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Regulations for the transport of nuclear and radioactive materials in Brazil

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Astract: The transportation of radioactive material involves a set of procedures as varied as they are complex, justifying its strong standardization. This article aims to demonstrate that the collaborative effort between two Brazilian licensing agencies, which resulted in the elaboration of a Joint Technical Note, was justified considering the legislative process. By consolidating various norms and procedures – from the configurations of packages containing radioactive material to the training program for drivers responsible for transportation, including environmental safety of routes – it proves to be a facilitator of the work for everyone involved in this activity. In conclusion, it is shown that there is strong standardization of this activity in Brazil and that the legislative process is dynamic, reflecting natural improvements in technical and legal aspects inherent to the nature of the material involved.

Keywords: environmental legislation, packaging, transportation, radioactive emission.

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Normativas brasileiras para realização de transporte de material nuclear e radioativo no Brasil

Resumo: O transporte de material radioativo envolve um conjunto de procedimentos tão variados quanto complexos, que justificam sua forte normatização. Este artigo busca mostrar que o esforço colaborativo entre dois órgãos licenciadores brasileiros, que resultou na elaboração de uma Nota Técnica Conjunta, se fez justificado tendo em vista o processo legiferante, mas que, por consolidar diversas normas e procedimentos – das configurações de embalados contendo material radioativo ao programa de preparo de motoristas encarregados do transporte, passando pela segurança ambiental de rotas – mostra-se como facilitador do trabalho de todos os envolvidos nesta atividade. É demonstrado, por fim, que há forte normatização dessa atividade no Brasil e que o processo legiferante é dinâmico, como reflexo natural dos aperfeiçoamentos técnicos e legais, inerentes à própria natureza do material envolvido.

Palavras-chave: legislação ambiental, embalagem, transporte, emissão radioativa.

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1. INTRODUCTION

The transportation of nuclear and radioactive materials, due to its crucial importance and responsibility, is strongly regulated by specific guidelines for each mode of transportation. The regulations aim to ensure the safety of the professionals involved, as well as the general population and the environment. In Brazil, this regulation extends beyond agencies dedicated to each mode of transportation. While the National Nuclear Energy Commission (Comissão Nacional de Energia Nuclear - CNEN) serves as the nuclear licensing authority, the Brazilian Institute of the Environment and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA) carries out actions related to national environmental policies. IBAMA is responsible for the environmental licensing of this activity at the federal level.

In this work, in addition to reviewing the regulations governing the transportation of radioactive and nuclear material, it is also demonstrated that the collaborative efforts between the environmental regulatory agency (IBAMA) and the nuclear licensing agency (CNEN) have led to the formulation of the Joint Technical Note Ibama-Cnen 01-2013) (NTC) [1]. The scope of this note was to gather and describe the legislation and regulations applicable to nuclear material and other radioactive material transportation operations. It also aimed to present models for the development of Transport Plans and consolidate the understanding of the safety of radioactive cargo transportation from origin to final destination.

Although the NTC is a document jointly developed by licensing agencies, the focus is on safety and environmental protection, considering the harmonization of actions between IBAMA and CNEN in "applying safety requirements for the safe transport of nuclear materials and other radioactive materials" [1]. Specifically in the environmental field, the NTC "applies to the process of obtaining the Environmental Transport Authorization issued

by IBAMA" [1], considering information contained in the General Transport Plan (GTP, see item 6.1 of this article) and Specific Transport Plan (STP, see item 6.2 of this article) which are part of that document.

2. MATERIALS AND METHODS

The transportation of nuclear and radioactive material in Brazil is mainly regulated by two agencies: the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) and the National Nuclear Energy Commission (CNEN). IBAMA, as the agency responsible for environmental protection, establishes guidelines and Norms for the safe transportation of radioactive material. It issues licenses and authorizations necessary for companies and institutions wishing to transport these materials.

Furthermore, IBAMA is also responsible for the inspection and monitoring of transportation activities to ensure compliance with established regulations. CNEN, on the other hand, is the agency responsible for the regulation and control of nuclear activities in Brazil. It establishes specific guidelines for the transportation of nuclear and radioactive materials, aiming at radiological protection and the physical safety of these materials. CNEN also issues licenses and permits for companies and institutions wishing to engage in transportation, in addition to conducting regular inspections and evaluations to verify compliance with established norms.

3. REGULATIONS AND SCOPE OF OPERATION FOR ENTITIES

A brief overview is provided of current international and general regulations in Brazil (for hazardous products) before specifically addressing regulations related to the transport of radioactive and nuclear materials.

3.1 International Regulation

Nuclear materials and other radioactive materials are assigned to Class 7 of the United Nations' classification of dangerous goods. The international transportation of this class is subject to the recommendations of the Orange Book [2] and the International Atomic Energy Agency (IAEA) [3] for the safe transport of radioactive materials.

For air transport, International Air Transport Association (IATA) [4] publishes the Dangerous Goods Regulations (DGR). This regulation consists of a set of procedures aimed at the air shipper and operator, for the safe transportation of dangerous products.

3.2 Regulation in Brazil for hazardous goods in transportation modes

In Brazil, the regulation for the transportation of dangerous goods, including nuclear and radioactive materials, is addressed by different authorities and regulations, with the main ones being (see Table 1):

Table 1: Regulation of the Transport of Hazardous Materials in Brazil by Mode[1]

MODE	AGENCY	NORMATIVE
Maritime Transport	Diretoria de Portos e Costas (DPC) da Marinha Brasileira[2]	Regulations of the Maritime Authority (NORMAMs)
Land Transport	ANTT – Agência Nacional de Transportes Terrestres[3]	Resolution Nº 5.998/2022 [6]
Air Transport	ANAC – Agência Nacional de Aviação Civil[4]	Brazilian Civil Aviation Regulation - RBAC 175 – Transportation of Dangerous Goods by Civil Aircraft.[7]

Source: NTC data.

[1] Free translation
[2] Ports and Coasts Directorate (DPC) of the Brazilian Navy
[3] National Land Transportation Agency
[4] Brazilian Civil Aviation Regulation

Among the regulations mentioned above, the following highlights (excerpts) are made:

I - For maritime transportation, we have NORMAM – 321/DPC from 2023, which establishes the following [5]:

(From Section III):

> 2.8 - RESPONSIBILITY
> Classification should be done by the shipper, consignor, consignee, or competent authority when determined.
> 2.9 - CLASSES AND DIVISIONS
> Class 7: comprises substances that emit radiation where the concentration and total activity are within parameters established in the IMDG Code[5]. In Brazil, the National Nuclear Energy Commission - CNEN establishes the Norms for packaging, testing, and transportation[6].

II - For the land transportation of radioactive material, we have Resolution 5.998/22 from ANTT, which includes, as an integral part, the List of Hazardous Products that refers to the Norms of CNEN, as shown in Table 2:

Table 2: Transportation of hazardous products in the land mode[7]

UN Number	Material Description	Packing and Portable Tanks - Procedure
2908, 2909, 2910, 2911, 2912, 2913, 2915, 2916, 2917, 2919, 2977, 2978, 3321, 3322, 3323, 3324, 3325, 3326, 3327, 3328, 3329, 3330, 3331, 3332, 3333	Radioactive Material. Various volume types, according to UN classification	To check CNEN Norms

Source of the data: Resolution 5.998/22 from ANTT (National Land Transportation Agency).

Additionally, regarding the safety of transportation, the mentioned Resolution states the following:

> Article 8: Vehicles used in the transportation of hazardous products must carry a set of equipment for emergency situations, appropriate to the type

[5] IMDG: International Code for Maritime Transport of Dangerous Goods
[6] Free translation
[7] Free translation

> of product being transported, located outside the vehicle's cargo compartment, according to the Supplementary Instructions attached to this Resolution.
>
> Sole Paragraph: Except for vehicles with a total gross weight of up to 3.5 tons, the equipment in the emergency kit can be placed in the cargo compartment, provided they are located near one of the doors or access hatches and are not obstructed by the transported cargo[8] [6].

III - For the air transportation of radioactive material, we have the Brazilian Civil Aviation Regulation - RBAC 175 – Transportation of Hazardous Articles on Civil Aircraft, which establishes the following:

> 175.303 General conditions
>
> d) Packaging for the transportation of radioactive material, Class 7, must comply with the specific regulations of CNEN (National Nuclear Energy Commission)[9] [7].

3.3 Regulation in Brazil by Licensing Authorities

In regard to the regulation and control of the safety of transportation of hazardous and radioactive materials, two licensing bodies in Brazil operate in this area: CNEN - National Nuclear Energy Commission, a federal agency established in 1956 and part of the structure of the Ministry of Science, Technology, Innovations, and Communications (MCTIC); and Ibama - Brazilian Institute of the Environment and Renewable Natural Resources, a federal agency created in 1989 and linked to the Ministry of the Environment and Climate Change (MMA).

a) The regulation by IBAMA for the transportation of hazardous products is comprised of the following documents:

Resolution No. 237/1997 [8] of the National Environment Council (CONAMA), which establishes:

[8] Free translation
[9] Free translation

> Article 4. It is the responsibility of the Brazilian Institute of the Environment and Renewable Natural Resources - IBAMA, the executing body of the National Environmental System (SISNAMA), to carry out the environmental licensing referred to in Article 10 of Law No. 6.938 [6], dated August 31, 1981, for enterprises and activities with significant environmental impact at the national or regional level, namely:
>
> (…)
>
> IV - intended for researching, extracting, producing, processing, transporting, storing, and disposing of radioactive material at any stage, or utilizing nuclear energy in any of its forms and applications, subject to the opinion of the National Nuclear Energy Commission – CNEN[10] [8].

- IBAMA Normative Instruction No. 05/2012 [9], which establishes:

> Article 1. This Normative Instruction establishes the transitional procedure for environmental authorization for the operation of maritime and interstate, terrestrial, and river transportation of hazardous products.
>
> (…)
>
> Paragraph 1. The National System for the Transportation of Hazardous Products must be an automated, interactive, and simplified system for remote service and information, with the completion of electronic forms via the Internet.
>
> (…)
>
> Article 4. Until the National System for the Transportation of Hazardous Products is implemented and made available to users, the document "Environmental Authorization for Interstate Transportation of Hazardous Products" will be issued to legal entities and individuals who meet the requirements for obtaining the Environmental Regularity Certificate, in accordance with the rules of the Federal Technical Registry of Potentially Polluting Activities or Users of Environmental Resources.
>
> Article 5. At the time of interstate transportation, the transporting company, whether it is the main office or a branch as indicated on the fiscal document, must have a copy of the Environmental Authorization for the Transportation of Hazardous Products for each vehicle or vehicular composition.
>
> Single Paragraph. Compliance with the provisions of this Normative Instruction does not exempt those engaged in the activity of maritime and interstate, terrestrial, and river transportation of hazardous products from complying with other applicable regulations, especially those published by

[10] Free translation

> the National Land Transportation Agency - ANTT, the National Waterway Transportation Agency - ANTAQ, and the Brazilian Navy[11] [9].

b) The regulation of CNEN for the transportation of radioactive and nuclear materials is, in turn, comprised of the following Norms:

CNEN-NN-5.01 Norm for the Transportation of Radioactive Materials [10] (CNEN Resolution 13-1988) and subsequent versions;

CNEN-NN-5.04 Norm for Tracking of Vehicles Transporting Radioactive Materials [11] (CNEN Resolution 148/2013);

CNEN-NN-5.05 Norm for Design and Testing Requirements for the Certification of Radioactive Materials, Packaging, and Packages [12];

Regulatory Position CNEN 3.01/001:2011 Criteria for Exclusion, Exemption, and Waiver of Radiological Protection Requirements [13].

3.4 Competencies

According to the NTC, the competencies of the Brazilian licensing bodies are transcribed as follows:

> CNEN is the competent authority for controlling the potential exposure of individuals, their properties, and the environment to ionizing radiation (radiological protection), through the certification of packaging used in transportation and the regulation of other actions related to the radiological aspects of nuclear materials and other radioactive materials transported by air, land, and water, as established by national laws.
>
> IBAMA is the competent authority for assessing subsidiary or secondary risks of radioactive loads to comply with the provisions of Complementary Law No. 140/2011 [14]. In the case of toxicological, explosiveness, spontaneous combustion, pyrophoric, oxidative, reactivity, and corrosiveness risks caused by the radioactive material to be transported,

[11] Free translation

IBAMA will complement the control actions carried out by CNEN, especially in the evaluation and application of Emergency Response Plans. IBAMA is also responsible for evaluating and limiting, when possible, the conduct of transportation activities in routes that include sensitive environmental areas, at inappropriate times, in large urban agglomerations, among other factors that may be considered as the required technical documents provide the necessary information to enhance the environmental control of this activity[12].

4. CLASSIFICATION FOR THE PURPOSE OF TRANSPORTING RADIOACTIVE AND NUCLEAR MATERIALS

4.1 Classification and Gradual Approach

The properties of the material, as well as its United Nations assigned hazard number, are criteria for the following classification:

70 - Radioactive Material with no subsidiary risk

72 - Radioactive gas

723 - Radioactive gas, flammable

73 - Radioactive liquid, flammable

74 - Radioactive solid, flammable

75 - Radioactive material, oxidizing

76 - Radioactive material, toxic

78 - Radioactive material, corrosive

For the risk assessment of radioactive materials, the following safety premises for the transportation of nuclear materials and other radioactive materials are adopted, as established by CNEN and specified in NTC: adequate containment of the material within its packaging

[12] Free translation

to prevent dispersion; control of the External Dose Rate through the incorporation of shielding into the volume and appropriate signage; control of the configuration of volumes containing fissile material; control of temperature levels on the surface of the volume and prevention of damage resulting from heat.

CNEN adopts the international practice of a gradual approach to define the degree of risk associated with shipments of nuclear materials and other radioactive materials. This approach is adopted by NTC, by comparing the activity of the material to be transported with the following types of volumes:

- Exceptive Package - A volume in which the packaging, of common industrial or commercial type, contains a small quantity of radioactive material with limited activity.

- Industrial Package - A volume in which the packaging, of reinforced industrial type, contains Low Specific Activity (LSA) material or Surface Contaminated Object (SCO) with limited activity.

- Type A Package - A volume consisting of Type A packaging and radioactive content subject to activity limits, without the need for CNEN project approval, except if it contains fissile material.

- Type B Package - A volume consisting of Type B packaging and radioactive content without a pre-established activity limit.

- Type C Package - A volume consisting of Type C packaging and radioactive content without a pre-established activity limit, intended for air transport.

- Type H Package - A volume designed to transport non-fissile or exceptive fissile uranium Aide.

The "Gradual Approach" considered in the safety of radioactive material transport, finds the following definitions in the "Glossary of the Brazilian Nuclear and Radiological Sector" [15], published by CNEN:

> a) application of nuclear physical security measures proportional to the potential consequences of unauthorized acts involving or directed at nuclear material, other radioactive material, facilities or associated activities, or other acts with the potential to cause radiological damage, as determined by the State;
>
> b) application of nuclear safety requirements in proportion to the characteristics of facilities, activities, or radioactive sources and associated risks[13].

The safety of radioactive material transportation operations depends on the design of the packaging. The type of packaging, in turn, depends on the characteristics of the material and the activity that this material exhibits. Tables 3 and 4 below summarize the basic information related to the type of packaging based on the classification and activity (radioactivity) of the material:

Table 3: Classification of radioactive materials based on Activity (A_1 e A_2)[14]

Classification of radioactive materials based on Activity (A_1 e A_2)	
A_1 Limit _ Special Form	Sealed Source
	Non-dispersible Solid
A_2 Limit – Other Form	SCO I, II, III
	LSA I, II, III
	Físsile Materials
	Liquid Sources
	Non-sealed Solid Sources
	Gaseous Sources

Source: NTC, adaptation of Table 1

[13] Free translation
[14] Free translation

Table 4: Radioactive material in special form and in other forms[15]

Radioactive Material in Special Form	Radioactive Material in Other Forms
Activity <<< A_1: Exceptive Packaging	Activity <<< A_2: Exceptive Packaging
Activity <= A_1: Type A Packaging	Activity <= A_2: Type A Packaging
Activity > A_1: Type B Packaging	Activity > A_2: Type B Packaging

Source: NTC, Table 2

Where:

A_1 - is the maximum activity (radioactivity) of a radioactive material in special form that can be transported in a Type A Package, according to NTC.

A_2 - is the maximum activity (radioactivity) of a radioactive material in other forms that can be transported in a Type A Package, according to NTC.

As examples, from Table II of CNEN-NN 5.01 Norm, we have the following values: For ^{137}Cs, $A_1 = 2$ TBq and $A_2 = 6 \times 10^{-1}$ TBq , with the information, in the aforementioned Norm, that the values of A1 and A2 include contributions from daughter nuclides with a half-life of less than 10 days, namely: Ba-137m (metastable); for ^{14}C: $A_1 = 4 \times 10^{1}$ TBq and $A_2 = 3$ TBq.

4.2 Application of the gradual approach regarding the need for the issuance of Environmental Authorization and Transport Approval.

The decision on whether or not to issue the Environmental Authorization and Transport Approval is based on the premises mentioned in the preceding section and the application of the gradual approach.

[15] Free translation

4.2.1 Fissile Materials

According to NTC data:

The transportation of fissile materials, as per the CNEN transportation Norm, is defined as having "the risk of the radioactive material reaching criticality, that is, a chain reaction that can pose high risks of radiological exposure to the population and the environment" [1][16]. Fissile materials include Unirradiated Fuel Elements and Irradiated Fuel Elements for research reactors and power nuclear reactors. Given their high activity and the risk of criticality events in case of accidents, the designs of volumes and transport operations for these materials are involved in high complexity. For the transport of these materials, the shipper must obtain the Environmental Authorization for Transport from IBAMA and Transport Approval from CNEN.

4.2.2 Materials transported in exceptive packages

"Exceptive package" is related to packaging containing small quantities of radioactive material with limited activity. Table 5 contains data from CNEN-NN-5.01 Norm:

Table 5: Activity limits for exceptive packages[17]

Content	Instruments and Articles		Material Limit
	Limits for Each Individual Item	Limits for volume	Limits for volume [(a)]
Solid / Special Form	$10^{-2} \times A_1$	A_1	$10^{-3} \times A_1$
Sólid / Other Forms	$10^{-2} \times A_2$	A_2	$10^{-3} \times A_2$
Líquids	$10^{-3} \times A_2$	$10^{-1} \times A_2$	$10^{-4} \times A_2$
Gases: tritium	$2 \times 10^{-2} \times A_2$	$2 \times 10^{-1} \times A_2$	$2 \times 10^{-2} \times A_2$
Gases / Special Form	$10^{-3} \times A_1$	$10^{-2} \times A_1$	$10^{-3} \times A_1$
Gases / Other Forms	$10^{-3} \times A_2$	$10^{-2} \times A_2$	$10^{-3} \times A_2$

[16] Free translation
[17] Free translation

Considering the data from the table above, it is observed that the transportation of radioactive materials in small quantities - such as sources used for checking and calibrating radiation meters - enables the exemption from obtaining Environmental Authorization for Transport from IBAMA for transport operations involving Exceptive Packages.

4.2.3 Materials transported in industrial packages

a) Low Specific Activity Materials – LSA

Low Specific Activity (LSA; BAE in Brazil) materials can be classified into three groups, LSA-I, LSA-II, and LSA-III, where LSA-II and LSA-III can be Fissile and Non-Fissile. The classification of LSA materials is contained in CNEN NN 5.01 Norm (Regulation for the Safe Transport of Radioactive Material):

- LSA-I: Ores containing natural radionuclides and concentrated uranium and thorium; natural uranium, depleted uranium, natural thorium, or solid or liquid compounds of these elements and their mixtures; non-irradiated and in solid or liquid form. For materials such as pyrophoric thorium metal, thorium nitrate, pyrophoric uranium metal, solid uranium nitrate, hexahydrated uranium nitrate, Cake II (by product of chemical processing of monazite), and mesothorium cake (resulting from the processing of Cake II), due to subsidiary risks, IBAMA will require the GTP to justify the issuance of the Environmental Authorization for Transport. Monazite, due to its low toxicity and solubility, and ores with associated thorium and uranium, with low concentrations of these radionuclides, are exempt from Environmental Authorization for Transport from IBAMA. Under CNEN: transport operations do not require Transport Approval for LSA-I materials.

- LSA-II: According to NTC, they include "radioactive materials such as non-solidified radioactive waste from the operation of nuclear fuel cycle facilities, such as low specific activity resins, filter sludges, absorbed liquids; and water with tritium (^{3}H) concentration up to 0.8 TBq/L, as well as other materials established by the CNEN Radioactive Material

Transport Norm"[18]. For LSA-II materials, regarding non-solidified radioactive waste generated by the operation of nuclear facilities and water with tritium (^3H) concentration above 0.8 TBq/L, obtaining the Environmental Authorization for Transport from IBAMA and Transport Approval from CNEN is required. For other materials in the LSA-II category, not described in the NTC, that present risks of contamination or other environmental damage in case of an accident, obtaining Environmental Authorization for Transport from IBAMA is required, and, therefore, the submission of the GTP.

Under CNEN: Transport operations are evaluated on a case-by-case basis regarding the need to submit the GTP. Note: Volumes less than 0.1 L, for sampling purposes, are exempt from regulation by both IBAMA and CNEN.

- LSA-III: This class of materials is not defined in the NTC but is classified in CNEN NN 5.01 as solid BAE materials, except for powders (e.g., consolidated waste and activated materials), for which:

> i - the radioactive material is distributed in a solid or a set of solid objects or is uniformly distributed in a compact solid binding material (such as concrete, asphalt, ceramic, etc.); ii - the estimated average specific activity of the solid, excluding any shielding material, does not exceed 2×10^{-3} A_2/g[19].

b) Surface Contaminated Objects (SCO)

Surface Contaminated Objects are divided into three groups: SCO-I, SCO-II, and SCO-III, Fissile or Non-Fissile. If the contamination of SCO is classified as fissile, regardless of whether SCO is I, II, or III, the shipper must submit the Specific Transport Plan to IBAMA and CNEN. Non-Fissile SCO, due to the absence of subsidiary risks and their reduced radiological risks, are exempt from obtaining Environmental Authorization for Transport from IBAMA and Transport Approval from CNEN.

[18] Free translation
[19] Free translation

4.2.4 Materials Transported in Type A Packages

a) Radioactive Material in Special Form (RMSF-A)

CNEN regulations classify sealed sources and non-dispersible solids (non-dispersible solids) with dimensions not less than 0.005 m as material in special form. In this type of transport, the technical aspects are related to safety and radiological protection, and their regulation is exclusively the responsibility of CNEN.

The characteristics and tests to which RMSF-A is subjected indicate that, in the event of accidents, such loads generate limited risks of environmental contamination.

Environmental Authorization for Type A Volumes for RMSF – not required, as it does not require an increase in safety or a reduction in environmental risk, as it does not present secondary or subsidiary risks.

b) Radioactive Material in Other Forms (RMOF-A)

The CNEN regulation classifies as material in other forms non-sealed sources and dispersible solids. The technical aspects related to RMOF are the same as those related to RMSF (Radioactive Material in Special Form), except for the activity limit, which is much lower. In this regard, being a material of limited activity, in the event of an accident, significant environmental contamination is not expected.

Radioactive pharmaceuticals[20] ("radiofármacos"): Their transport is exempt from obtaining Environmental Authorization for Transport (IBAMA) and Transport Approval (CNEN) for the following reasons: (i) The products have a short half-life of hours or days – therefore, in the event of an accident, the consequences are expected to be minimal in case of loss of containment; (ii) Environmental control of this type of product by the environmental agency is irrelevant to their safety and could cause disruptions to the dynamics of meeting their demand due to their short half-life; (iii) the volumes, due to their shielding,

[20] Free translation

comply with safety requirements established by the nuclear licensing agency, reducing the possibility of loss of containment and, consequently, exposure of people and the environment to ionizing radiation.

c) Materials transported in Type AF volumes

The Type AF volume is not defined in the NTC, but it is included in Table 3 of this document. It refers to the Type A Fissile volume.

4.2.5 Materials transported in Type B volumes

a) Radioactive material in special form Type B (RMSF-B) packages are designed for transporting large quantities (activities) of radioactive materials, and, for this reason, they are subject to rigorous certification tests by regulatory agencies in their country of origin. These certificates are validated by the nuclear regulatory agency for use in Brazil.

Considering that RMSF-B is subject to more rigorous testing and severe transportation conditions, and also considering the level of security established by the nuclear regulatory agency, the issuance of the Environmental Transport Authorization for Radioactive Materials transported in Type B volumes can be considered automatic - without the need for prior analysis of the GTP by IBAMA.

b) Radioactive material in other forms (RMOF-B): for RMOF-B (A_2), the activity limits are much lower than those of RMSF-B (A_1).

Examples of this category include[21]:

i) Radioactive material for medical diagnosis (e.g., non-fractionated Molybdenum for the production of radiopharmaceuticals);

[21] Free translation

ii) Uranium Hexafluoride. Such materials have a greater potential for dispersion compared to RMSF-B. Therefore, both the nuclear regulatory agency and the environmental regulatory agency will evaluate the GTP for all cases of Radioactive Material in Other Forms in Type B volumes for the issuance of their respective transport authorizations.

4.2.6 Materials transported in Type C volumes

Type C volumes are those containing unlimited quantities of radioactive material, and therefore, their transport is assumed to be of high risk to people and the environment. Thus, the transport of Type C volume is subject to Environmental Transport Authorization (environmental regulatory agency) and Transport Authorization (nuclear regulatory agency).

4.2.7 Materials Transported in Type H Volumes

The Type H volume is related to uranium hexafluoride.

a) Transport of UF_6 samples

International norms and regulations from the national nuclear regulatory agency exempt from regulatory control the transport containing quantities below 0.1 kg of uranium hexafluoride. Therefore, it is exempt from Environmental Transport Authorization (environmental regulatory agency) and Transport Authorization (nuclear regulatory agency).

b) Transport of UF_6 (samples) for the manufacture of fuel elements

These are data extracted from NTC[22]:

> Uranium Hexafluoride (UF_6) is a compound used in one of the stages of uranium enrichment. This material has a low boiling point, a low melting

[22] Free translation

> point, and is extremely volatile, being utilized in gaseous form for isotopic separation. The primary subsidiary risk of UF_6 is its corrosiveness (it belongs to Hazard Class 8 of dangerous goods) and it may also exhibit toxicological characteristics, with the potential for the formation of Hydrofluoric Acid upon contact with atmospheric moisture [1].

Considering the risks associated with this type of transportation, nuclear and environmental regulatory bodies will need to evaluate the GTP for the purpose of issuing respective Transport Authorizations.

4.2.8 Transport under special arrangement

In cases where it is impractical to meet any of the requirements of CNEN-NE-5.01, transportation can only occur as a "Special Arrangement". In this type of transport, transport authorizations will be issued provided that alternative safety measures are accepted by the nuclear and environmental regulatory agencies.

The information is extracted from the NTC it self[23]:

> The most common case of transportation operation under special arrangement involves the transfer of spent cobalt-60 sources used in teletherapy to storage facilities located in CNEN institutes. The unavailability of Type B packaging results in these source transportation operations being carried out within the equipment itself (commonly referred to as the head) used in patient treatments. The basis for CNEN's acceptance of this special arrangement is provided by a study conducted by Canada, for which a special arrangement approval certificate was granted by the regulatory authority of that country [1].

[23] Free translation

5. SECURITY ASPECTS ASSOCIATED WITH VOLUME TYPES

The typology of volumes is based on CNEN NN 5.01, which establishes parameters regarding the type of material to be transported, activity limits, and the associated risk of its transportation. However, for each type of volume, there is a safety criterion associated with it, involving tests and safety trials of packaging containing radioactive material samples. For such tests, scale models may be used, with adjustments made to the test parameters. The relevant regulation governing this matter is CNEN NN 5.05 [12].

Examples of test parameters extracted from the mentioned regulation are as follows:

a) For low dispersivity radioactive material: The dose rate at three meters from an unshielded radioactive material should not exceed 10 mSv/h.

b) For radioactive material in a special form:

(i) Impact test - the sample should fall from a height of nine meters onto the target[24].

(ii) Percussion test – "the sample should be placed on a lead plate supported by a smooth and solid surface and should be struck by the flat face of a mild steel bar in a manner to cause an impact equivalent to that resulting from a 1.4 kg mass in free fall from a height of one meter"[25].

(iii) Thermal test: "the sample must be heated in air at a temperature of 800 °C and maintained at this temperature for ten minutes, after which it must cool naturally"[26].

c) For Type C volumes under accidental transport conditions (from article 110)[27]:

[24] Free translation
[25] Free translation
[26] Free translation
[27] Free translation

> Expose a sample for a period of 30 minutes in a thermal environment that provides a heat flow at least equivalent to that of a fire resulting from the burning of a hydrocarbon fuel with air, in sufficiently calm ambient conditions to provide an average emissivity coefficient of the flame of 0.9 and an average temperature of at least 800°C, completely enclosing the sample [12].

5.1 General design requirement for packaging and volumes – transportation by any means

From the mentioned CNEN NN 5.05 Norm, the following excerpts are highlighted[28]:

> Article 44 A volume must be designed in such a way as to provide sufficient shielding to ensure that, under routine transport conditions and with the maximum radioactive content that the volume may contain, the Dose Rate does not exceed the following values:
>
> I - 5 μSv/h at any point on the external surface of an exempted volume;
>
> II - 2 μSv/h at any point on the external surface, except if the package or overpack is transported exclusively by road or rail and under the conditions imposed by Subsection III of this article, or in the Special Arrangement mode by sea or air (Note: under conditions established in the aforementioned article, which are not reproduced here) [12].

5.2 Additional requirements for air transport

From the mentioned CNEN NN 5.05 Norm, the following excerpts are highlighted[29]:

> Article 46 Volumes to be transported by air must meet the following additional design requirements:
>
> I - The temperature of accessible surfaces, without taking into account insolation, must not exceed 50 ºC at an ambient temperature of 38 ºC;
>
> II - The integrity of the containment of the volumes must not decrease when subjected to ambient temperatures ranging from -40 ºC to +55 ºC; (...)[12].

[28] Free translation
[29] Free translation

6. GENERAL TRANSPORTATION PLAN (GTP) AND SPECIFIC TRANSPORTATION PLAN (STP)

6.1 General Transportation Plan (GTP)

A General Transportation Plan (GTP) consists of a safety analysis report in which the operator describes the characteristics of the material or materials to be transported, the estimated number of shipments, or, in the case of routine transport, the frequency with which these shipments are carried out. The GTP must also include a description of safety actions to comply with related regulations.

6.2 Specific Transportation Plan (STP)

The Specific Transportation Plan (STP) is prepared based on the guidelines of Annex I of the NTC. Its content may, at times, be simpler compared to the GTP, in the sense that the gradual approach application may reveal moderate risks in accidents with loss of containment. The specific plan is submitted for the transportation of self-owned material (e.g., radiopharmaceuticals, transportation of instruments or articles) and transportation of ores and minerals containing associated radionuclides.

However, the NTC makes the following caveat[30]:

> Although the operator is given the freedom to define which information from the plan model is relevant in an STP, the completeness assessment conducted by CNEN and IBAMA may result in the need for additional information. Attachments and Appendices may be included in the transportation plan to provide additional and pertinent information [1].

[30] Free translation

7. DISCUSSION

The selection of topics in this article strictly followed the structure of the NTC. This choice was made because the document itself provides a broad spectrum of regulations related to the transport of radioactive material in Brazil, presented in a summarized manner. Additionally, while the NTC is not a regulation in itself, it contains elements, definitions, and procedures extracted from other Norms, especially those of CNEN, serving as a comprehensive guide for transportation operators and other stakeholders in the field.

The reproduction of excerpts or entire sections of Norms was a deliberate choice to ensure the accuracy of terms and their contextualization. This was done to highlight the complexity of the topic, given the richness of details contained in these Norms. The radiological theme inherently involves specific terms and technologies, demanding careful reproduction. Indeed, the variety of terms and procedures for each type of volume and material justified the presentation of a summary table in the NTC, which is reproduced in this work with slight adaptations[31].

It is evident that the Brazilian normative process enables different regulatory bodies (linked to different ministries) to act on the same topic of transporting radioactive materials. In this case, there is a kind of horizontal distribution of responsibilities, as different agencies from the same federal entity address the same topic (i.e., it is not a vertical distribution of competencies, where, for example, concurrent competence occurs between federal and state entities). Moreover, for the transportation of radioactive materials, agencies regulating transportation modes treat the transportation of radioactive materials as part of the transportation of hazardous materials. Therefore, they regulate such transportation in a general sense, leaving the responsibility for detailed procedures to licensing agencies, considering environmental, facility, and personal safety.

[31] (see Appendix 1)

It is interesting to note that the regulations of the agencies overseeing transportation modes refer to CNEN legislation regarding safety aspects related to the transportation of radioactive materials. On the other hand, the role of the environmental licensing agency (IBAMA) is to assess subsidiary or secondary risks arising from the transportation of radioactive materials, especially due to the threat and risk of accidents. Hence, the environmental licensing agency needs to evaluate the environmental safety of a specific transportation route chosen by the transport agent. This task is carried out through the analysis of the General (or Specific) Transportation Plan.

A significant part of the NTC is dedicated to the types of volumes that can house radioactive material, and the core of the matter is transport safety, which involves the type of material to be transported, activity limits, risk associated with its transport, and, in this sense, the gradual approach is emphasized. The foundation for the types of volumes is found in CNEN NN 5.01. Another important aspect to consider is that the safety requirements involve tests with packaging presented as prepared for transport, containing representative samples of radioactive material. Such tests and trials are the basis for volume projects and must comply with the requirements of CNEN NN 5.05, generally subject to unilateral approval by CNEN.

The NTC was elaborated in 2013 (with the co-author of this article – Cruz – having acted as a collaborator and reviewer of its text), revised in 2020, and, considering that the legislative process is dynamic, it is noted that the Norm in question is selectively outdated, and it is expected that a new revision will be carried out. However, the goal is for the NTC to be redeveloped as a regulatory Norm. A technical study conducted by legal consulting understood that the appropriate instrument to configure it as a joint regulation between two agencies belonging to different ministries - as is the case here - would be an Interministerial Ordinance.

Finally, it is evident that academic production related to the transport of radioactive material is quite significant and is distributed among articles focusing on the risks and safety

issues associated with this activity, as well as relevant legislation (in addition to ref. [5], [6], [7] and [14], see also, for example, ref. [16], [17], [18] and [19]). The uniqueness of this article lies in the disclosure of a Joint Technical Note resulting from collaborative efforts between two licensing agencies of the same Brazilian federal entity (the Union). Although it is an article published in a different context (sharing sensitive information due to potential threats against operators storing and transporting highly radioactive material), the sharing of information between regulatory agencies and authorities related to intelligence and legislation services has been postulated as a best practice [20]. Similarly, we advocate that collaboration between licensing agencies for the development of joint technical notes or regulations related to the safety of transporting radioactive and nuclear material should be considered a best practice.

8. CONCLUSIONS

The transportation of nuclear and radioactive materials in Brazil is a highly regulated activity, with guidelines established by IBAMA and CNEN. These regulations are fundamental to ensure the safety of those involved, environmental protection, and the control of threats, aiming to minimize the risks associated with these materials.

Strict compliance with the established guidelines by these agencies is essential to ensure that transportation is carried out safely and efficiently, protecting both the population and the environment.

The establishment and maintenance of Brazilian regulations for the transportation of nuclear and radioactive materials are of utmost importance, guaranteeing safety and radiological protection at every stage of this activity.

The continuous commitment to transparency, improvement, and enhancement of these regulations contributes to the safety and sustainable development of Brazil in the field of nuclear technology knowledge and regulation.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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APPEDIX I – NTC - SUMMARY

Table 6: Synthesis of the NTC Data[32]

Volume	Material[33]	IBAMA Authorization	Automatic IBAMA Authorization	CNEN Approv	IBAMA Exemption	CNEN Exemption
Any	Fissile*	X		X		
Exceptive	Any				X	X
Industrial	SCO I*				X	X
	SCO II*				X	
	SCO III*				X	
	LSA I	X	X		X**	
	LSA II	X	X	X		
	LSA III	X		X		
A Type	Special Form				X	X
	Other Forms				X	X
AF Type	Any	X		X		
B Type	Special Form	X	X	X		
	Other Forms	X		X		
C Type	Any	X		X		
H Type	UH_6	X		X		

*Excluding the exceptives. ** IBAMA exempts the transport of monazite and ores containing associated uranium and thorium. Source: NTC, Table 3 (adapted).

[32] Free translation
[33] Free Translation: SCO – Surface Contamined Object / LSA – Low Specific Activy Materiais

APPEDIX II

Guidelines for the Elaboration of the General Transportation Plan

This Annex outlines the key points of[34]

> […] a model accepted by IBAMA and CNEN for the elaboration of transportation plans, a document in which the applicant for authorization or approval of transportation describes the actions and safety measures to be adopted in transportation operations, aiming to establish and maintain the required safety level according to regulations [1].

1. INTRODUCTION

This chapter is dedicated to identifying the party responsible for transportation, its purpose, the acronyms used in the plan, as well as the general characteristics of transportation operations. The following items should be included: responsible parties for transportation; acronyms and definitions; objectives and general characteristics of transportation.

Additionally, this chapter provides a description of the radioactive materials to be transported, including their respective types of packaging. Moreover, it should include information on the number of shipments in the transportation operation subject to Transport Authorization. If more than one shipment is planned, an estimate of the frequency of such shipments, the quantity of material to be transported, and, if applicable, the transport companies involved in the activity should be provided. Information on the primary environmental risks associated with the transportation of the radioactive materials involved in the operation should also be included.

[34] Free translation

2. SPECIFICATION AND CLASSIFICATION OF MATERIAL

2.1 Specification and Classification of the Material

Specify all Radioactive Materials to be transported, classifying them according to CNEN's transportation regulations, providing the UN number associated with the materials, and the risk number.

2.2 Characteristics of the Material

In accordance with the NTC[35]:

> To provide information on the activity of each material to be transported, by volume (packaged), per transport unit, and per shipment, when applicable.
>
> Specify the physical and chemical form of the radioactive material, considering important properties in case of accidents, such as solubility, toxicity, explosiveness, reactivity, corrosiveness, materials susceptible to spontaneous combustion, pyrophoricity, oxidizers, among other properties capable of posing subsidiary risks to Class 7.
>
> The specification of subsidiary risks should also consider classification according to packaging groups and hazard division, indicating possible effects of contamination and environmental and human health damage, if applicable.
>
> Attach: the certificate of the radioactive source within the validity period [1].

2.3 Packaging

In accordance whit the NTC[36]:

> Describe the packaging intended for each radioactive material to be transported during the validity of the Transport Authorization (TA). Attach: the valid packaging certificate; the photographic record of the packaging [1].

[35] Free translation
[36] Free translation

3. TRANSPORT UNIT (TU)

This section includes information on the origin and destination of the cargo, as well as details of the route to be used, taking into consideration: "States involved in the main and alternative routes; Major urban centers intersected by the route; Primary highways used (road transport); Main railway lines used (rail transport (…) Strategic aspects and locations that may impose restrictions on the transport activity, such as timings, speed, unavailability of resources, and support in case of accidents, among others"[37] [1].

3.2 Composition and Operational Structure of the Transport Unit (TU)

> Provide detailed information regarding the composition and structure of the Transport Unit, including support units for emergency cases, when applicable.
> Provide information regarding: stops or temporary storage; modal changes in transportation (air, maritime, or land) [1].

Attach a copy of a document confirming that the driver is authorized to transport hazardous products. This requirement does not exempt the driver from other training provided by SPR (Radiation Protection Service).

3.3 Securing the Load to the Transport Unit (TU)

Attach a photographic record of the load secured to the vehicle.

3.4 Signaling of the Transport Unit (TU)

> Describe how the signaling of the transporting vehicle will be carried out and provide a photographic record of the Transport Unit (TU) in a way that allows visualization of:
> - General safety conditions of the vehicle;

[37] Free translation

- Placards (UN Number, Hazard Number, Hazard Label) correctly positioned on the vehicle.

Attach: documentation of the properly signaled vehicles[38][1].

3.5 Mandatory Documents for Transport Operations

"Present the necessary documents for the transport of radioactive material, providing copies of each"[39] [1].

3.6 Personal Protective Equipment and Emergency Kit

"Provide information on the Personal Protective Equipment (PPE) and Emergency Kit available on the transporting vehicle. Attach: Photographic record of the PPE and Emergency Kit available on the vehicle"[40] [1].

3.7 Transport Unit (TU) Tracking

Attach: the contract with the vehicle tracking company.

3.8 Procedures for Transport under Special Arrangement

The CNEN will assess whether it is not possible to fulfill all the requirements described in the regulation in order to issue authorization for transportation under special arrangement. For this, the security level must be at least equivalent to what would be obtained if transported in regular packaging. Attach: Photographic record of the final arrangement[41] [1].

[38] Free translation
[39] Free translation
[40] Free translation
[41] Free translation

4. RESPONSIBILITIES AND INFORMATION TO THE DRIVER

In this chapter, the following information should be included: Responsibilities and Information to the Driver; Responsibilities of the Transporter and Notifications to the Competent Authorities ("Specify under which situations CNEN, or the competent authority of another country, should be notified" [1][42]).

5. EMERGENCY SCENARIOS AND RADIATION PROTECTION

This chapter is dedicated to potential emergency scenarios, and for each identified scenario, it describes response actions as well as applicable radiation protection measures during transport.

5.1 Emergency Measures

In the event of an accident, "actions must demonstrate the ability to mitigate or revert the consequences of the accident to levels acceptable to CNEN and IBAMA for the public, workers, and the environment'; the same applies to 'subsidiary risks of radioactive materials that may cause environmental contamination"'[1][43].

At a minimum, the following scenarios will be considered:

i) Collision of the transporting vehicle; ii) Rollover; iii) Fire; iv) Cargo/vehicle theft; v) Vehicle/cargo falling into the water [1].

[42] Free translation
[43] Free translation

5.2 Radiological Protection Program for Transportation

Conduct simulations of potential doses received by occupationally exposed individuals (OEI), provide their dose records, and anticipate radiological protection measures to be adopted if OEI exceeds the dose limits specified in CNEN regulations.

Attach: Control dosimetric record of OEIs and Report on notification of high doses to OEI.

6. PERSONNEL TRAINING AND MEDICAL CONTROL

6.1 Basic Training Program

> The training program will be developed by a CNEN-certified Radiation Protection Supervisor and must include, at a minimum: Subject topics (content); Duration (initial minimum of 40 hours and annual minimum of 8 hours); Frequency (initial and annual, at a minimum); Refresher training (annual, at a minimum); Evaluation criteria; Training records.
>
> Attach: Training records of OEIs (signed and with the obtained score)[44] [1].

6.2 Periodic Medical Examinations

Specify the medical exams to which the Occupationally Exposed Individuals (OEIs) will be subjected and to anticipate the dosimetric record for each individual involved in the transportation of radioactive material.

7. MANAGEMENT SYSTEMS (QUALITY ASSURANCE PROGRAM – QAP)

At a minimum, where applicable, this chapter will include the following items[45]:

[44] Free translation
[45] Free translation

Record of radiation protection service equipment; Quality control of radiation monitors; Dosimetric control sheet; Vehicle control; Vehicle inspection procedures before transportation; Material unloading/delivery procedures; Control of physical/digital records.

Note: It is requested that the company qualified for the transportation of Class 7 materials send to SASTR/CNEN, at the end of each year, a report containing the company's numbers.

These numbers include: Number of transport operations for each type of packaged material; Number of transport operations for each type of radioactive material/UN Number [1].

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