



Article Use of Tailings as a Substitute for Sand in Concrete Blocks Production: Gravimetric Mining Wastes as a Case Study

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Abstract: This study assesses the feasibility of reusing tailings from a gold mining area in southern Ecuador in concrete block (CB) manufacturing. For this purpose, physical, chemical, and mineralogical analyses were performed to characterize the tailings. Furthermore, the tailing samples were subjected to the European Standard EN 12457-2 leaching test to assess the potential risk of releasing toxic elements (PTE) into the environment. The CBs were made conventionally and replaced 50% and 70% of the sand with tailings. Lastly, mechanical resistance tests (MRTs) were performed to evaluate the indirect tensile strength, compressive strength, and absorption. The study results show that tailings are feasible as a substitute for sand in manufacturing CBs. Furthermore, the leaching tests complied with the set limit for non-hazardous mining wastes. Regarding the MRT, the CBs made with 50% of tailings were the ones that gave the most favorable results; however, the compressive strength and absorption did not comply with the regulations. In this regard, making CBs with less than 50% tailings is recommended to evaluate their mechanical properties. This study offers an alternative for recycling tailings and contributing to the circular economy.

Keywords: circular economy; recycling; contamination indices; leaching tests; inert waste

1. Introduction

The mining industry produces economic and social benefits worldwide through the supply of raw materials [1]. However, mining activities also produce massive amounts of waste that negatively impact the environment if not suitably managed [2–4]. One of the main concerns regarding mining waste is the amount generated, even up to 65 billion tons per year [5]. These wastes are usually put into storage facilities (tailings dams and waste rock piles), many of which are built without adequate safety standards, mainly in developed countries [6,7].

Regarding the tailings, the intensive space–time deposition and the characteristics of wastes make them a potential risk structure for the environment, human health, and safety [3,8,9]. In addition, the lack of mining–environmental regulations and the inadequate management of mining wastes have caused several accidents with tailings dams around the world [10], as well as environmental contamination and risks to the ecosystem and the population [6,11–13]. For example, in Ecuador, the last mining tailing accident was in July 2020, caused by the failure of a retaining wall, discharging about 50 tons of contaminants into the Tenguel river in the Ponce Enriquez mining area [7]. Accordingly, numerous papers deal with tailings issues, from historical analysis of tailings dam failure risk [14] to developments and new insights for environmental sustainability and disaster control of tailings dams [15]. First, however, it is necessary to work on the sustainable management of tailings and to see them with a possibility of reuse [16]. Therefore, reasonable utilization



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Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). of tailings may shift the waste material into valuable raw materials and harness and improve the surroundings. Tailings should be thoroughly recycled and reused because they constitute a secondary resource [16].

According to the sustainable development goals from the United Nations Development Programme for 2015 to 2030, mining can contribute with actions based on the circular economy and collaborate throughout the supply chain to minimize waste, and reuse and recycle it. In this regard, it is sought after that the waste of one becomes the raw material of the other [17,18]. However, it is relevant to mention that there is no generic way to address the mining tailings issues. Each approach will depend directly on the characteristics of the tailings. In some cases, the tailings may be reused as a potential critical mineral resource [19]. Sometimes, they will not represent toxicity potential to the environment [20] and can be employed as a substitute for raw construction materials, reconstruction of landforms, or rehabilitation of mining areas [21]. However, whatever use and reuse is given to the tailings will already be a sustainable option for environmental mitigation.

In the circular economy, the reuse and recycling of mining waste can considerably reduce the environmental impacts and the potential risk related to mining waste storage [5,22]. On the other hand, the demand for raw materials grows yearly, so mining waste production also increases. In this sense, the transition towards a sustainable mining industry, in agreement with environmental legal frameworks, is essential [1,23,24].

In recent years, diverse mining waste reuse and recycling strategies have been studied [2,25–27]. One favorable application for these uses is in the construction industry [28–30]. This industry demands the intensive exploitation of natural resources, so using mining wastes as a replacement for raw materials is a sustainable alternative to mitigate the environmental impacts [31,32].

Recent works have evaluated the use of abandoned base-metal tailings as fine aggregates for mortar preparation [29], the incorporation of sulphidic mining wastes from inactive Pb-Zn and Cu-Zn-Pb mines in ceramic roof tiles and blocks [33], the use of Mnmining wastes as a filler material in Portland cement [34], cement production using kaolin mining wastes [35], the use of lead ore flotation waste in building ceramics [36], bricks production using mining wastes [8], and the production of wall and floor tiles using boron mining wastes [37], obtaining favorable results in most of the studies mentioned above.

Despite the progress in this research field, more than 150 mineral processing plants in Ecuador generate large amounts of mining waste. Consequently, its management and final disposal become an economic, social, and environmental problem. Therefore, this study aims to conduct experimental research to assess the viability of reusing tailings as a substitute for sand in manufacturing concrete blocks. This approach promotes an alternative sustainable approach to managing mining wastes with economic and environmental benefits. In addition, with tailings reuse the extraction of raw materials for the construction industry can be reduced, thus promoting the circular economy.

2. Materials and Methods

2.1. Study Area

The study area is part of the *Campanillas* mining concession in southern Ecuador, located in Zamora Chinchipe (Figure 1). *Campanillas* is a small-scale mining concession that processes between 20 and 30 tons/day using gravimetric processes, generating around 19 tons/day of tailings. These mining wastes are stored in a tailings dam with an approximate capacity of 12,250 m³. *Campanillas* was selected as a case study because it presents common characteristics of small-scale gold mining activity in Ecuador and because of the mining company's interest in implementing sustainable strategies for reusing mining waste.



Figure 1. Location of the study area, Zamora Chinchipe province, and satellite image where the tailing dam is highlighted.

The study area presents two geological units. The main unit is Piuntza, a group of Inferior Jurassic rocks, where sandstones, clays, and argillites have been reported. The unit is a sequence of volcano-sedimentary rocks composed of andesites with tuffs and volcanic breccias of varied texture, with sediments of volcanic origin with fine to medium grain sizes of greenish–gray color. There are also mineralizations in skarn-type rock with hydrothermal alterations [38]. In addition, outcrops can be found in the NW–SW direction, with pyrite and chalcopyrite veins and highly fractured rocks that host mainly Au, Cu, and Zn in vetiform mineralization [39]. The second unit is Zamora, which is considered a batholith type I. This unit comprises a series of lithologies, ranging from granites to granodiorites and coarse to medium-grained hornblende-biotitic, including potassium feldspar megacrysts, quartzmonzodiorites with pink perthite megacrysts, granular subvolcanic intrusives such as microdiorites, and hornblende porphyries [40].

2.2. Sample Collection and Preparation

According to the methodology proposed by Smith [41], six sites were sampled randomly at the tailing dam (Figure 1). First, a surface layer of 0.1 m was removed in each one, then 36.5 kg of tailings were collected at a depth between 0.1 and 0.5 m using a hand shovel. As a result, a composite sample of 219 kg was collected. This sample was transported in polyethylene bags and stored at room temperature. In the laboratory, the composite sample was air-dried and homogenized. Then, the sample was sieved through an 8 mm and 4 mm stainless steel sieve. Then, the sample was spread on the floor on a polyethylene film covering an approximate surface of 1.15×1.45 m and a deepness of 0.1 m. Following the division method by increments [42], a homogenized lot with 20 arrangements was obtained. Finally, by random sampling, ten samples of 1 kg each were collected in arrays 3, 7, 8, 10, 12, 14, 15, 16, 17, and 20. Each sample was reduced to 0.5 kg using a riffle splitter. The number of kg used for physicochemical and mineralogical analysis was 0.4, and 0.1 kg was used for leaching tests. Samples were labeled CA, standing for *Campanillas*, followed by a consecutive sampling number.

2.3. Analytical Procedures

2.3.1. Tailing Physicochemical and Mineralogical Properties

The grain size distribution was determined using eight grain-size classes according to the normalized protocol ASTM C 117 [43]. The Gay-Lussac BOECO[®] pycnometer analyzed the bulk and real density according to the Villaseñor-Ortiz [44] method. Mineralogy was determined by X-ray diffraction spectroscopy (XRD) [45]. XRD analyses were carried out using a Bruker AXS D8 Advance diffractometer equipped with a copper anticathode, scanning over a diffraction angle range of 4° to 75° with a step size of 0.01° per step. Minerals were identified based on the peaks and d-spaces using the software DIFFRAC.EVA for identification and DIFFRAC.TOPAS for quantification.

Potentially toxic elements (PTE), As, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, Se, V, and Zn, were identified and quantified using the optical spectroscopy technique according to E2941-14 [46] and 6010D [47] standard methods. An optical emission spectrometer (ICP-OES) from Perkin Elmer[®], model OPTIMA 8300, was used with previous total digestion with four acids (HNO₃-HCl-HClO₄-HF). The reference standard employed was ERA D110-540 Metals in Soil, PriorityPollutnTTM. Major elements (Na₂O, MgO, Al₂O₃, SiO₂, P₂O₅, SO₃, K₂O, CaO, TiO₂, Mn₂O₃, Fe₂O₃) were analyzed using the XRF fluorescence E1621-13 standard method [48,49], using Bruker S8 Tiger Series 2 spectrometer equipment. In addition, Hg content was quantified by cold-vapor atomic absorption spectrometry following the 30501A [50] and 7471B [51] standard methods. During the analytical procedures, all the obtained results were assessed with an internal quality control system of the IIGE labs, which has a management system implemented under the NTE INEN-ISO/IEC17025:2018 standard.

2.3.2. Leaching Tests

The tailing samples were leached by the European compliance laboratory leaching test (EN LLT) [52] (Table 1). An extraction test with deionized water was carried out to simulate scenarios in which the tailings are in contact with solutions with low buffering capacity, such as rainwater [53].

-LLT	EN-LLT	Characteristic
atch	Batch	Test type
.0:1	10:1	Liquid to solid ratio
zed water	Deionized wa	Extracting fluid
oH < 7.5	5.0 < pH < 7	pH of extracting fluid
mm	<2 mm	Particle size used
00 g	100 g	Sample amount
4 h	24 h	Duration of agitation
otatory (5–10 rpm)	End-over-end rotatory	Agitation method
tration device	Vacuum filtration	Filtration
cellulose	Nitro-cellulo	Filter type
icrometer	0.45 microme	Filter pore size
u	0.45 m	Filter type Filter pore size

Table 1. Parameters of the leaching tests.

Source: Guzmán-Martínez et al. [54].

The eluates' pH, specific conductivity (SC), and redox potential (Eh) were measured with a HATCH[®] portable multimeter. In addition, PTE was quantified by inductively coupled plasma mass spectroscopy (ICP-MS) from Agilent 7700x, according to 3120D [55] and 6020B [56] standard methods.

2.4. Indices of Contamination (IC)

The IC from Alberruche del Campo et al. [57] is a tool used to determine the contaminant potential from mining wastes and is calculated by the following equation:

$$IC = (1/n) \left(\sum_{i=1}^{n} [X]_i / RL_x \right)$$

$$\tag{1}$$

where X is the element concentration in mining waste leachate; RL_X is the reference levels for each element measured in the leachate; and n is the number of elements measured whose concentrations are above the values adopted in RL_X . The Ecuadorian legislation established the reference levels [58]. The assessment of the IC results was evaluated according to the classification proposed by Arranz-González et al. [59], as follows: very low (<3.2), low (3.2–6.4), medium (6.4–9.6), high (9.6–12.8), and very high (>12.8).

2.5. Concrete Blocks Production, Mechanical Resistance, and Leaching

The concrete blocks were made with three raw material proportions (Table 2). Firstly, with a conventional method with 100% sand. Secondly, by replacing 50% of the sand with tailing, and finally by replacing 70% of the sand with tailing. These values were selected based on the literature review [8,60–62]. A pallet of 14 blocks was produced for each proportion of raw materials. Each block measured $0.65 \times 0.22 \times 0.1$ m.

Table 2. Proportions of raw materials used for concrete blocks production

Method	Sand (kg)	Tailing (kg)	Crushed Stone (kg)	Portland Cement (kg)	Water (L)	Blocks Produced	Sample Code *
Conventional method	17	0	0	1.8	1.4	14	CA-Bn
By replacing 50% of the sand with tailing	11.4	11.4	11.4	3.6	2.8	14	CA-50%-Bn
By replacing 70% of the sand with tailing	7.8	18.2	13.0	4.0	2.4	14	CA-70%-Bn

* n is the consecutive number of the sample.

To produce concrete blocks using the conventional method, 17 kg of sand was mixed with 1.8 kg of Portland cement and approximately 1.4 L of water, then mixed at 33.3 rpm for 8 min. Subsequently, the mixture was placed for 6 s inside the molds in the Vibro-pressing machine. Afterward, the curing process was carried out, moistening the blocks thrice a day for five days. Finally, the setting was completed, allowing the blocks to dry for 23 days at room temperature [63]. Then, the same procedure described in the conventional method was used to produce blocks with tailings as a substitute for sand (Figure 2a), with the proportions shown in Table 2.



Figure 2. (**a**) Concrete blocks produced with tailings, (**b**) compressive strength test, (**c**) indirect tensile strength test, and (**d**) absorption test.

Three were randomly selected for mechanical resistance tests from each pallet of blocks (made with each of the three raw material proportions). Assays were carried out in the Soil Laboratory of the Engineering Faculty in Earth Sciences of the Littoral Superior School of Ecuador. The tests applied to each concrete block were the compressive strength test (Figure 2b), using the standardized ASTM C140 method [64], and the absorption (Figure 2c) and indirect tensile strength tests (Figure 2d) using the Ecuadorian technical standard NTE-INEN 3040 methodology [65]. In addition, five concrete blocks were randomly selected from each pallet to determine which PTE could be solubilized. Then the blocks were crushed to a particle size of 2 mm, and the leaching EN LLT test was applied.

3. Results

3.1. Mining Wastes Characterization

As shown in Figure 3, the samples correspond to sands as the particle size is between 65 and 1000 μ m [66]. These results suggest that tailings can replace sands in the elaboration of concrete blocks since they can be categorized as sands. Furthermore, the samples present an average d80 of 73.8 μ m because these mining wastes come from a size reduction stage consisting of crushing–sorting–grinding. This particle size is expected because a ball mill is used in the grinding stage; therefore, the tailings' particle size corresponds to fines (<100 μ m). The tailings samples have nearly similar bulk densities (1.7 g/cm³ on average) and real densities (2.4 g/cm³ on average) (Table 3), which are close to quartz density [29], the principal mineralogical constituent of the samples and the main constituent of the sands used in the production of concrete blocks.



Figure 3. Granulometric curves of samples from Campanillas tailings.

Fable 3. Physicochemical characterization and PTE content in tailing

Sample	Bulk Density	Real Density		PTE Content (mg/kg)													
-	(g/cm³)	(g/cm ³)	As	Cd	Со	Cr	Cu	Hg	Мо	Ni	Pb	Se	Sb	v	Zn		
CA-01	1.7	2.3	<dl< td=""><td><dl< td=""><td><dl< td=""><td>76</td><td>34</td><td>0.2</td><td><dl< td=""><td><dl< td=""><td>26</td><td><dl< td=""><td><dl< td=""><td>73</td><td>159</td><td>1.8</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>76</td><td>34</td><td>0.2</td><td><dl< td=""><td><dl< td=""><td>26</td><td><dl< td=""><td><dl< td=""><td>73</td><td>159</td><td>1.8</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>76</td><td>34</td><td>0.2</td><td><dl< td=""><td><dl< td=""><td>26</td><td><dl< td=""><td><dl< td=""><td>73</td><td>159</td><td>1.8</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	76	34	0.2	<dl< td=""><td><dl< td=""><td>26</td><td><dl< td=""><td><dl< td=""><td>73</td><td>159</td><td>1.8</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>26</td><td><dl< td=""><td><dl< td=""><td>73</td><td>159</td><td>1.8</td></dl<></td></dl<></td></dl<>	26	<dl< td=""><td><dl< td=""><td>73</td><td>159</td><td>1.8</td></dl<></td></dl<>	<dl< td=""><td>73</td><td>159</td><td>1.8</td></dl<>	73	159	1.8	
CA-02	1.6	2.4	<dl< td=""><td><dl< td=""><td><dl< td=""><td>78</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>70</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>78</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>70</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>78</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>70</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	78	33	<dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>70</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>70</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>70</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<>	35	<dl< td=""><td><dl< td=""><td>70</td><td>161</td><td>1.5</td></dl<></td></dl<>	<dl< td=""><td>70</td><td>161</td><td>1.5</td></dl<>	70	161	1.5	
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CA-04	1.7	2.3	<dl< td=""><td><dl< td=""><td><dl< td=""><td>77</td><td>32</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>43</td><td><dl< td=""><td><dl< td=""><td>71</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>77</td><td>32</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>43</td><td><dl< td=""><td><dl< td=""><td>71</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>77</td><td>32</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>43</td><td><dl< td=""><td><dl< td=""><td>71</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	77	32	<dl< td=""><td><dl< td=""><td><dl< td=""><td>43</td><td><dl< td=""><td><dl< td=""><td>71</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>43</td><td><dl< td=""><td><dl< td=""><td>71</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>43</td><td><dl< td=""><td><dl< td=""><td>71</td><td>161</td><td>1.5</td></dl<></td></dl<></td></dl<>	43	<dl< td=""><td><dl< td=""><td>71</td><td>161</td><td>1.5</td></dl<></td></dl<>	<dl< td=""><td>71</td><td>161</td><td>1.5</td></dl<>	71	161	1.5	
CA-05	1.7	2.5	<dl< td=""><td><dl< td=""><td><dl< td=""><td>75</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>69</td><td>171</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>75</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>69</td><td>171</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>75</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>69</td><td>171</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	75	35	<dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>69</td><td>171</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>69</td><td>171</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>69</td><td>171</td><td>1.5</td></dl<></td></dl<></td></dl<>	35	<dl< td=""><td><dl< td=""><td>69</td><td>171</td><td>1.5</td></dl<></td></dl<>	<dl< td=""><td>69</td><td>171</td><td>1.5</td></dl<>	69	171	1.5	
CA-06	1.6	2.5	<dl< td=""><td><dl< td=""><td><dl< td=""><td>80</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>72</td><td>165</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>80</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>72</td><td>165</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>80</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>72</td><td>165</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	80	35	<dl< td=""><td><dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>72</td><td>165</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>72</td><td>165</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>72</td><td>165</td><td>1.4</td></dl<></td></dl<></td></dl<>	29	<dl< td=""><td><dl< td=""><td>72</td><td>165</td><td>1.4</td></dl<></td></dl<>	<dl< td=""><td>72</td><td>165</td><td>1.4</td></dl<>	72	165	1.4	
CA-07	1.7	2.5	<dl< td=""><td><dl< td=""><td><dl< td=""><td>82</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>70</td><td>183</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>82</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>70</td><td>183</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>82</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>70</td><td>183</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	82	33	<dl< td=""><td><dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>70</td><td>183</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>70</td><td>183</td><td>1.5</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>29</td><td><dl< td=""><td><dl< td=""><td>70</td><td>183</td><td>1.5</td></dl<></td></dl<></td></dl<>	29	<dl< td=""><td><dl< td=""><td>70</td><td>183</td><td>1.5</td></dl<></td></dl<>	<dl< td=""><td>70</td><td>183</td><td>1.5</td></dl<>	70	183	1.5	
CA-08	1.7	2.7	<dl< td=""><td><dl< td=""><td><dl< td=""><td>87</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>87</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>87</td><td>33</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	87	33	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<></td></dl<>	<dl< td=""><td>70</td><td>160</td><td>1.4</td></dl<>	70	160	1.4	
CA-09	1.7	2.2	<dl< td=""><td><dl< td=""><td><dl< td=""><td>72</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>72</td><td>161</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>72</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>72</td><td>161</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>72</td><td>35</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>72</td><td>161</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	72	35	<dl< td=""><td><dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>72</td><td>161</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>72</td><td>161</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>35</td><td><dl< td=""><td><dl< td=""><td>72</td><td>161</td><td>1.4</td></dl<></td></dl<></td></dl<>	35	<dl< td=""><td><dl< td=""><td>72</td><td>161</td><td>1.4</td></dl<></td></dl<>	<dl< td=""><td>72</td><td>161</td><td>1.4</td></dl<>	72	161	1.4	
CA-10	1.7	2.3	<dl< td=""><td><dl< td=""><td><dl< td=""><td>76</td><td>32</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>31</td><td><dl< td=""><td><dl< td=""><td>70</td><td>156</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>76</td><td>32</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>31</td><td><dl< td=""><td><dl< td=""><td>70</td><td>156</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>76</td><td>32</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>31</td><td><dl< td=""><td><dl< td=""><td>70</td><td>156</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	76	32	<dl< td=""><td><dl< td=""><td><dl< td=""><td>31</td><td><dl< td=""><td><dl< td=""><td>70</td><td>156</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>31</td><td><dl< td=""><td><dl< td=""><td>70</td><td>156</td><td>1.4</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>31</td><td><dl< td=""><td><dl< td=""><td>70</td><td>156</td><td>1.4</td></dl<></td></dl<></td></dl<>	31	<dl< td=""><td><dl< td=""><td>70</td><td>156</td><td>1.4</td></dl<></td></dl<>	<dl< td=""><td>70</td><td>156</td><td>1.4</td></dl<>	70	156	1.4	
Ecuadorian reference levels ^b			12	0.5	10	54	25	0.1	5	19	19	1	*	76	60		

^a Contamination index. ^b Reference levels according to Unified Text on Secondary Environmental Legislation [58]. <DL below detection limit. * PTE not listed in the reference level.

Regarding mineralogical characterization (Figure 4a), the samples have a typical tailing composition, with more than 85% silicates and less than 12% carbonates [67]. Although, it is worth noting the absence of sulfides in the XRD analysis since they usually represent between 1% and 40% of the tailing's composition. The fact that no sulfides were found in the samples suggests that there will be no leaching of potentially toxic elements in the short term. On the other hand, the most significant mineralogical contents in tailing samples were quartz, at 36%. Other significant minerals in abundance were the plagioclase group (Albite and Anorthite) (22%) and andradite (19%). The group of K-feldspars (Orthoclase, Microcline, Sanidine) and calcite, both with neutralizing capacity, were found in a low proportion, with 7% and 6%, respectively. Calcite is a typical mineral in tailings and the most rapidly reacting carbonate mineral to contribute to neutralization processes [68,69]. Major elements determined by fluorescence XRF are presented in Figure 4b. The tailings were found to have a high content of SiO₂, while CaO, Fe₂O₃, and Al₂O₃ were minor components. The content of SiO_2 is related to the presence of quartz and other silicates. The CaO corresponds to the presence of calcite (CaCO₃), which, when subjected to 1000 °C, originated CaO and CO₂ 4% of calcination losses (CL). Finally, the presence of Fe₂O₃ may be due to the high concentration of andradite $((SiO_4)_3Fe_2Ca_3)$. The amount of quartz detected in the tailing samples is relevant because it has a high mechanical resistance to impact, influencing the mechanical resistance of the concrete blocks made with tailings (Lam et al., 2020).



Figure 4. (a) Mineralogical characterization determined by X-ray diffraction, and (b) chemical composition of tailing by XRF fluorescence.

Physicochemical characterization and PTE content in mining wastes are present in Table 3. As, Cd, Co, Mo, Ni, Se, and Sb were below the detection limit (DL) in all samples, while Hg was below DL in nine out of ten samples. On the other hand, the concentration of Ba, Cr, Cu, Pb, and Zn were above the reference levels according to the Ecuadorian Environmental Legislation [58] in the ten samples. Such concentration indicates a potential environmental risk since the tailings are mostly made up of fine materials easily transported by the wind [70].

3.2. Assessment of Pollution Potential from Tailing Samples

IC was used as an indicator of the pollution level of the tailings due to the probability of erosion contamination scenarios [4]. The IC calculated stood between 1.4 and 1.8 (Table 3) which falls into the category of very low risk (IC < 3.2), which means that in the long term the tailings of this study present a very low probability of contamination due to erosion processes [59]. The percentage contribution of PTE in the contamination index result is similar in most samples (Figure 5). As previously mentioned, Ba, Cr, Cu, and Zn exceeded the Ecuadorian reference levels for soil quality in 100% of the analyzed samples, 90% in Pb, and Hg was only higher than the reference levels in sample CA-01. Nevertheless, based on



the IC, the tailings are categorized as having very low pollution, suggesting no potential environmental risk.

Figure 5. Contribution of PTE contained in the sample to the index of contamination.

The results of the release of PTE from the tailings are presented in Table 4. It is important to note that no element exceeds the reference values of the Royal Decree 646/2020, so they are considered inert waste and, therefore, are suitable for reuse as a sand substitute. In addition, the mine tailings' pH is neutral, with values between 7.0 and 7.3, suggesting a low degree of solubilization of the elements contained in the tailings. These results agree with Argane et al. [29], who reported that tailings used as aggregates in the manufacturing of construction material in the Moulouya region (Morocco) have very low generating potential of contaminated effluents; therefore, their reuse is an efficient alternative for tailing management.

Sample	pН	Eh (µS/cm)	SC (mV)	PTE Release (mg/kg)															
				As	Ba	Cd	Со	Cr	Cu	Мо	Ni	Pb	Sb	Se	v	Zn	SO_4	F -	Cl-
CA-01	7.0	181	104	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<></td></dl<>	<dl< td=""><td>0.2</td><td>161</td><td>2</td><td>412</td></dl<>	0.2	161	2	412
CA-02	7.2	162	98	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>145</td><td>1</td><td>233</td></dl<></td></dl<>	<dl< td=""><td>145</td><td>1</td><td>233</td></dl<>	145	1	233
CA-03	7.2	163	97	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>135</td><td><dl< td=""><td>122</td></dl<></td></dl<>	135	<dl< td=""><td>122</td></dl<>	122
CA-04	7.3	154	95	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<></td></dl<>	<dl< td=""><td>0.4</td><td>147</td><td>1</td><td>105</td></dl<>	0.4	147	1	105
CA-05	7.1	150	112	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>159</td><td><dl< td=""><td>17</td></dl<></td></dl<>	159	<dl< td=""><td>17</td></dl<>	17
CA-06	7.2	178	125	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.3</td><td>142</td><td><dl< td=""><td>202</td></dl<></td></dl<>	0.3	142	<dl< td=""><td>202</td></dl<>	202
CA-07	7.3	169	117	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.2</td><td>157</td><td><dl< td=""><td>121</td></dl<></td></dl<>	0.2	157	<dl< td=""><td>121</td></dl<>	121
CA-08	7.2	161	120	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>155</td><td><dl< td=""><td>200</td></dl<></td></dl<>	155	<dl< td=""><td>200</td></dl<>	200
CA-09	7.2	170	118	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.2</td><td>166</td><td><dl< td=""><td>9</td></dl<></td></dl<>	0.2	166	<dl< td=""><td>9</td></dl<>	9
CA-10	7.1	148	121	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.3</td><td>168</td><td><dl< td=""><td>25</td></dl<></td></dl<>	0.3	168	<dl< td=""><td>25</td></dl<>	25
LLV ^a				0.5	20	0.04	*	0.5	2	0.5	0.4	0.5	0.06	0.1	*	4	1000	10	800

Table 4. Release of PTE obtained (mg/kg) from the EN-LLT leaching test method.

^a LLV: leaching limit values for inert waste admissible in landfills for inert waste by Royal Decree 646/2020. <DL below detection limit. * PTE not listed in the limit values for leaching.

3.3. Mechanical Resistance Tests of Concrete Blocks

The mechanical resistance results for the concrete blocks produced conventionally and with 50% and 70% of tailing are presented in Figure 6. The indirect traction test showed that only two of the concrete blocks made with 50% of tailings (CA-50%-B1 and CA-50%-B2) gave resistance values greater than 2.9 MPa (Figure 6a), which are the compliance criteria set by the Ecuadorian technical standard NTE-INEN 3040. This standard sets concrete blocks' materials, properties, requirements, and test methods [65].



Figure 6. Comparative assessment of (**a**) the indirect traction, (**b**) compression, and (**c**) absorption tests performed on the concrete blocks concerning the compliance criteria. The concrete blocks made with 50% tailings met the resistance values established by the Ecuadorian technical standard. On the contrary, the compression and absorption tests did not comply with the limits established in the regulations.

Regarding compressive strength, according to the standard ASTM C140 [64], the minimum value requirement is 55 MPa. Nevertheless, all the blocks analyzed reported values lower than the compliance criteria. As shown in Figure 6b, the sample CA-50%-B1 was the closest to the compliance criteria, so further studies could evaluate how to improve the compressive strength in detail. Compressive strength is related to the water-cement ratio; reducing this proportion could decrease porosity and increase compressive

strength [34]. In addition, high compressive strength is attributed to the high bonding interactions between particles due to the fineness of waste particles and their plasticity [71].

Concerning the absorption test (Figure 6c), no block met the maximum absorption value of 6% established in the standard NTE-INEN 3040. The concrete blocks produced conventionally and using 50% of tailing were in the same absorption range. In comparison, the blocks manufactured with the highest amount of waste (70%) showed the highest value for absorption. Based on these results, the use of 70% tailings in the production of blocks presents the least favorable results. On the other hand, more tests should be carried out with blocks with 50% tailings to obtain more conclusive results. In addition, making blocks with a lower proportion of tailings, for example, 40% and 30%, is recommended to evaluate their mechanical properties and have more conclusive results.

3.4. Environmental Considerations about the Concrete Blocks

Studying the environmental behavior of concrete blocks is essential to guarantee that they will be safe for users and the environment. Table 5 shows the leaching test results applied to the concrete blocks. As can be seen, the concentration of PTE in blocks produced using both 50% and 70% of tailing is significantly lower than the limit set for inert wastes established in the Royal Decree 646/2020. The As, Ba, Cd, Co, Cu, Mo, Ni, Pb, Sb, Se, V, Zn, SO_4 , F^- , and Cl^- content in all concrete blocks sample leachates was insignificant or below detection limits for the ICP-MS analysis. Cr showed similar concentrations for all blocks ranging from 1 to 4 mg/kg, which is higher than the Royal Decree 646/2020 limits (0.5 mg/kg). The Cr release in block samples may be related to their leachates' higher pH (12 on average). However, few studies have investigated the Cr in mining wastes. In addition, unlike other PTE in which the total concentration is relevant, the toxicity depends on the available oxidation states in Cr. Therefore, a future study should look into the oxidation states of Cr present in the blocks since Cr (III) is considered benign and essential as a micronutrient. At the same time, Cr (VI) is highly toxic and carcinogenic [72]. On the other hand, as shown in Table 4 (tailings leaching) and Table 5 (blocks leaching), the pH ranged from neutral to basic and the Eh from positive to negative. These results suggest that in the tailings the conditions are oxidizing and neutral, while in the cement blocks there are reducing and basic conditions, which could mean that the PTE has less mobilization potential in the cement blocks than in the tailings.

Sample	рН	Eh (S/cm)	SC (mV)	PTE Release (mg/kg)															
				As	Ba	Cd	Со	Cr	Cu	Мо	Ni	Pb	Sb	Se	V	Zn	SO_4	\mathbf{F}^{-}	Cl-
CA-50%-B1	12.1	-42	1424	<dl< td=""><td>0.3</td><td><dl< td=""><td><dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.3	<dl< td=""><td><dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.02</td><td><dl< td=""><td>30</td><td>1</td><td>12</td></dl<></td></dl<>	0.02	<dl< td=""><td>30</td><td>1</td><td>12</td></dl<>	30	1	12
CA-50%-B2	12.1	-48	1467	<dl< td=""><td>0.4</td><td><dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>50</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.4	<dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>50</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>50</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	2	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>50</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>50</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>50</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.02</td><td><dl< td=""><td>50</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.02</td><td><dl< td=""><td>50</td><td>1</td><td>11</td></dl<></td></dl<>	0.02	<dl< td=""><td>50</td><td>1</td><td>11</td></dl<>	50	1	11
CA-50%-B3	12.0	-36	1200	<dl< td=""><td>0.3</td><td><dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>50</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.3	<dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>50</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>50</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	2	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>50</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>50</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>50</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>50</td><td>1</td><td>12</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.03</td><td><dl< td=""><td>50</td><td>1</td><td>12</td></dl<></td></dl<>	0.03	<dl< td=""><td>50</td><td>1</td><td>12</td></dl<>	50	1	12
CA-50%-B4	12.1	-36	1454	<dl< td=""><td>0.3</td><td><dl< td=""><td><dl< td=""><td>3</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.3	<dl< td=""><td><dl< td=""><td>3</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>3</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	3	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>11</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>11</td></dl<></td></dl<>	0.03	<dl< td=""><td>60</td><td>1</td><td>11</td></dl<>	60	1	11
CA-50%-B5	11.6	-9	561	<dl< td=""><td>0.2</td><td><dl< td=""><td><dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.2	<dl< td=""><td><dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.07</td><td><dl< td=""><td>60</td><td>1</td><td>3</td></dl<></td></dl<>	0.07	<dl< td=""><td>60</td><td>1</td><td>3</td></dl<>	60	1	3
CA-70%-B1	12.1	-28	1240	<dl< td=""><td>0.01</td><td><dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.01	<dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	2	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.09</td><td><dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<></td></dl<>	0.09	<dl< td=""><td>80</td><td>1</td><td>1.1</td></dl<>	80	1	1.1
CA-70%-B2	12.3	-30	2170	<dl< td=""><td>0.3</td><td><dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>14</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.3	<dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>14</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>14</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	2	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>14</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>14</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>14</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>14</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.03</td><td><dl< td=""><td>60</td><td>1</td><td>14</td></dl<></td></dl<>	0.03	<dl< td=""><td>60</td><td>1</td><td>14</td></dl<>	60	1	14
CA-70%-B3	11.7	-17	694	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>4</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>4</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>4</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>4</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	4	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.03</td><td><dl< td=""><td>380</td><td>1</td><td>10</td></dl<></td></dl<>	0.03	<dl< td=""><td>380</td><td>1</td><td>10</td></dl<>	380	1	10
CA-70%-B4	12.0	-17	1104	<dl< td=""><td>0.07</td><td><dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>100</td><td>1</td><td>16</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.07	<dl< td=""><td><dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>100</td><td>1</td><td>16</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>2</td><td><dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>100</td><td>1</td><td>16</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	2	<dl< td=""><td>0.1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>100</td><td>1</td><td>16</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>100</td><td>1</td><td>16</td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>100</td><td>1</td><td>16</td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.09</td><td><dl< td=""><td>100</td><td>1</td><td>16</td></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.09</td><td><dl< td=""><td>100</td><td>1</td><td>16</td></dl<></td></dl<>	0.09	<dl< td=""><td>100</td><td>1</td><td>16</td></dl<>	100	1	16
CA-70%-B5	11.4	-1	386	<dl< td=""><td>0.05</td><td><dl< td=""><td><dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	0.05	<dl< td=""><td><dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td>1</td><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	1	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td><dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<></td></dl<></td></dl<>	<dl< td=""><td><dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<></td></dl<>	<dl< td=""><td>0.09</td><td>1</td><td>40</td><td>1</td><td><dl< td=""></dl<></td></dl<>	0.09	1	40	1	<dl< td=""></dl<>
LLV ^a				0.5	20	0.04	*	0.5	2	0.5	0.4	0.5	0.06	0.1	*	4	1000	10	800

Table 5. EN-LLT leaching test applied to the concrete blocks.

^a LLV: leaching limit values for inert waste admissible in landfills by Royal Decree 646/2020. <DL below detection limit. * PTE not listed in the reference level.

4. Conclusions

This paper assessed the potential use of tailings as a substitute for sand in concrete block production. For this purpose, physical, chemical, mineralogical, and mechanical characterization were performed on tailings and concrete block samples. As a result, the Index of Contamination (IC) used as an indicator of the pollution level was into the category of very low risk (IC < 3.2) for all of the samples, which means that in the long term the tailings present a very low probability of pollution. Furthermore, the results show that the

leachates from the tailings of the Campanillas mine have low contents of PTE and comply with the reference values of the Royal Decree 646/2020 for inert waste. Therefore, the tailings are suitable for use as a sand substitute.

Moreover, the leaching test results for concrete blocks (with 50% and 70% of tailing) concluded that the concrete blocks made with tailings do not produce toxic leachates. Therefore, they are not considered potentially dangerous for users and the environment. Regarding the mechanical resistance tests, the concrete blocks made with 50% of tailings were the ones that gave the most favorable results; however, the compressive strength and absorption did not comply with the regulations. Therefore, further research should be undertaken to improve the mechanical resistance of blocks manufactured with tailings as a substitute for sand. This study constitutes a proposal to reuse tailings simply, thus promoting the circular economy and sustainability in the mining industry. However, the characteristics of mining waste can vary significantly and, thus, vary its applicability in the construction industry. Therefore, the residues and products made from them must be duly examined and monitored so that their use is not dangerous for users.

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