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Evaluation of the acceptance and knowledge of the Brazilian population on nuclear science and technology

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NUCLEAR AND RADIOPHARMACEUTICALS SCENARIO IN BRAZIL

The growth and development of nuclear science and technology in Brazil in various fields such as medicine, industry, safety, engineering and research is quite evident and significant. In the Brazilian scenario, this science was effectively stimulated in the mid-1950s, with the first radiological research centers and nowadays, the country boasts 4 research reactors and 2 nuclear power reactors in operation, 11 fuel cycle facilities, and about 1900 authorized radioactivity facilities that supply 432 nuclear medicine services [1,2,3,4]. In this context, the Comissão Nacional de Energia Nuclear (Brazilian National Commission for Nuclear Energy - CNEN) is the government body in charge of regulating, licensing and controlling nuclear energy usage and through research, development, and production of radioisotopes, such as the radiopharmaceuticals[1][5].

Radiopharmaceuticals are used in the nuclear medicine area for diagnosis and illnesses treatment. Their application has allowed around two million medical procedures to be performed every year in Brazil, mainly in cardiology and oncology, considering that 30% of these procedures are covered by the public health system [6].

The Brazilian production comprises 38 radiopharmaceuticals, where the most commonly used are the ^{99m}Tc (67.3%), ^{131}I (13.7%), ^{67}Ga (2.9%), ^{177}Lu DOTATATE (2.9%), and ^{18}F-FDG (1.1%). From these, 67% of those substances are produced in nuclear reactors and 33% in particles accelerators (cyclotron) [7]. The main producing units are the: Instituto de Pesquisas Energéticas e Nucleares (IPEN - São Paulo), Centro de Desenvolvimento da Tecnologia Nuclear (CDTN - Belo Horizonte), Centro Regional Nordeste de Ciências Nucleares (CRCN-NE - Recife), and Instituto de Engenharia Nuclear (IEN - Rio de Janeiro) [6].

Besides reactors being used for radiopharmaceuticals production, Brazil houses two nuclear power plants (Angra 1 and 2) located in the state of Rio de Janeiro, whose operational responsibility is Eletrobras Eletronuclear's. These units possess a nominal production of about 2.000 MW, which represents approximately 3% of the national energy matrix [8]. However, this percentage does not reflect the full nuclear energetic potential in Brazil, once the country has the seventh largest uranium reservoir worldwide and is one of the few countries which masters the whole nuclear fuel cycle [9].

The perspectives for the Brazilian Nuclear scenario are positive, due to the development of projects that involve the conclusion of the third nuclear power plant (Angra 3), as well as the implementation of new nuclear power plants in the Northeast of Brazil. It is also worth it to be mentioned the implementation of the Brazilian Multipurpose Reactor (RMB), which targets at national independence regarding the radiopharmaceuticals demand, enabling some samples production obtained exclusively through importation, prioritizing the molybdenum-99 (Mo-99) used to produce the radioisotope ^{99m}Tc [6,8].

KNOWLEDGE AND PUBLIC APPROVAL

The Brazilian energy matrix is made of 80% of renewable energy sources (65% hydraulic, 7% biomass, 4% eolic, and 4% solar) and of 20% of non-renewable sources (10% natural gas, 4% coal, 3% petroleum, and 3% nuclear) [10]. The low representativity of nuclear energy may be related to the great Brazilian renewable electrical potential, mainly hydroelectrical, once the country holds 12% of all fresh water on the planet's surface [10,11]. Nonetheless, in 2001, Brazil suffered a hydric crisis, known as "blackout crisis". At that moment there was a greater concern about the diversification of the country's electric energy matrix. It was just then when the Brazilian government established a new energy plan (PNE 2030) recommending, among other goals, the beginning of the commercial operation of Angra 2, the conclusion of Angra 3 and the implementation of new nuclear power plants in strategic sites. The commitment of seeking other sources in a time of crisis in the country positively impacts on public approval regarding the power generation through alternative sources, as it happened to the nuclear energy [12].

Other factors that influence public approval in the use of nuclear energy and even the radiopharmaceuticals production are related to the negative effects associated with nuclear science and technology, such as Chernobyl's nuclear accidents (1986), Fukushima (2011) and the radiological accident in Goiânia, Brazil (1987) [13]. Besides that, it requires cutting-edge technology and being relatively new in human history, nuclear science is still seen as something "obscure". Thus, common citizens end up not having the chance to better fundament their opinion. This issue makes nuclear energy a rich field for sensational exploitation [14].

A survey conducted in 2018 by Eletronuclear confirmed the high influence of the means of communication in Brazilian public opinion formation. Eletronuclear's survey counted 1160 participants, from which 39% believed in the reliability of information transmitted on television, furthermore in this group, 32% agreed that this is the major source for information seeking [15]. As the researchers Gibelli and Xavier stated, "public opinion is molded through the means of communication" and, therefore, information transmitted on these means need to be clearer, since they have the power to rupture the stigma that haunts nuclear science [16].

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[1] **Radiopharmaceuticals**: chemical substances that have some radioisotope recognized by the organism as similar to some substance processed by an organ or tissue. They are non-sealed radioactive sources that are introduced in the patient's body through ingestion, inhalation or injection.

Another survey found in specialized literature has emphasized that 86% of the broadcast news about nuclear energy in Brazil raises public awareness solely on its risks and low performance. As a consequence, 80% of the target audience analyzed by Eletronuclear had “very little or no knowledge” about nuclear energy, even though they brought up that 27% believed that the use of nuclear energy would not bring proven benefits and 26% was against the use of this technology [15].

In face of this deadlock, an initiative for assessing Brazilian public comprehension and approval on science and nuclear science has emerged, aimed more specifically at the application and manufacturing of radiopharmaceuticals and the use of nuclear energy.

PUBLIC OPINION: METHODOLOGY

During the period from June 15th to July 15th 2019, questionnaires were applied to 348 people from different regions all over Brazil. The objective of this survey was to assess public knowledge and assessment of a small sampling of the Brazilian population about the **radiopharmaceuticals** and **nuclear energy** topics. In order to do that, a questionnaire was developed and applied, containing 9 questions with the following approaches:

- Questions 1 to 3: trace the respondents’ profiles, accordingly with the geographic regions they live, age and level of schooling;
- Questions 4 to 7: verify the public knowledge and approval degree on the use of radiopharmaceuticals in diagnosing and treating illnesses;
- Questions 8 to 9: investigate populational perception of nuclear energy and its uses in the generation of power.

Figure 1: Nuclear 2019 Olympics participant team applying a printed questionnaire in an inner event at CDTN.

The access link for the questionnaire was made available through different digital means of communication such as: e-mail, Whatsapp, Instagram, Linkedin, and Facebook. The questionnaire had a self-explanatory note contextualizing its filling up purpose, without providing detailed any explanation that could influence on the respondents’ answers, preserving impartiality in their answers. Moreover, this questionnaire was printed and applied together with our civil servants, collaborators and third parties from Centro de Desenvolvimento da Tecnologia Nuclear (CDTN), in an event that took place on June 27th in 2019 (Figure 1).

RESULTS AND DISCUSSION

The sampling profile was traced based on obtained data referring to the geographic region where the respondents live, their ages and their levels of schooling. 96.2% of the interviewees lived in the Southeast region while the others, 2.4% in the Northeast, 1.0% in the South, and 0.4% North. The largest respondents’ participation are from the Southeast region due to the range of the surveyors who live in this area. Besides, it is essential to highlight that around 70% of the nuclear research centers are located in the Southeast region, as well as the country’s nuclear power reactors [3]. According to Figure 2, it was verified that 54% of the respondents were in the age group between 21 and 30 years old. Among the interviewees, it was noted a higher concentration in the highest levels of schooling, grouped in: postgraduate (30%), graduate (37%), undergraduate (24%) (Figure 3). Such information has met the research goals, once a relevant part of the data collection took place at the Research Center at CDTN, where graduates, masters, doctors and nuclear area researchers are habitually present [17].

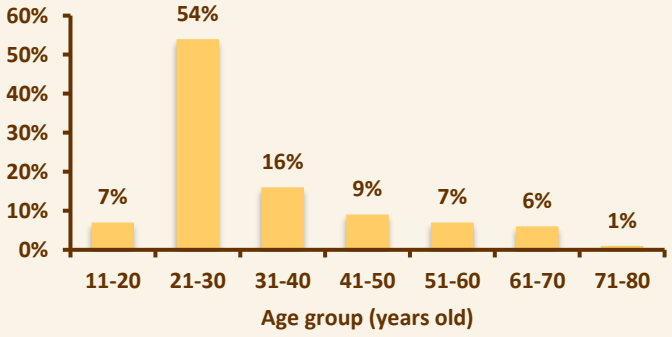

Figure 2: Representation of the sampling percentage according to age group.

Afterwards, the respondents’ degree of knowledge was assessed about the radiopharmaceuticals topic. According to Figure 4, it has become clear that 39% of the interviewees had none or little knowledge on the theme. This can be justified by the fact that 77% of the respondents had never been through any procedure that involved the use of radiopharmaceuticals and 9% do not even know whether they had or not. Furthermore, when questioned about the production of these medicaments, only 34% of the survey participants showed some knowledge on the topic.

However, after the radiopharmaceuticals concept had been introduced in the questionnaire, the results showed that 73% of the interviewees would agree to its use and approximately 4% would probably not. These results were similar to those reported in literature [18], in which high school students of the country's Southeast region initially associated the use of radiation with its harms to health and environment. Nevertheless, after all content about ionizing radiation had been exposed to them in an interactive and contextualized approach, the students also started associating this radiation to its benefits, such as for illnesses treatment. Thus, it was proved the importance of information for a better public approval as to the use of radiation, pointing to the need of an effective diffusion on the theme (Figure 5).

A simplified study on public perception regarding the nuclear energy field was also conducted. The data represented on Figure 6 shows that 55% of the respondents considered to have at least “good knowledge” on the topic and only 21% had “little or no knowledge”. Besides, according to Figure 7, 69% of the interviewees seemed to strongly favor the use of nuclear energy as power source. This fact suggests that a deeper understanding of the issue aids positively in its approval.

Furthermore, it is paramount to mention that among the mentioned reasons by 9% of the respondents, who were against the use of nuclear energy, are: the lack of safety regarding the production and conditioning of rejects, the environmental impact and the accidents involving the power plants and the high cost for power generation via nuclear power plants. The justifications for these negative evaluations are similar to the research conducted by Eletrobras in 2019 [15], in which 13% of the respondents believed it was a hazardous source of power, 22% considered it a high potential harm to the environment, 5% felt unsafe towards this type of energy, 7% considered its production cost high, and 9% considered the existence of more appealing power-generating sources.

Such results relate to the importance the means of communication play and its utmost role in the straight and impartial information spreading to the population, as evidenced in the survey conducted by Eletrobras, 2019, in which was demonstrated that the means of communication to be considered the most trustworthy were the television (39%), the internet (14%) and the newspaper (14%). As a result, an interference-free promotion on the related themes is critical for wider public approval.

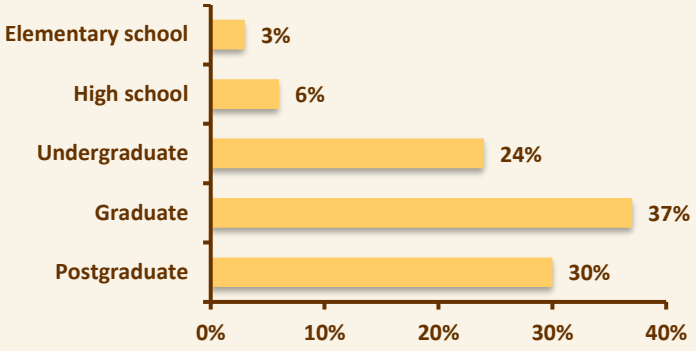

Figure 3: Representation of the sampling percentage regarding schooling level.

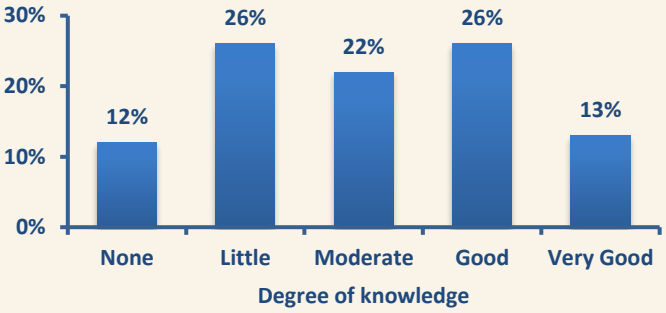

Figure 4: Representation of the percentage according to the degree of knowledge on radiopharmaceuticals.

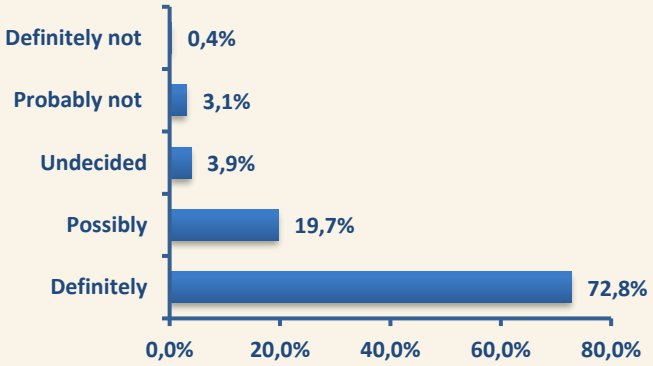

Figure 5: Representation of the sampling percentage of those who would agree to the use of radiopharmaceuticals after the term conception is elucidated.

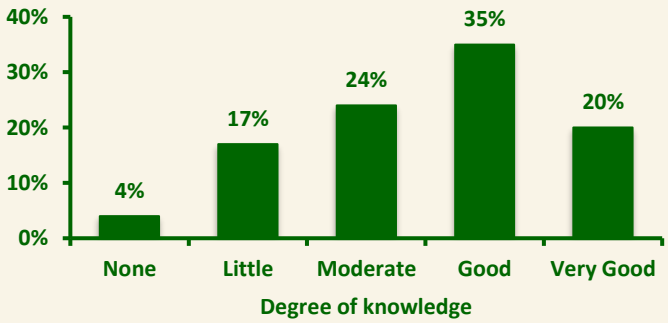

Figure 6: Representation of the percentage according to the degree of knowledge on nuclear energy.

CONCLUSION AND RECOMMENDATIONS

In face of the collected and analyzed data, it was possible to observe that the degree of knowledge about the radiopharmaceuticals and nuclear energy issues had influenced the respondents’ degree of approval. However, it is

possible to identify that there is still a significant part of the sampling that associates nuclear energy mainly to its harms to mankind and the environment. Being the respondents' major information source the television and the internet, they are subjected, mainly, to what is broadcast on the TV news whose focus is on the negative aspects, accidents and problems related to nuclear science and technology. As a result of so much online information, people get vulnerable to fake news which only intensifies prejudice and disapproval on the themes.

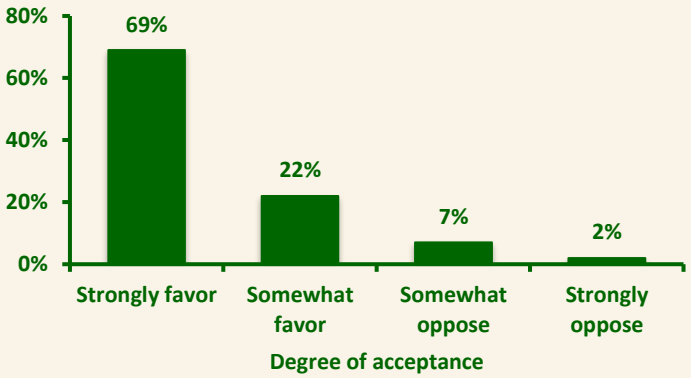

Figure 7: Representation of the sampling percentage regarding the degree of approval about nuclear energy.

As strategies to improve this scenario it is necessary to break some paradigms involving the radiation uses, through clear and accessible information, once ignorance leads to fear and rejection, allowing misconceptions derived from informal communication. There is a need of demystifying the applications of ionizing radiations, through debate incentives on the topic, opening nuclear research centers for regular visitation, as well as developing researches and its potential contributions for society.

Besides that, it is important the involvement of the Brazilian educational system from the teacher to the students from elementary to high school, through formation courses of human resources, spreading of educational video and provisioning of didactic material, in which nuclear science is inserted and scaffolded, aiming at the deepening of scientific, technological, economic, historical and social understanding. Likewise, it is identified a need for development programs that stimulate the popularization of science across society by using different means of communication, such as social networks (Facebook, Instagram, Twitter, WhatsApp, etc), making the scientific community well-known and accessible to all. Consequently, those who possess a favorable positioning towards nuclear technology could be the emerging promoters of the initiative.

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