulative distribution functions (cdf) and estimated BTV for Sodium



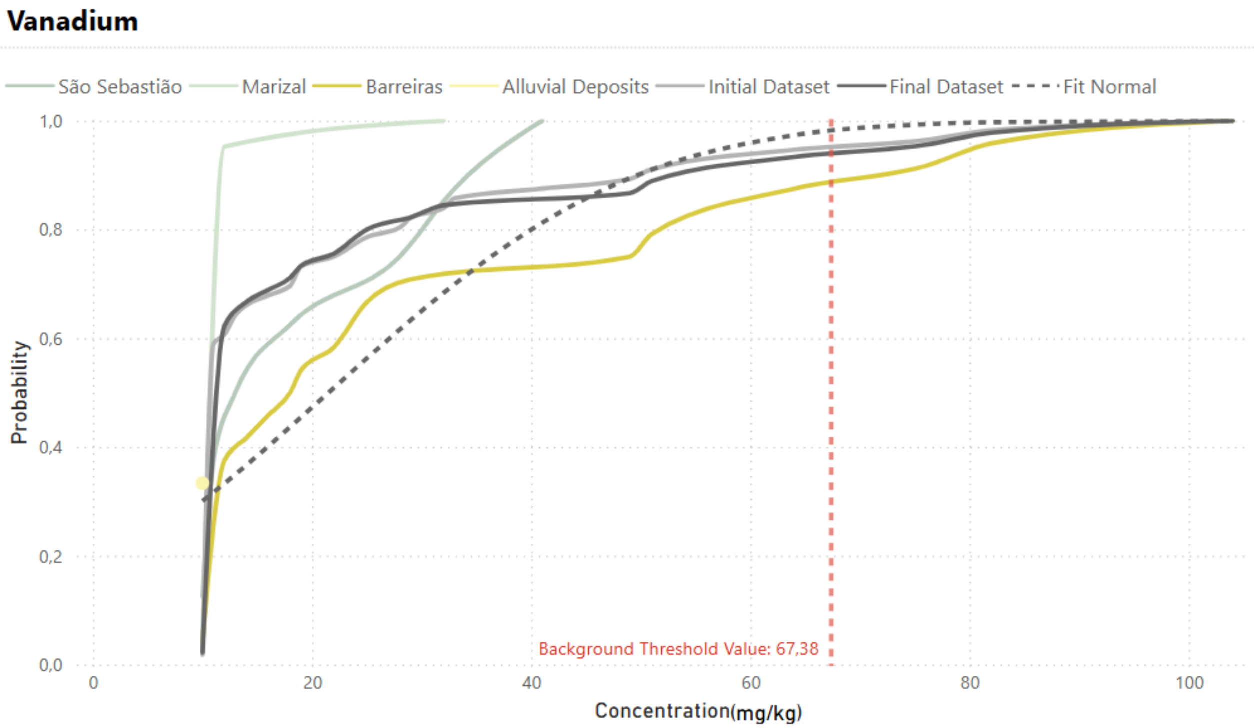
Graph B.13 – Cumulative distribution functions (cdf) and estimated BTV for Sulfate



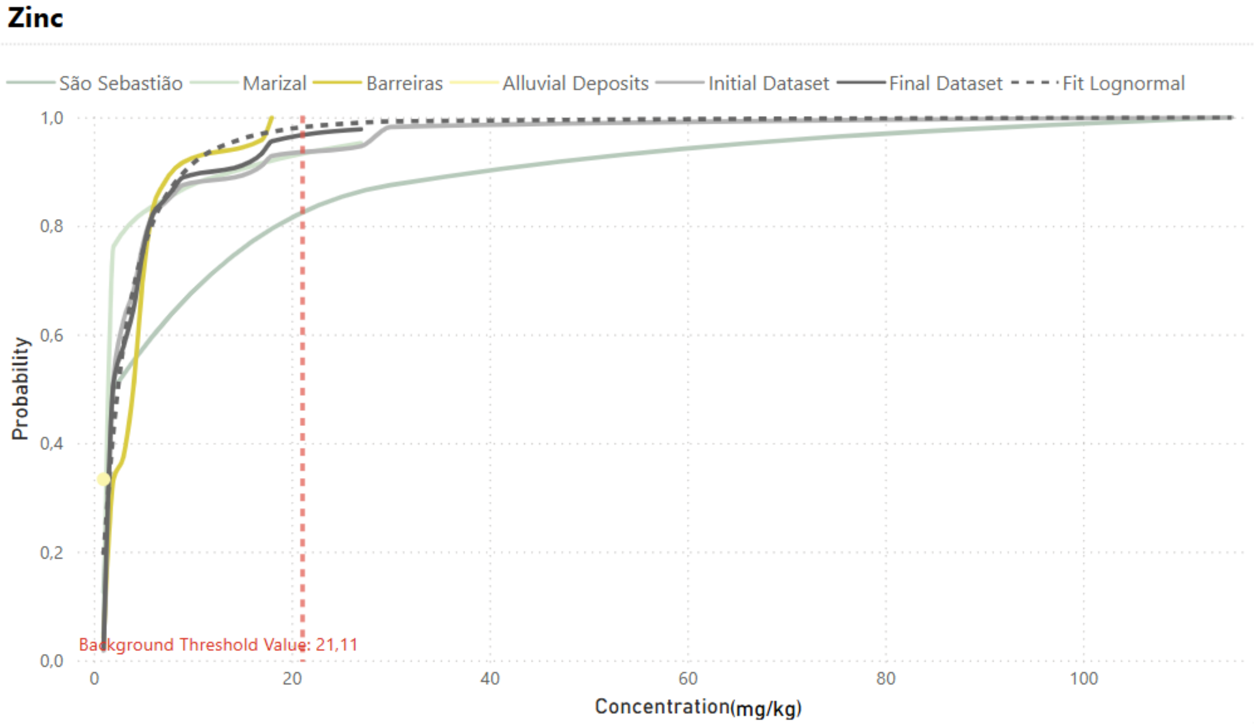
Graph B.14 – Cumulative distribution functions (cdf) and estimated BTV for Sulfite



Graph B.15 – Cumulative distribution functions (cdf) and estimated BTV for Titanium



Graph B.16 – Cumulative distribution functions (cdf) and estimated BTV for Vanadium



Graph B.17 – Cumulative distribution functions (cdf) and estimated BTV for Zinc

ANEXO A – JUSTIFICATIVA DA PARTICIPAÇÃO DOS CO-AUTORES

A participação do Prof. Dr. Harald Klammler como coautor do artigo foi importante para garantir a qualidade técnica e científica do trabalho. Ele possui ampla experiência acadêmica e científica na caracterização e remediação de aquíferos contaminados, assim como no tratamento (geo)estatístico e probabilístico de dados ambientais. Em especial, o professor Harald desempenhou um papel essencial ao contribuir de forma significativa na parte estatística, na revisão e validação dos métodos adotados e resultados obtidos, o que assegurou a robustez e a confiabilidade das análises realizadas. Além disso, o professor participou ativamente da revisão do documento, corrigindo aspectos técnicos, estruturando melhor a apresentação dos dados e aprimorando a clareza e a coesão da escrita, garantindo que as ideias fossem transmitidas de forma precisa e objetiva. Dessa forma, sua contribuição foi indispensável para o sucesso e a qualidade do artigo submetido, refletindo a importância do trabalho colaborativo.

Lattes: http://lattes.cnpq.br/2687932024943414

ORCID: https://orcid.org/0000-0002-7808-721X

Google Scholar: https://scholar.google.com/citations?user=Z38SvCYAAAAJ&hl=en

ANEXO B – REGRAS DE FORMATAÇÃO DA REVISTA ENVIRONMENTAL SCIENCE & POLICY

About the journal

Aims and scope

Environmental Science & Policy advances research in the intersections between environmental science, policy and society. The journal invites scholarship within this broad thematic that fits with one or more of the following four focal areas: 1) Studies of the relationship between the production and use of knowledge in decision making; 2) Studies of the relation between science and other forms of environmental knowledge, including practical, local and indigenous knowledge; 3) Analyses of decision making practices in government, civil society, and businesses and the ways that they engage environmental knowledge; or 4) Studies that present actionable environmental research with a clear description of how it responds to specific policy directives and the pathways by which this research is informing (or could inform) decision-making.
Research can address a wide number of environmental issues, such as climate change, food systems, biodiversity loss, human and ecological well-being, resource use- and extraction, land use change, and sustainability more generally. The journal aspires to achieve an appropriate balance between perspectives from the global North as well as the global South and welcomes discussions of (environmental) justice, equity and inclusion. The journal is particularly interested in cutting edge developments in inter- and transdisciplinary work on co-production; arts-based research; integrated nexus and landscape approaches; the trade-offs and synergies between environmental issues and policies; innovations in integrated assessment, monitoring and evaluation; and transitions and transformative change.

Editorial Policy:
Submitted articles can offer empirical analysis and can also advance new theory, conceptual frameworks or other innovations. To be considered for publication, articles should fit with the aims and scope of the journal. This means that they should address the relation between environmental science and knowledge, policy and society. To be considered, environmental research articles must go beyond simply stating potential societal and policy relevance. Submitted articles should be of international relevance and well embedded in relevant scholarly conversations and debates, and they should consider the scholarship that has been published in the journal. They should provide a compelling objective and specify how they advance the state of the knowledge beyond the current state of the art. In-depth case studies or local issues may be considered if articles clearly and sufficiently articulate their wider international significance.

The journal will consider the following article types: research papers, reviews, perspectives, and letters to the editor. Specific requirements and guidance for each article type can be found in the guide for authors. The journal welcomes proposals or Special Issues, guidance for preparing and submitting a proposal can be found here. Authors should not submit to a special issue unless they have explicit approval by the managing guest editor of the special issue.

Benefits to Authors: We also provide many author benefits, such as free PDFs, a liberal copyright policy, special discounts on Elsevier publications and much more. Please click here for more information on our author services.

Please see our Guide for Authors for information on article submission. If you require any further information or help, please visit our Support Center

Article types

The journal will consider the following article types: research papers, reviews, perspectives, and letters to the editor. Specific requirements and guidance for each article type can be found in the guide for authors. The journal welcomes proposals or Special Issues, guidance for preparing and submitting a proposal can be found here. Authors should not submit to a special issue unless they have explicit approval by the managing guest editor of the special issue.

Research papers

Research papers present original research. Research papers can be up to 7000 words maximum (excluding reference list, tables, figures, captions, author details, titles, abstract and acknowledgement). Research papers that exceed this limit will be automatically returned to the author. Research papers have to advance knowledge and understanding beyond the current state of the art and they should clearly articulate their contribution to key scientific debates on the topic of the manuscript. Research papers must also contain a description of their methods including the different steps taken to collect and analyze the data (there is the option to submit an expanded version as a separate MethodsX paper in an open access journal or as supplementary material).

Reviews

Reviews offer a synthesis of scientific publications and typically do not present original research results. The journal will consider so-called systematic as well as focused and critical review articles. Reviews can be up to 7000 words (excluding reference list, tables, figures, captions, author details, titles, abstract and acknowledgement). Reviews that exceed this limit will be automatically returned to the author. Reviews have to advance knowledge and understanding beyond the current state of the art and they should clearly assess current research in the context of key debates on the topic and identify potential pathways forward in this field of review. Reviews must contain a description of their approach taken to select and synthesize the literature that they discuss (there is the option to submit an expanded version as a separate MethodsX paper in an open access journal or as supplementary material).

Perspectives

Perspectives are cutting edge articles at the forefront of current scholarly, societal, or political debates and developments of international significance. They offer a rigorous academic argument that is well-referenced using international scientific literature. Perspectives must fit with squarely within the journal's aims and scope and they should clearly articulate their contribution to relevant scientific, societal and/or policy debates. Although the arguments that a perspective advances must be well substantiated, a perspective typically does not present a comprehensive or systematic review of literature, or a detailed methodological description. Perspectives can be up to 5000 words (excluding reference list, tables, figures, captions, author details, titles, abstract and acknowledgement). Perspectives that exceed this limit will be automatically returned to the author.

Letters to the editor

Letters to the editor are short articles that directly respond to published articles in ES&P. Letters are meant to offer a rapid response and dialogical space to advance key scientific debates and raise awareness about areas of consensus and dissensus around specific topics, research results, methodological approaches and theoretical perspectives. They can be up to 1000 words (excluding reference list, tables, figures, captions, author details, titles, abstract and acknowledgement) and can contain maximum 10 references. Letters to the editor that exceed these limits will be automatically returned to the author. Letters must specify what article they respond to and should clearly articulate a contrasting view or offer additional constructive points of views that help delineate the target article's contribution to key scientific debates. In case the journal intends to consider the letter for publication, the authors of the original article will be offered the opportunity to submit a counter response. The journal editors can decide whether to consider further exchanges on the topic for publication.

Special Issues

The journal welcomes proposals or Special Issues, guidance for preparing and submitting a proposal can be found here.

Authors should not submit to a special issue unless they have explicit approval by the managing guest editor of the special issue.

Peer review

This journal follows a double anonymized review process. Your submission will initially be assessed by our editors to determine suitability for publication in this journal. If your submission is deemed suitable, it will typically be sent to a minimum of two reviewers for an independent expert assessment of the scientific quality. The decision as to whether your article is accepted or rejected will be taken by our editors. Authors who wish to appeal the editorial decision for their manuscript may submit a formal appeal request in accordance with the procedure outlined in Elsevier’s Appeal Policy. Only one appeal per submission will be considered and the appeal decision will be final.

Read more about peer review.

Our editors are not involved in making decisions about papers which:

- they have written themselves.
- have been written by family members or colleagues.
- relate to products or services in which they have an interest.

Any such submissions will be subject to the journal's usual procedures and peer review will be handled independently of the editor involved and their research group. Read more about editor duties.

Special issues and article collections

The peer review process for special issues and article collections follows the same process as outlined above for regular submissions, except, a guest editor will send the submissions out to the reviewers and may recommend a decision to the journal editor. The journal editor oversees the peer review process of all special issues and article collections to ensure the high standards of publishing ethics and responsiveness are respected and is responsible for the final decision regarding acceptance or rejection of articles.

Open access

We refer you to our open access information page to learn about open access options for this journal.

Ethics and policies

Ethics in publishing

Authors must follow ethical guidelines stated in Elsevier's Publishing Ethics Policy.

Submission declaration

When authors submit an article to an Elsevier journal it is implied that:

- the work described has not been published previously except in the form of a preprint, an abstract, a published lecture, academic thesis or registered report. See our policy on multiple, redundant or concurrent publication.
- the article is not under consideration for publication elsewhere.
- the article's publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out.
- if accepted, the article will not be published elsewhere in the same form, in English or in any other language, including electronically, without the written consent of the copyright-holder.

To verify compliance with our journal publishing policies, we may check your manuscript with our screening tools.

Authorship

All authors should have made substantial contributions to all of the following:

1. The conception and design of the study, or acquisition of data, or analysis and interpretation of data.
2. Drafting the article or revising it critically for important intellectual content.
3. Final approval of the version to be submitted.

Authors should appoint a corresponding author to communicate with the journal during the editorial process. All authors should agree to be accountable for all aspects of the work to ensure that the questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Changes to authorship

The editors of this journal generally will not consider changes to authorship once a manuscript has been submitted. It is important that authors carefully consider the authorship list and order of authors and provide a definitive author list at original submission.

The policy of this journal around authorship changes:

- All authors must be listed in the manuscript and their details entered into the submission system.

- Any addition, deletion or rearrangement of author names in the authorship list should only be made prior to acceptance, and only if approved by the journal editor.
- Requests to change authorship should be made by the corresponding author, who must provide the reason for the request to the journal editor with written confirmation from all authors, including any authors being added or removed, that they agree with the addition, removal or rearrangement.
- All requests to change authorship must be submitted using this form. Requests which do not comply with the instructions outlined in the form will not be considered.
- Only in exceptional circumstances will the journal editor consider the addition, deletion or rearrangement of authors post acceptance.
- Publication of the manuscript may be paused while a change in authorship request is being considered.
- Any authorship change requests approved by the journal editor will result in a corrigendum if the manuscript has already been published.
- Any unauthorised authorship changes may result in the rejection of the article, or retraction, if the article has already been published.

Declaration of interests

All authors must disclose any financial and personal relationships with other people or organizations that could inappropriately influence or bias their work. Examples of potential competing interests include:

- Employment
- Consultancies
- Stock ownership
- Honoraria
- Paid expert testimony
- Patent applications or registrations
- Grants or any other funding

The Declaration of Interests tool should always be completed.

Authors with no competing interests to declare should select the option, "I have nothing to declare".

The resulting Word document containing your declaration should be uploaded at the "attach/upload files" step in the submission process. It is important that the Word document is saved in the .doc/.docx file format. Author signatures are not required.

We advise you to read our policy on conflict of interest statements, funding source declarations, author agreements/declarations and permission notes.

Funding sources

Authors must disclose any funding sources who provided financial support for the conduct of the research and/or preparation of the article. The role of sponsors, if any, should be declared in relation to the study design, collection, analysis and interpretation of data, writing of the report and decision to submit the article for publication. If funding sources had no such involvement this should be stated in your submission.

List funding sources in this standard way to facilitate compliance to funder's requirements:

Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

It is not necessary to include detailed descriptions on the program or type of grants, scholarships and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding.

If no funding has been provided for the research, it is recommended to include the following sentence:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of generative AI in scientific writing

Authors must declare the use of generative AI in scientific writing upon submission of the paper. The following guidance refers only to the writing process, and not to the use of AI tools to analyse and draw insights from data as part of the research process:

- Generative AI and AI-assisted technologies should only be used in the writing process to improve the readability and language of the manuscript.
- The technology must be applied with human oversight and control and authors should carefully review and edit the result, as AI can generate authoritative-sounding output that can be incorrect, incomplete or biased. Authors are ultimately responsible and accountable for the contents of the work.
- Authors must not list or cite AI and AI-assisted technologies as an author or co-author on the manuscript since authorship implies responsibilities and tasks that can only be attributed to and performed by humans.

The use of generative AI and AI-assisted technologies in scientific writing must be declared by adding a statement at the end of the manuscript when the paper is first submitted. The statement will appear in the published work and should be placed in a new section before the references list. An example:

- Title of new section: Declaration of generative AI and AI-assisted technologies in the writing process.
- Statement: During the preparation of this work the author(s) used [NAME TOOL / SERVICE] in order to [REASON]. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

The declaration does not apply to the use of basic tools, such as tools used to check grammar, spelling and references. If you have nothing to disclose, you do not need to add a statement.

Please read Elsevier’s author policy on the use of generative AI and AI-assisted technologies, which can be found in our GenAI Policies for journals.

Please note: to protect authors’ rights and the confidentiality of their research, this journal does not currently allow the use of generative AI or AI-assisted technologies such as ChatGPT or similar services by reviewers or editors in the peer review and manuscript evaluation process, as is stated in our GenAI Policies for journals. We are actively evaluating compliant AI tools and may revise this policy in the future.

Preprints

Preprint sharing

Authors may share preprints in line with Elsevier's article sharing policy. Sharing preprints, such as on a preprint server, will not count as prior publication.

We advise you to read our policy on multiple, redundant or concurrent publication.

Use of inclusive language

Inclusive language acknowledges diversity, conveys respect to all people, is sensitive to differences, and promotes equal opportunities. Authors should ensure their work uses inclusive language throughout and contains nothing which might imply one individual is superior to another on the grounds of:

- age
- gender
- race
- ethnicity
- culture
- sexual orientation
- disability or health condition

We recommend avoiding the use of descriptors about personal attributes unless they are relevant and valid. Write for gender neutrality with the use of plural nouns ("clinicians, patients/clients") as default. Wherever possible, avoid using "he, she," or "he/she."

No assumptions should be made about the beliefs of readers and writing should be free from bias, stereotypes, slang, reference to dominant culture and/or cultural assumptions.

These guidelines are meant as a point of reference to help you identify appropriate language but are by no means exhaustive or definitive.

Reporting sex- and gender-based analyses

There is no single, universally agreed-upon set of guidelines for defining sex and gender. We offer the following guidance:

- Sex and gender-based analyses (SGBA) should be integrated into research design when research involves or pertains to humans, animals or eukaryotic cells. This should be done in accordance with any requirements set by funders or sponsors and best practices within a field.
- Sex and/or gender dimensions of the research should be addressed within the article or declared as a limitation to the generalizability of the research.
- Definitions of sex and/or gender applied should be explicitly stated to enhance the precision, rigor and reproducibility of the research and to avoid ambiguity or conflation of terms and the constructs to which they refer.

We advise you to read the Sex and Gender Equity in Research (SAGER) guidelines and the SAGER checklist (PDF) on the EASE website, which offer systematic approaches to the use of sex and gender information in study design, data analysis, outcome reporting and research interpretation.

For further information we suggest reading the rationale behind and recommended use of the SAGER guidelines.

Definitions of sex and/or gender

We ask authors to define how sex and gender have been used in their research and publication. Some guidance:

- Sex generally refers to a set of biological attributes that are associated with physical and physiological features such as chromosomal genotype, hormonal levels, internal and external anatomy. A binary sex categorization (male/female) is usually designated at birth ("sex assigned at birth") and is in most cases based solely on the visible external anatomy of a newborn. In reality, sex categorizations include people who are intersex/have differences of sex development (DSD).
- Gender generally refers to socially constructed roles, behaviors and identities of women, men and gender-diverse people that occur in a historical and cultural context and may vary across societies and over time. Gender influences how people view themselves and each other, how they behave and interact and how power is distributed in society.

Jurisdictional claims

Elsevier respects the decisions taken by its authors as to how they choose to designate territories and identify their affiliations in their published content. Elsevier’s policy is to take a neutral position with respect to territorial disputes or jurisdictional claims, including, but not limited to, maps and institutional affiliations. For journals that Elsevier publishes on behalf of a third party owner, the owner may set its own policy on these issues.

- Maps: Readers should be able to locate any study areas shown within maps using common mapping platforms. Maps should only show the area actually studied and authors should not include a location map which displays a larger area than the bounding box of the study area. Authors should add a note clearly stating that "*map lines delineate study areas and do not necessarily depict accepted national boundaries*”. During the review process, Elsevier’s editors may request authors to change maps if these guidelines are not followed.

- Institutional affiliations: Authors should use either the full, standard title of their institution or the standard abbreviation of the institutional name so that the institutional name can be independently verified for research integrity purposes.

Writing and formatting

File format

We ask you to provide editable source files for your entire submission (including figures, tables and text graphics). Some guidelines:

- Save files in an editable format, using the extension .doc/.docx for Word files and .tex for LaTeX files. A PDF is not an acceptable source file.
- Lay out text in a single-column format.
- Use spell-check and grammar-check functions to avoid errors.

We advise you to read our Step-by-step guide to publishing with Elsevier.

LaTeX

We encourage you use our LaTeX template when preparing a LaTeX submission. You will be asked to provide all relevant editable source files upon submission or revision.

Support for your LaTeX submission:

- LaTeX submission instructions and templates
- Journal Article Publishing Support Center LaTeX FAQs and support
- Researcher Academy’s Beginners’ guide to writing a manuscript in LaTeX

Double anonymized peer review

This journal follows a double anonymized review process which means author identities are concealed from reviewers and vice versa.To facilitate the double anonymized review process, we ask that you provide your title page (including author details) and anonymized manuscript (excluding author details) separately in your submission.

The title page should include:

- Article title
- Author name(s)
- Affiliation(s)
- Acknowledgements
- Declaration of Interest statement
- Corresponding author address (full address is required)

- Corresponding author email address

The anonymized manuscript should contain the main body of your paper including:

- References
- Figures
- Tables

It is important that your anonymized manuscript does not contain any identifying information such as author names or affiliations.

Read more about peer review.

Title page

You are required to include the following details in the title page information:

- Article title. Article titles should be concise and informative. Please avoid abbreviations and formulae, where possible, unless they are established and widely understood, e.g., DNA).
- Author names. Provide the given name(s) and family name(s) of each author. The order of authors should match the order in the submission system. Carefully check that all names are accurately spelled. If needed, you can add your name between parentheses in your own script after the English transliteration.
- Affiliations. Add affiliation addresses, referring to where the work was carried out, below the author names. Indicate affiliations using a lower-case superscript letter immediately after the author's name and in front of the corresponding address. Ensure that you provide the full postal address of each affiliation, including the country name and, if available, the email address of each author.
- Corresponding author. Clearly indicate who will handle correspondence for your article at all stages of the refereeing and publication process and also post-publication. This responsibility includes answering any future queries about your results, data, methodology and materials. It is important that the email address and contact details of your corresponding author are kept up to date during the submission and publication process.
- Present/permanent address. If an author has moved since the work described in your article was carried out, or the author was visiting during that time, a "present address" (or "permanent address") can be indicated by a footnote to the author's name. The address where the author carried out the work must be retained as their main affiliation address. Use superscript Arabic numerals for such footnotes.

Abstract

You are required to provide a concise and factual abstract which does not exceed 250 words. The abstract should briefly state the purpose of your research, principal results and major conclusions. Some guidelines:

- Abstracts must be able to stand alone as abstracts are often presented separately from the article.
- Avoid references. If any are essential to include, ensure that you cite the author(s) and year(s).

- Avoid non-standard or uncommon abbreviations. If any are essential to include, ensure they are defined within your abstract at first mention.

Keywords

You are required to provide 1 to 7 keywords for indexing purposes. Keywords should be written in English. Please try to avoid keywords consisting of multiple words (using "and" or "of").

We recommend that you only use abbreviations in keywords if they are firmly established in the field.

Highlights

You are required to provide article highlights at submission.

Highlights are a short collection of bullet points that should capture the novel results of your research as well as any new methods used during your study. Highlights will help increase the discoverability of your article via search engines. Some guidelines:

- Submit highlights as a separate editable file in the online submission system with the word "highlights" included in the file name.
- Highlights should consist of 3 to 5 bullet points, each a maximum of 85 characters, including spaces.

We encourage you to view example article highlights and read about the benefits of their inclusion.

Graphical abstract

You are encouraged to provide a graphical abstract at submission.

The graphical abstract should summarize the contents of your article in a concise, pictorial form which is designed to capture the attention of a wide readership. A graphical abstract will help draw more attention to your online article and support readers in digesting your research. Some guidelines:

- Submit your graphical abstract as a separate file in the online submission system.
- Ensure the image is a minimum of 531 x 1328 pixels (h x w) or proportionally more and is readable at a size of 5 x 13 cm using a regular screen resolution of 96 dpi.
- Our preferred file types for graphical abstracts are TIFF, EPS, PDF or MS Office files.

We encourage you to view example graphical abstracts and read about the benefits of including them.

Units, classifications codes and nomenclature

This journal requires you to use the international system of units (SI) which follows internationally accepted rules and conventions. If other units are mentioned within your article, you should provide the equivalent unit in SI.

Tables

Tables must be submitted as editable text, not as images. Some guidelines:

- Place tables next to the relevant text or on a separate page(s) at the end of your article.

- Cite all tables in the manuscript text.
- Number tables consecutively according to their appearance in the text.
- Please provide captions along with the tables.
- Place any table notes below the table body.
- Avoid vertical rules and shading within table cells.

We recommend that you use tables sparingly, ensuring that any data presented in tables is not duplicating results described elsewhere in the article.

Figures, images and artwork

Figures, images, artwork, diagrams and other graphical media must be supplied as separate files along with the manuscript. We recommend that you read our detailed artwork and media instructions. Some excerpts:

When submitting artwork:

- Cite all images in the manuscript text.
- Number images according to the sequence they appear within your article.
- Submit each image as a separate file using a logical naming convention for your files (for example, Figure_1, Figure_2 etc).
- Please provide captions for all figures, images, and artwork.
- Text graphics may be embedded in the text at the appropriate position. If you are working with LaTeX, text graphics may also be embedded in the file.

Artwork formats

When your artwork is finalized, "save as" or convert your electronic artwork to the formats listed below taking into account the given resolution requirements for line drawings, halftones, and line/halftone combinations:

- Vector drawings: Save as EPS or PDF files embedding the font or saving the text as "graphics."
- Color or grayscale photographs (halftones): Save as TIFF, JPG or PNG files using a minimum of 300 dpi (for single column: min. 1063 pixels, full page width: 2244 pixels).
- Bitmapped line drawings: Save as TIFF, JPG or PNG files using a minimum of 1000 dpi (for single column: min. 3543 pixels, full page width: 7480 pixels).
- Combinations bitmapped line/halftones (color or grayscale): Save as TIFF, JPG or PNG files using a minimum of 500 dpi (for single column: min. 1772 pixels, full page width: 3740 pixels).

Please do not submit:

- files that are too low in resolution (for example, files optimized for screen use such as GIF, BMP, PICT or WPG files).

- disproportionally large images compared to font size, as text may become unreadable.

Figure captions

All images must have a caption. A caption should consist of a brief title (not displayed on the figure itself) and a description of the image. We advise you to keep the amount of text in any image to a minimum, though any symbols and abbreviations used should be explained.

Provide captions in a separate file.

Color artwork

If you submit usable color figures with your accepted article, we will ensure that they appear in color online.

Please ensure that color images are accessible to all, including those with impaired color vision. Learn more about color and web accessibility.

For articles appearing in print, you will be sent information on costs to reproduce color in the printed version, after your accepted article has been sent to production. At this stage, please indicate if your preference is to have color only in the online version of your article or also in the printed version.

Generative AI and Figures, images and artwork

Please read our policy on the use of generative AI and AI-assisted tools in figures, images and artwork, which can be found in Elsevier's GenAI Policies for Journals. This policy states:

- We do not permit the use of Generative AI or AI-assisted tools to create or alter images in submitted manuscripts.
- The only exception is if the use of AI or AI-assisted tools is part of the research design or methods (for example, in the field of biomedical imaging). If this is the case, such use must be described in a reproducible manner in the methods section, including the name of the model or tool, version and extension numbers, and manufacturer.
- The use of generative AI or AI-assisted tools in the production of artwork such as for graphical abstracts is not permitted. The use of generative AI in the production of cover art may in some cases be allowed, if the author obtains prior permission from the journal editor and publisher, can demonstrate that all necessary rights have been cleared for the use of the relevant material, and ensures that there is correct content attribution.

Supplementary material

We encourage the use of supplementary materials such as applications, images and sound clips to enhance research. Some guidelines:

- Cite all supplementary files in the manuscript text.
- Submit supplementary materials at the same time as your article. Be aware that all supplementary materials provided will appear online in the exact same file type as received. These files will not be formatted or typeset by the production team.

- Include a concise, descriptive caption for each supplementary file describing its content.
- Provide updated files if at any stage of the publication process you wish to make changes to submitted supplementary materials.
- Do not make annotations or corrections to a previous version of a supplementary file.
- Switch off the option to track changes in Microsoft Office files. If tracked changes are left on, they will appear in your published version.

We recommend you upload research data to a suitable specialist or generalist repository. Please read our guidelines on sharing research data for more information on depositing, sharing and using research data and other relevant research materials.

Video

This journal accepts video material and animation sequences to support and enhance your scientific research. We encourage you to include links to video or animation files within articles. Some guidelines:

- When including video or animation file links within your article, refer to the video or animation content by adding a note in your text where the file should be placed.
- Clearly label files ensuring the given file name is directly related to the file content.
- Provide files in one of our recommended file formats. Files should be within our preferred maximum file size of 150 MB per file, 1 GB in total.
- Provide "stills" for each of your files. These will be used as standard icons to personalize the link to your video data. You can choose any frame from your video or animation or make a separate image.
- Provide text (for both the electronic and the print version) to be placed in the portions of your article that refer to the video content. This is essential text, as video and animation files cannot be embedded in the print version of the journal.

We publish all video and animation files supplied in the electronic version of your article.

For more detailed instructions, we recommend that you read our guidelines on submitting video content to be included in the body of an article.

Research data

We are committed to supporting the storage of, access to and discovery of research data, and our research data policy sets out the principles guiding how we work with the research community to support a more efficient and transparent research process.

Research data refers to the results of observations or experimentation that validate research findings, which may also include software, code, models, algorithms, protocols, methods and other useful materials related to the project.

Please read our guidelines on sharing research data for more information on depositing, sharing and using research data and other relevant research materials.

For this journal, the following instructions from our research data guidelines apply.

Option C: Research data deposit, citation and linking

You are **required** to:

- Deposit your research data in a relevant data repository.
- Cite and link to this dataset in your article.
- If this is not possible, make a statement explaining why research data cannot be shared.

Data statement

To foster transparency, you are required to state the availability of any data at submission.

Ensuring data is available may be a requirement of your funding body or institution. If your data is unavailable to access or unsuitable to post, you can state the reason why (e.g., your research data includes sensitive or confidential information such as patient data) during the submission process. This statement will appear with your published article on ScienceDirect.

Read more about the importance and benefits of providing a data statement.

Data linking

Linking to the data underlying your work increases your exposure and may lead to new collaborations. It also provides readers with a better understanding of the described research.

If your research data has been made available in a data repository there are a number of ways your article can be linked directly to the dataset:

- Provide a link to your dataset when prompted during the online submission process.
- For some data repositories, a repository banner will automatically appear next to your published article on ScienceDirect.
- You can also link relevant data or entities within the text of your article through the use of identifiers. Use the following format: Database: 12345 (e.g. TAIR: AT1G01020; CCDC: 734053; PDB: 1XFN).

Learn more about linking research data and research articles in ScienceDirect.

Research Elements

This journal enables the publication of research objects (e.g. data, methods, protocols, software and hardware) related to original research in Elsevier's Research Elements journals.

Research Elements are peer-reviewed, open access journals which make research objects findable, accessible and reusable. By providing detailed descriptions of objects and their application with links to the original research article, your research objects can be placed into context within your article.

You will be alerted during submission to the opportunity to submit a manuscript to one of the Research Elements journals. Your Research Elements article can be prepared by you, or by one of your collaborators.

Article structure

Article sections

- Divide your article into clearly defined and numbered sections. Number subsections 1.1 (then 1.1.1, 1.1.2, ...), then 1.2, etc.
- Use the numbering format when cross-referencing within your article. Do not just refer to "the text."
- You may give subsections a brief heading. Headings should appear on a separate line.
- Do not include the article abstract within section numbering.

Glossary

Please provide definitions of field-specific terms used in your article, in a separate list.

Acknowledgements

Include any individuals who provided you with help during your research, such as help with language, writing or proof reading, in the acknowledgements section. Include acknowledgements **only** in the **title page** since this journal follows a double anonymized peer review process. Do not add it as a footnote to your title.

Author contributions: CRediT

Corresponding authors are required to acknowledge co-author contributions using CRediT (Contributor Roles Taxonomy) roles:

- Conceptualization
- Data curation
- Formal analysis
- Funding acquisition
- Investigation
- Methodology
- Project administration
- Resources
- Software
- Supervision
- Validation
- Visualization
- Writing – original draft
- Writing – review and editing

Not all CRediT roles will apply to every manuscript and some authors may contribute through multiple roles.

We advise you to read more about CRediT and view an example of a CRediT author statement.

Funding sources

Authors must disclose any funding sources who provided financial support for the conduct of the research and/or preparation of the article. The role of sponsors, if any, should be declared in relation to the study design, collection, analysis and interpretation of data, writing of the report and decision to submit the article for publication. If funding sources had no such involvement this should be stated in your submission.

List funding sources in this standard way to facilitate compliance to funder's requirements:

Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

It is not necessary to include detailed descriptions on the program or type of grants, scholarships and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding.

If no funding has been provided for the research, it is recommended to include the following sentence:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendices

We ask you to use the following format for appendices:

- Identify individual appendices within your article using the format: A, B, etc.
- Give separate numbering to formulae and equations within appendices using formats such as Eq. (A.1), Eq. (A.2), etc. and in subsequent appendices, Eq. (B.1), Eq. (B. 2) etc. In a similar way, give separate numbering to tables and figures using formats such as Table A.1; Fig. A.1, etc.

Vitae

Please submit a short (maximum 100 words) biography of each author. Please provide the biography in an editable format (e.g. Word, not in PDF format).

References

References within text

Any references cited within your article should also be present in your reference list and vice versa. Some guidelines:

- References cited in your abstract must be given in full.
- We recommend that you do not include unpublished results and personal communications in your reference list, though you may mention them in the text of your article.

- Any unpublished results and personal communications included in your reference list must follow the standard reference style of the journal. In substitution of the publication date add "unpublished results" or "personal communication."
- References cited as "in press" imply that the item has been accepted for publication.

Linking to cited sources will increase the discoverability of your research.

Before submission, check that all data provided in your reference list are correct, including any references which have been copied. Providing correct reference data allows us to link to abstracting and indexing services such as Scopus, Crossref and PubMed. Any incorrect surnames, journal or book titles, publication years or pagination within your references may prevent link creation.

We encourage the use of Digital Object Identifiers (DOIs) as reference links as they provide a permanent link to the electronic article referenced.

Reference format

This journal does not set strict requirements on reference formatting at submission. Some guidelines:

- References can be in any style or format as long as the style is consistent.
- Author names, journal or book titles, chapter or article titles, year of publication, volume numbers, article numbers or pagination must be included, where applicable.
- Use of DOIs is recommended.

Our journal reference style will be applied to your article after acceptance, at proof stage. If required, at this stage we will ask you to correct or supply any missing reference data.

Reference style

All citations in the text should refer to:

- Single author: the author's name (without initials, unless there is ambiguity) and the year of publication.
- Two authors: both authors' names and the year of publication.
- Three or more authors: first author's name followed by 'et al.' and the year of publication.

Citations can be made directly (or parenthetically). Groups of references can be listed either first alphabetically, then chronologically, or vice versa. Examples: "as demonstrated (Allan, 2020a, 2020b; Allan and Jones, 2019)" or "as demonstrated (Jones, 2019; Allan, 2020). Kramer et al. (2023) have recently shown".

The list of references should be arranged alphabetically and then chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.

Abbreviate journal names according to the List of Title Word Abbreviations (LTWA).

Examples:

Reference to a journal publication:

Van der Geer, J., Handgraaf, T., Lupton, R.A., 2020. The art of writing a scientific article. J. Sci. Commun. 163, 51–59. https://doi.org/10.1016/j.sc.2020.00372.

Reference to a journal publication with an article number:

Van der Geer, J., Handgraaf, T., Lupton, R.A., 2022. The art of writing a scientific article. Heliyon. 19, e00205. https://doi.org/10.1016/j.heliyon.2022.e00205.

Reference to a book:

Strunk Jr., W., White, E.B., 2000. The Elements of Style, fourth ed. Longman, New York.

Reference to a chapter in a book:

Mettam, G.R., Adams, L.B., 2023. How to prepare an electronic version of your article, in: Jones, B.S., Smith, R.Z. (Eds.), Introduction to the Electronic Age. E-Publishing Inc., New York, pp. 281–304.

Reference to a website:

Cancer Research UK, 2023. Cancer statistics reports for the UK. http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/ (accessed 13 March 2023).

Reference to a dataset:

Oguro, M., Imahiro, S., Saito, S., Nakashizuka, T., 2015. Mortality data for Japanese oak wilt disease and surrounding forest compositions [dataset]. Mendeley Data, v1. https://doi.org/10.17632/xwj98nb39r.1.

Reference to software:

Coon, E., Berndt, M., Jan, A., Svyatsky, D., Atchley, A., Kikinzon, E., Harp, D., Manzini, G., Shelef, E., Lipnikov, K., Garimella, R., Xu, C., Moulton, D., Karra, S., Painter, S., Jafarov, E., & Molins, S., 2020. Advanced Terrestrial Simulator (ATS) v0.88 (Version 0.88) [software]. Zenodo. https://doi.org/10.5281/zenodo.3727209.

Web references

When listing web references, as a minimum you should provide the full URL and the date when the reference was last accessed. Additional information (e.g. DOI, author names, dates or reference to a source publication) should also be provided, if known.

You can list web references separately under a new heading directly after your reference list or include them in your reference list.

Data references

We encourage you to cite underlying or relevant datasets within article text and to list data references in the reference list.

When citing data references, you should include:

- author name(s)

- dataset title
- data repository
- version (where available)
- year
- global persistent identifier

Add [dataset] immediately before your reference. This will help us to properly identify the dataset. The [dataset] identifier will not appear in your published article.

Preprint references

We ask you to mark preprints clearly. You should include the word "preprint" or the name of the preprint server as part of your reference and provide the preprint DOI.

Where a preprint has subsequently become available as a peer-reviewed publication, use the formal publication as your reference.

If there are preprints that are central to your work or that cover crucial developments in the topic, but they are not yet formally published, you may reference the preprint.

Reference management software

Most Elsevier journals have their reference template available in popular reference management software products. These include products that support Citation Style Language (CSL) such as Mendeley Reference Manager.

If you use a citation plug-in from these products, select the relevant journal template and all your citations and bibliographies will automatically be formatted in the journal style. We advise you to remove all field codes before submitting your manuscript to any reference management software product.

If a template is not available for this journal, follow the format given in examples in the reference style section of this Guide for Authors.

Submitting your manuscript

Submission checklist

Before completing the submission of your manuscript, we advise you to read our submission checklist:

- One author has been designated as the corresponding author and their full contact details (email address, full postal address and phone numbers) have been provided.
- All files have been uploaded, including keywords, figure captions and tables (including a title, description and footnotes) included.
- Spelling and grammar checks have been carried out.
- All references in the article text are cited in the reference list and vice versa.

- Permission has been obtained for the use of any copyrighted material from other sources, including the Web.
- For gold open access articles, all authors understand that they are responsible for payment of the article publishing charge (APC) if the manuscript is accepted. Payment of the APC may be covered by the corresponding author's institution, or the research funder.

After receiving a final decision

Article Transfer Service

If your manuscript is more suitable for an alternative Elsevier journal, you may receive an email asking you to consider transferring your manuscript via the Elsevier Article Transfer Service.

The recommendation could come from the journal editor, a dedicated in-house scientific managing editor, a tool-assisted recommendation or a combination.

If you agree with the recommendation, your manuscript will be transferred and independently reviewed by the editors of the new journal. You will have the opportunity to make revisions, if necessary, before the submission is complete at the destination journal.

Publishing agreement

Authors will be asked to complete a publishing agreement after acceptance. The corresponding author will receive a link to the online agreement by email. We advise you to read Elsevier's policies related to copyright to learn more about our copyright policies and your, and your employer's/institution's, additional rights for subscription and gold open access articles.

License options

Authors will be offered open access user license options which will determine how you, and third parties, can reuse your gold open access article. We advise that you review these options and any funding body license requirements before selecting a license option.

Open access

We refer you to our open access information page to learn about open access options for this journal.

Permission for copyrighted works

If excerpts from other copyrighted works are included in your article, you must obtain written permission from the copyright owners and credit the source(s) within your article using Elsevier's permission request and license form (Word).

Proof correction

To ensure a fast publication process we will ask you to provide proof corrections within two days.

Corresponding authors will be sent an email which includes a link to our online proofing system, allowing annotation and correction of proofs online. The environment is similar to Word. You can edit text, comment on figures and tables and answer questions raised by our copy editor. Our web-based proofing service ensures a faster and less error-prone process.

You can choose to annotate and upload your edits on the PDF version of your article, if preferred. We will provide you with proofing instructions and available alternative proofing methods in our email.

The purpose of the proof is to check the typesetting, editing, completeness and correctness of your article text, tables and figures. Significant changes to your article at the proofing stage will only be considered with approval of the journal editor.

Responsible sharing

We encourage you to share and promote your article to give additional visibility to your work, enabling your paper to contribute to scientific progress and foster the exchange of scientific developments within your field. Read more about how to responsibly share and promote your article.

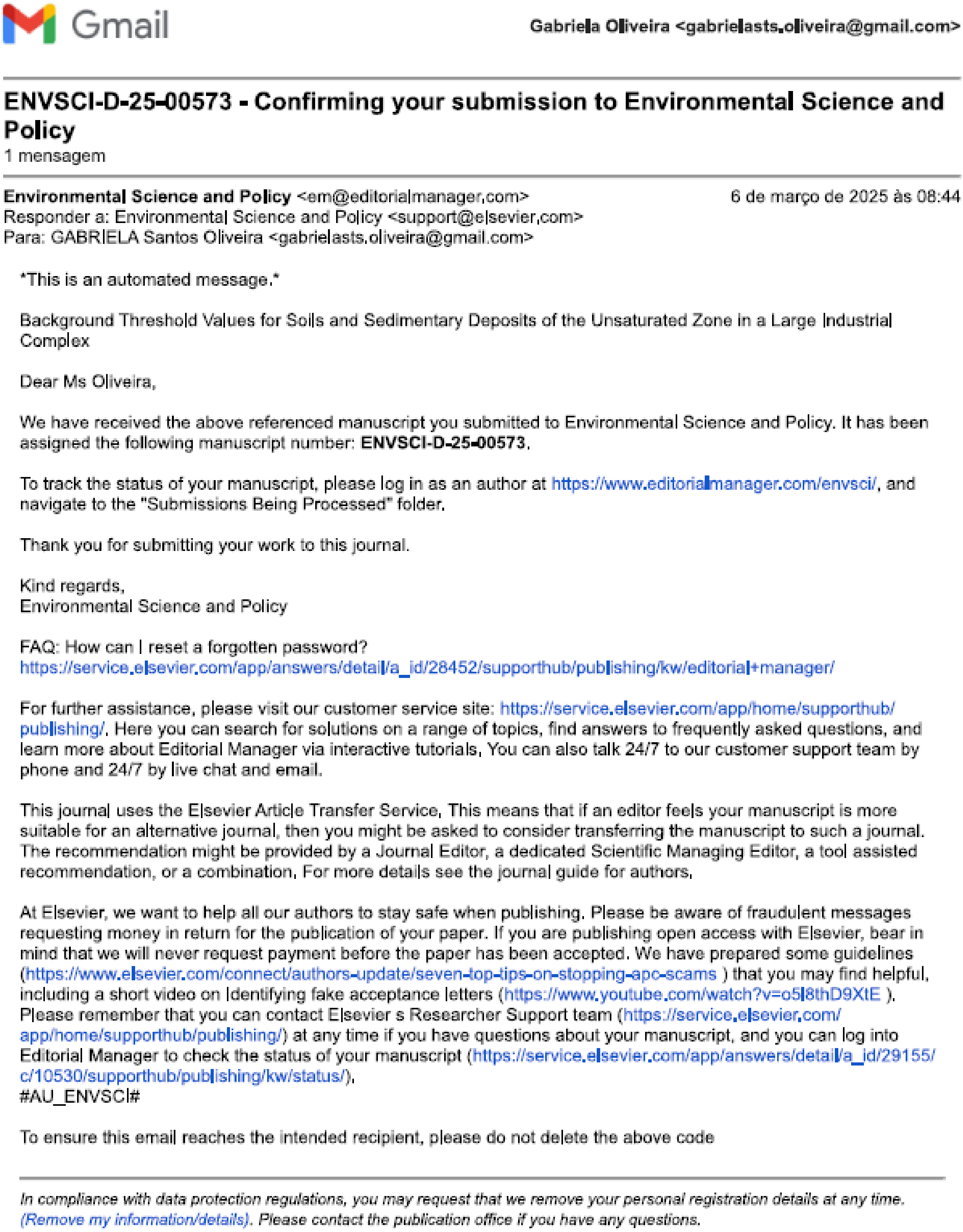
Resources for authors

Elsevier Researcher Academy

If you would like help to improve your submission or navigate the publication process, support is available via Elsevier Researcher Academy.

Elsevier Researcher Academy offers free e-learning modules, webinars, downloadable guides and research writing and peer review process resources.

ANEXO C – COMPROVANTE DE SUBMISSÃO DO ARTIGO



Gmail

Gabriela Oliveira <gabrielasts.oliveira@gmail.com>

ENVSCI-D-25-00573 - Confirming your submission to Environmental Science and Policy

1 mensagem

Environmental Science and Policy <em@editorialmanager.com> 6 de março de 2025 às 08:44

Responder a: Environmental Science and Policy <support@elsevier.com>

Para: GABRIELA Santos Oliveira <gabrielasts.oliveira@gmail.com>

This is an automated message.

Background Threshold Values for Soils and Sedimentary Deposits of the Unsaturated Zone in a Large Industrial Complex

Dear Ms Oliveira,

We have received the above referenced manuscript you submitted to Environmental Science and Policy. It has been assigned the following manuscript number: **ENVSCI-D-25-00573**.

To track the status of your manuscript, please log in as an author at https://www.editorialmanager.com/envsci/, and navigate to the "Submissions Being Processed" folder.

Thank you for submitting your work to this journal.

Kind regards,
Environmental Science and Policy

FAQ: How can I reset a forgotten password?
https://service.elsevier.com/app/answers/detail/a_id/28452/supporthub/publishing/kw/editorial+manager/

For further assistance, please visit our customer service site: https://service.elsevier.com/app/home/supporthub/publishing/. Here you can search for solutions on a range of topics, find answers to frequently asked questions, and learn more about Editorial Manager via interactive tutorials, You can also talk 24/7 to our customer support team by phone and 24/7 by live chat and email.

This journal uses the Elsevier Article Transfer Service, This means that if an editor feels your manuscript is more suitable for an alternative journal, then you might be asked to consider transferring the manuscript to such a journal. The recommendation might be provided by a Journal Editor, a dedicated Scientific Managing Editor, a tool assisted recommendation, or a combination, For more details see the journal guide for authors,

At Elsevier, we want to help all our authors to stay safe when publishing. Please be aware of fraudulent messages requesting money in return for the publication of your paper. If you are publishing open access with Elsevier, bear in mind that we will never request payment before the paper has been accepted. We have prepared some guidelines (https://www.elsevier.com/connect/authors-update/seven-top-tips-on-stopping-apc-scams) that you may find helpful, including a short video on Identifying fake acceptance letters (https://www.youtube.com/watch?v=o5l8thD9XtE). Please remember that you can contact Elsevier s Researcher Support team (https://service.elsevier.com/app/home/supporthub/publishing/) at any time if you have questions about your manuscript, and you can log into Editorial Manager to check the status of your manuscript (https://service.elsevier.com/app/answers/detail/a_id/29155/c/10530/supporthub/publishing/kw/status/).
#AU_ENVSCI#

To ensure this email reaches the intended recipient, please do not delete the above code

---

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Remove my information/details). Please contact the publication office if you have any questions.