25 YEARS OF NORM SYMPOSIA
FUTURE: RESIDUES APPLIED IN A CIRCULAR ECONOMY

NORM INVENTORY IN BRAZIL:
Case study of the production of Nb and Sn

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INTRODUCTION

Brazil is a country that has vast mineral reserves and plays an important role in the international trade of mineral commodities.

The gross added value of the Mineral Sector (extraction and mineral processing industry), estimated for 2020, was 3.2% of the Brazilian GDP.

Nb and Sn are defined by Brazilian government as strategic minerals. The related industries may cause NORM radiation exposure.

In relation to Niobium, Brazil has the world's largest reserves and is responsible for more than 98 % of the world's production, **generating approximately 7.17 million tonnes of NORM residue per year**.

Brazil has also approximately 8% of the world’s reserves of contained tin, being the fifth largest world producer, **generating about 7.37 million tonnes of NORM residue per year**.

MAIN OBJECTIVES

This study aims at performing a NORM inventory of the niobium and tin industry in Brazil.

Challenges and difficulties in establishing and keeping such inventories updated are also presented.

The data presented on the production and generation of mining waste, was collected based on information provided by companies, that seek authorization and registration by CNEN during regulatory inspections. All the radioactivity measurements were performed by CNEN laboratories.

THE REGULATORY FRAMEWORK IN BRAZIL

Company	Mining Concession Application	Evironmental License Application	Authorization Application for mining and milling facilities that process materials that contain natural radionuclides associated
National Mining Agency (ANM)	Mining Concession		
Environmental Protection Agency (IBAMA)		Environmental License	
National Commission of Nuclear Energy (CNEN)			Authorization for mining and milling facilities that process materials that contain natural radionuclides associated

Fig 1. Procedures of licensing and authorization of conventional ore mining that occurs with radionuclides

There are different regulatory bodies that establish requirements and control for mining and milling facilities

THE REGULATORY FRAMEWORK IN BRAZIL

Standard CNEN-NN-4.01 – Requirements of Safety and Radiation Protection for mining and milling facilities establishes requirements for the authorization procedure based on total activity concentration and dose rate.

Category	Total activity concentration	Documents required
Category III	< 100 Bq/g	Basic information
Category II	≥100 Bq/g and ≤ 500 Bq/g	Basic information Occupational Radiological Protection Plan; Environmental Radiological Monitoring Plan; Radioactive Waste Management Plan; and Preliminary Radiological Decommissioning Plan
Category I	> 500 Bq/g	Basic Information Radiation Safety Analysis Report (SAR)

Fig 2. Application Documents according to facility classification

Facilities exempted from this regulation must have activity concentrations below 10 Bq/g, annual effective dose to workers below 1 mSv and annual dose to the representative individual below 0.3 mSv.

THE REGULATORY FRAMEWORK IN BRAZIL

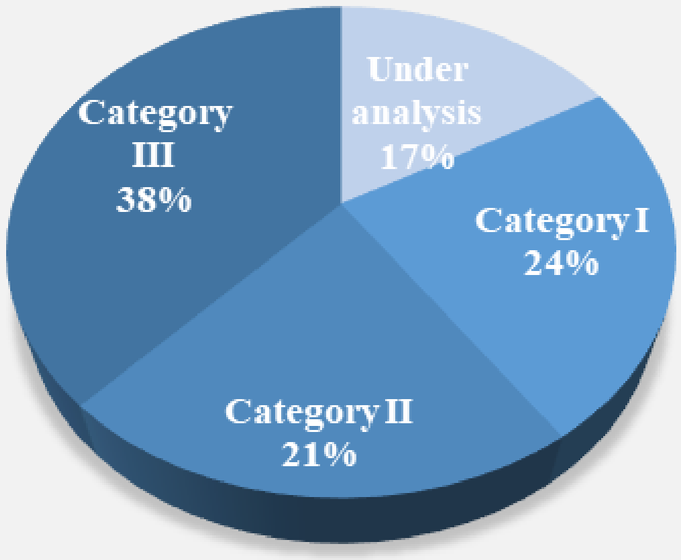

Fig 3. Distribution of the 43 regulated NORM facilities by category (excluding Oil & Gas and uranium mining and milling)

Category	Total Activity Concentration (Bq/g)		
	Minimum	Maximum	Mean
Categoria I	567.4	50,930	7,999
Categoria II	197.7	449.25	330.05
Categoria III	15.7	87.00	39.82

Fig 4. Minimum, maximum and mean total activity concentration by category of the 43 regulated NORM facilities.

CASE STUDY OF NIOBIUM INVENTORY

Currently, there are seven facilities, including mines and milling and processing plants for niobium under regulatory control. Of these facilities, four are classified as Category I (more restrictive), one as Category II, and two as Category III.

The highest concentration of radionuclides occurs in the metallurgical process, where radionuclides tend to migrate to the waste. In mining, the samples with the highest concentrations are ore or barren material.

Facility	Category	Higher Total Activity Concentration (Bq/g)	Sample with higher activity concentration
Milling	I	747.59	Slag
Milling	I	931.00	Bag Filter
Milling	I	7,718.00	Slag
Milling	I	5,172.00	Solid from aluminothermic fusion gas scrubber
Mine	II	319.30	Ore
Mine	III	87.00	Barren
Mine	III	31.00	Ore

Fig 5. Category, and activity concentration of the sample responsible by classification of niobium facilities

CASE STUDY OF NIOBIUM INVENTORY – RESIDUES AND WASTE

Facility	Residue/waste sample	Activity Concentration (Bq/g)					
		U	Th	Ra-226	Ra-228	Pb-210	Total
I	Digestion sludge - alloy Fe/Ta/Nb	12.29	4.52	8.46	4.96	4.72	175.53
	Columbite digestion sludge	11.26	4.29	37.0	11.26	13.5	424.43
	Effluent treatment sludge	0.22	0.01	0.05	0.005	0.05	1.61
II	Pre-concentration waste	0.26	0.09	0.02	0.01	0.02	1.62
III	Barren Material	0.828	6.529	0.993	7.61	0.73	87,391
IV	Sludge	9.01	1.31	1.71	8.44	1.99	108.0
	Magnetite	0.81	0.32	0.15	0.79	0.14	11.0
	Fltation waste	3.43	0.9	1.05	4.32	0.93	56.0
	Bag filter with Pb	24.6	3.75	1.9	29.6	203.1	931.0
V	Slag	289.737	183.383	288.17	157.59	25.014	4,855.0
	dust abatement	40.386	32.425	76.495	54.674	962.574	4,073.0
VI	Scalp waste	0,15	0,21	0,06	0,81	0,06	8,79
	Processing Waste (tailings dam)	0,04	0,49	0,18	2,14	0,12	21,38
VII	Waste (tailings dam)	0,07	0,34	0,25	1,46	0,21	15,95
	Milling Waste (tailings dam)	0,39	0,29	1,73	1,19	1,14	26,73
	Waste (tailings dam)	0,6	0,48	3,05	2,17	1,68	46,36
	Aluminothermic Slag	11,74	17,55	11,22	26,43	0,01	382,39
	Slag	12,45	18,52	8,77	16,19	1,01	282,18

Fig 6. Activity concentration of radionuclides in waste and residues samples

The distribution of the activity concentration depends on chemical and mineralogical characteristics of the mine's geological formation, as well as on the beneficiation process.

The activity concentration of the tailings and residues of Nb production ranged from 1 Bq/g to 4,855 Bq/g.

CASE STUDY OF NIOBIUM INVENTORY – RESIDUES AND WASTE

According to data reported by the companies to **CNEN**, the Fe-Nb alloy and niobium oxide production was **48.39 thousand tonnes/year** (from 2015 to 2017).

The amount of waste and residue generated by the controlled facilities ranged from **7.18 million tonnes/year to 21.50 million tonnes/year**.

CASE STUDY OF TIN INVENTORY

There are nine facilities, including mining, milling and processing for tin under the regulatory control of CNEN, regarding the aspects of radiation protection.

Three of them are mining facilities and seven milling industries. All the non-exempted mines are classified as Category III, under the criteria of CNEN-NN-4.01, and the samples with higher activity are the mineral concentrate.

Due to the process of metallurgy, the milling facilities are classified as Category I, with total activity concentration higher than 500 Bq/g.

Facility	Category	Higher Total Activity Concentration (Bq/g)	Sample with higher activity concentration
Mine	III	38	Mineral concentrate
Milling	I	2813	Sn/Pb Alloy
Milling	I	567.4	Slag
Milling	II	329	Slag
Mine	III	44	Mineral concentrate
Milling	I	7578	Refined metallic lead
Mine	III	67	Ore
Milling	I	1274	Slag
Milling	I	2259	Sn/Pb Alloy

Fig 7. Category, and activity concentration of the sample responsible by classification of niobium facilities

CASE STUDY OF TIN INVENTORY – RESIDUES AND WASTE

Facility	Residue/waste sample	Activity Concentration (Bq/g)					
		U	Th	Rs 226	Ra 228	Pb	Total
VIII	Waste	0.31	0.1	0.07	0.08	0.07	3.0
IX	-	Waste transferred to another facility					
X	-	Data is not available. To be sent in 2022					
XI	Bag Filter	0.576	0.592	2.713	6.643	8.808	106.0
	Slag	11.062	15.955	7.757	21.769	0.41	315.0
	Sn-Pb Alloy	0.089	0.262	0.062	0.012	39.557	121.0
XII	Waste (tailings dam)	0.262	0.168	0.05	0.193	0.061	4.0
XIII	Slag	70.18	71.63	25.823	67.332	9.253	1211.0
XIV	Waste (tailings dam)	1.552	1.441	1.733	1.198	1.707	36.0
XV	-	Waste transferred to another facility					
XVI	Slag	6.034	11.713	7.117	15.331	0.088	355.0
	Bag filter	0.262	0.089	0.716	0.502	1.14	13.6
	Sn-Pb Alloy	1.037	0.089	0.23	0.013	751.766	2259.0

Fig 8. Activity concentration of radionuclides in waste and residues samples

The characteristics of residues and waste depend on the geology and geochemical aspects of the deposits from where the ore is extracted, it being also strongly influenced by the beneficiation process.

The activity concentration of the tailings and residues of tin production ranged from 3 Bq/g to 2,259 Bq/g.

CASE STUDY OF TIN INVENTORY – RESIDUES AND WASTE

In 2015, Brazil produced **18.90 thousand tonnes** of tin (metal contained in the concentrate).

The annual generation of waste and residues (from 2015 to 2017) registered by CNEN was **7. 36 Mt to 9.12 Mt annually,** according to information provided by the companies.

However, out of the nine tin facilities, one did not provide production data; two did not report quantities on an annual basis. There are also two facilities that process slag but return the waste to the origin facility for disposal.

CHALLENGES AND DIFFICULTIES TO ESTABLISH AND KEEP UPDATED NORM INVENTORIES

NORM inventory is essential for subsidizing the development of policies for residues and wastes management, in the context of the circular economy.

Although CNEN Standard requires sufficient data to build the **national inventory** of NORM-related industries in Brazil, some aspects need to be improved:

- There is no uniformity of data reported by companies on the production of waste and residues, which makes it difficult to estimate the amount of stored waste;
- Lack of information on the chemical and mineralogical characterization of the waste and residue (only radionuclides are measured by CNEN laboratory);
- Name, location and photos of industries cannot be disclosed by CNEN;
- Private Laboratories which provide radiometric analysis services in Brazil are scarce. Besides, conditions for accreditation of these laboratories to guarantee analysis traceability of NORM samples must be improved.

CONCLUSION

Although the country has organizations (at different levels) and professionals with a good understanding of the various aspects of NORM, there is still space for improvement.

Sampling and characterization must be designed to meet each specific type of NORM.

It is important to adapt the system of radiation protection to the paradigm of circular economy, including improvement of policies and standardization of inventory.

Such improvements are essential for establishing reliable inventories, verifying compliance with regulatory requirements, and adequately manage NORM residues and wastes.

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Thank you for your attention