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Precautionary and preventive measures in Brazilian law applied to radioactive waste management

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ABSTRACT

Nuclear technologies and radiation have offered technological and scientific growth nowadays, but there is a frequent paradox in this. While these technologies substantially increase the quality of human life, they also produce radioactive waste, which, when not properly managed, can generate risks that threaten to harm the environment and health. As a result, in risk management of radioactive waste, decision-making processes need to be guided by a framework of principles, including the precautionary and preventive principles. For this reason, the present work proposes to develop a legal analysis on radioactive waste risk management using the principles of precaution and prevention. These principles have similarities, but it is the differences in their structure that deserve to be highlighted, which is discussed and exemplified throughout this work. Furthermore, national and international experience in environmental damage has taught us that an identification and assessment of risk is necessary, because if preventive measures are not taken radioactive waste can be dispersed and harm the environment. When it comes to assessing the risk of radioactive waste, one of the precautionary measures is the application of a conservative stance in modelling scenarios, as there are still uncertain risks. Therefore, comprehending the different circumstances surrounding precautionary and preventive measures and having effective information about risk is essential for successful risk management.

Keywords: **radioactive waste, risk management, Brazilian environmental law, precautionary principle, prevention principle.**

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1. INTRODUCTION

The scientific and technological progress provided by nuclear technologies and radiation in current society often seems to be contradictory. On the one hand, there is a significant improvement in the quality of human life. On the other hand, it cannot be ignored that these technologies generate radioactive waste, which creates risk with potential damage to the environment and health if not properly managed. Therefore, it is necessary to implement a framework of principles that guide decision-making processes in a risk scenario involving radioactive waste, especially in terms of precautionary and preventive measures [1].

Based on these principles, legal, political, and economic authorities can respond to the demands of this new post-industrial society format. This is called "risk society", whose development activities generate not only risks but also scientific uncertainties. Consequently, it is essential to consider risk information in different scenarios.

At this point, risk analysis and legal instruments appear to help reduce regulatory and enforcement problems in order to establish more effective environmental laws. The term "risk" is largely guided by environmental framework and technical documents. Likewise, the legal theory of risk relates decision-making with scientific uncertainty about the possible damage that technological developments may cause.

The act of understanding the laws that support the management of radioactive waste risks implies a necessary understanding of the types of hazards brought by contemporary society. This understanding can reveal post-industrial risks and those inherent to the current social format.

In this regard, there are two types of environmental hazards, namely: abstract and concrete. Both are closely related to the distinction between the precautionary principle and the prevention principle because these principles work as legal protocols to be followed for the assessment and management of environmental risks according to the particularities of each case [2].

With access to information on risks, the precautionary and prevention principles become functional and serve as guides for decision-making in situations of uncertainty. It is not by chance that the use of these principles protects legal rights and assets such as the environment, which transcend individuality and affect the entire community, being called "diffuse rights".

A healthy and ecologically balanced environment is a diffuse right guaranteed by the Federal Constitution of 1988, the supreme Brazilian law currently in force, which demonstrates a commitment to environmental preservation. In summary, the protection of the environment is a constitutional assurance and, therefore, can only be carried out through environmental defense guidelines and instruments – such as the precautionary and prevention principles applied to risk management, particularly in radioactive waste management.

As will be seen, based on the environmental legal framework that has been formed over time, the Federal Constitution of 1988 highlights, in a systematic and specific way, the compatibility between economic development and sustainability, and in the sense that one does not necessarily exclude the other.

One of the facets of sustainable development is precisely the management of environmental risks. By recognizing that some activities pose a risk to health and the environment, if a certain action is not sustainable, it puts future generations at risk.

According to the sustainable development concept, the value pursued is sustainability. It is the most abstract guideline of Environmental Law, but also the most comprehensive, as it influences all environmental frameworks. It is the integration of the economic dimension with the social and environmental dimensions [2].

The 1988 Constitution therefore represents a legal framework for sustainability and for the management of environmental risks. Based on its set of rules, it is understood that Brazil has a constitutional commitment to defend the environment. Hence, it needs to adopt a management based on well-structured principles. In managing the environmental risks of radioactive waste, this approach must be carried out in terms of precaution and prevention, which is precisely the subject of this work.

1.1. Brief historical context of environmental protection

Since the time of the Brazilian Empire, there has been some concern for environmental protection in the laws. However, these laws were sparse and protected specific goods, such as ore and water. It was a timid way of protecting the environment.

In 1948, Brazil adhered to the Universal Declaration of Human Rights. Although this Declaration already shows a concern for health and human life, it does not provide that a healthy environment is a fundamental human right [1].

However, at the same time, a society with mass consumption habits began to emerge. Then, in 1972, the Stockholm Declaration was promulgated, which consisted of a UN conference between countries with important environmental concerns. In that Declaration, the environment was recognized as a diffuse and collective interest that needs to be protected for human life and health. The Stockholm Declaration was an international landmark and served as a pillar for the national environmental policy in many countries. However, Brazil, which was amid an "economic miracle", defended the use of natural resources at any cost, without caring about environmental preservation [1].

Nevertheless, in 1977, Law No. 6453 was enacted, providing for civil liability for nuclear damage and criminal liability for acts related to nuclear activities.

Finally, in 1981, Law No. 6938/1981 was the first one to systematize the protection of the environment, which established the Brazilian National Environmental Policy (Política Nacional do Meio Ambiente) and created the Brazilian National Council for the Environment (CONAMA). The 1988 Brazilian Constitution not only accepted the aforementioned law, making it compatible with constitutional rules, but also expanded the environmental protection previously provided.

Thus, the National Environmental Policy, in accordance with its art. 2, aims to preserve, improve, and recover the life-friendly environmental quality, to guarantee conditions for sustainable economic development in Brazil. Moreover, its art. 4, I, determines the compatibility of economic and social development with the preservation of the environmental quality and ecological balance.

In fact, since 1988, when the Brazilian Federal Constitution came into force, there has been a growing concern with environmental protection in the most varied aspects of life in society. Initially, art. 5, LXXIII, of the Brazilian Constitution, provides for the possibility of filing a class action to protect the environment, which is also supported by the Popular Action Law (Law No. 4717/1965).

Indeed, Art. 23, VI and VII, of the Brazilian Constitution deals with the common competence of all political entities (Federal Union, States, Municipalities, and the Federal District) to protect the

environment, forest, fauna, and flora. That is to say, the legislator assigned police power to all entities to act in environmental protection, being a common task for all.

Art. 129, III, of the Brazilian Constitution provides that the Public Ministry may file a public civil action to protect the environment. At this point, it should be noted that, since 1985, the Public Civil Action Law itself (Law No. 7347/1985) provides for the possibility of using this judicial instrument to defend the environment.

Art. 170, VII, of the Brazilian Constitution provides that one of the principles of economic activity is to protect the environment. It is worth noticing that the idea of reconciling the production of wealth without attacking the environment arises. In other words, economic activity must observe environmental preservation, which is the very idea of sustainable development.

That leads us to the most significant constitutional provision in environmental defense: art. 225 of the Brazilian Constitution. It expresses the obligation of state intervention, which imposes on the government and Public Power the constitutional duty to protect the environment and intervene in environmental matters.

In 1992, the United Nations Conference on Environment and Development, often known as the "Earth Summit", took place in Rio de Janeiro, Brazil, and had several important achievements, including the program of action "Agenda 21" and the "Rio Declaration", with the aim of renewing the political commitment to sustainable development [3,4]. Although few Agenda 21 commitments have been fulfilled by the country, as well as by the governments of other countries, the Earth Summit was a milestone for Brazilian society to raise awareness of environmental preservation and for the country's legal framework. In 1997, the International Congress on Environmental Law proposed to carry out a preliminary analysis of the realization of the Rio Declaration results.

Furthermore, in 2012, the United Nations Conference on Sustainable Development was held again in Rio de Janeiro, also known as the "Earth Summit 2021" and "Rio+20" (as it took place 20 years after the Rio Conference in 1992). Like the 1992 Conference, Rio+20 sought to renew the commitment to sustainable economic development, debating green economy issues in the context of sustainable development and poverty eradication, as well as the institutional framework for sustainable development [2].

In 2018, an important regional treaty on environmental issues was signed in Escazú, Costa Rica, known as the "Regional Agreement on Access to Information, Public Participation and Justice in

Environmental Matters in Latin America and the Caribbean", or simply "Escazú Agreement". This treaty, to which Brazil is a signatory country, reaffirms the Rio Declarations of 1992 and 2012. It also brings, in its art. 3, the consolidation of a list of Environmental Law principles, including precaution and prevention [2].

In addition, with the enactment of Law No. 12305/2010, the National Solid Waste Policy was instituted. In its art. 6, I, it is explicitly recognized as guiding principles of this policy: precaution and prevention, systemic vision, sustainable development, among many others.

With that in mind, the present work aims to present a legal analysis on risk management of radioactive waste based on the precautionary and prevention principles. The specific objectives of the paper are to demonstrate the use of these measures to assess an environmental risk management of radioactive waste, and to clarify the regulatory framework for decision making about a risk in a situation of scientific uncertainty.

Hence, it is possible to summarize the work issue as the need to apply the principles of precaution and prevention to environmental risk management, always observing proportionality and adequacy.

The justification for this lies in the fact that the legal and regulatory framework for radioactive waste management is evolving and the lack of these principles in risk management can compromise the whole process, produce unsatisfactory results and, in the worst-case scenario, fail to take precautions and prevent environmental risks.

2. MATERIALS AND METHODS

Considering that the present study is theoretical and analytical, the main research method was bibliographical and documentary. Thus, the study focused primarily on reading doctrines and articles that debate environmental risk management and the precautionary and prevention principles, as well as the legal and regulatory framework about risk management of radioactive waste.

In the following moment, a data collection on the main concepts and issues related to the theme was adopted as a research method. Data collection also included a survey of the entire legal and

regulatory framework for applying the principles of precaution and prevention to risk management of radioactive waste.

The research was also based on the analytical method, which consists of the analysis itself on the issues related to the subject and the use of the precautionary and prevention principles on risk management of radioactive waste. Finally, a critical analysis was developed around how the precautionary and prevention measures can structure and systematize radioactive waste management.

At last, the qualitative method was applied to the research, through reflections and critical comments left by the author to arouse in the reader questions about the topic, especially the indiscriminate use of the precautionary principle and the necessary balance between deficient and excessive precaution.

3. RESULTS AND DISCUSSION

In the decision-making process on environmental risks, it is reasonable to formulate public policies that anticipate the uncertainty generated by technological and social advances. However, the connection between environmental risk and the precautionary and prevention principles cannot be ignored.

3.1. Environmental risk and risk society

To analyze the relevance of the precautionary and prevention principles and their impact on environmental risk management of radioactive waste, it is also appropriate to briefly discuss the term “environmental risk” and its insertion in the Theory of Risk Society.

In a time as recent in Human history as the end of the Middle Ages, the perception of risk was not even known. However, nowadays, with environmental changes, the concept of “environmental risk” consists of its probability of threat and danger to human life and the environment. In other words, risk is related to the potential for harm and destruction. The extent of risk comprehends a new approach, which did not exist before and which is the result of human behavior [1].

In this sense, the Theory of Risk Society emerges, formulated by Ulrich Beck, a German sociologist. Beck defines "risk society" as the way in which modern society responds to risks. Hence, a new society involves new risks. According to the sociologist, in the current context of technological evolution, human beings no longer perceive risks, such as the reduction of non-renewable energy sources [1].

This ends up causing hidden and irreversible damage that will only be detectable by science. Consequently, the risk measurement instruments become of great social and political relevance, such as environmental risk management.

3.2. Principles of precaution and prevention

In this context, it is indispensable to distinguish the precautionary and prevention principles. Although they are similar and even considered the same principle by some researchers, they have structural differences that are worth mentioning.

3.2.1 Precautionary principle

The principle of precaution is related to cases in which there is **scientific uncertainty or lack of knowledge** about the risk of damage from an activity that can potentially cause a **significant environmental impact**. It is applicable to hypotheses of abstract and potential hazard, in which there are indications that the activity will result in serious or irreversible damage [5,6].

Therefore, precaution is understood as the immediate implementation of environmental protection measures, due to the uncertainties associated with a possible environmental risk [5].

The 1992 Rio Declaration, in its principle 15, postulates a legal-normative concept of the precautionary principle, in the following terms:

> In order to protect the environment, the precautionary principle must be widely observed by States, according to their capabilities. When there is a threat of serious or irreversible damage, the absence of absolute scientific certainty cannot serve as a reason to postpone effective and economically viable measures to prevent environmental degradation. [3]

To summarize, when it comes to future damage that is uncertain or unknown to Science, environmental protection measures are precautionary. If future damage is scientifically certain, the measures will be preventive, as will be discussed below.

3.3. Prevention principle

The principle of prevention is associated with **scientific knowledge or certainty** about the risk of damage from an activity that can potentially (most likely) cause an **environmental impact**. For that reason, preventive measures must be taken to avoid or to mitigate damage to the environment [5,6].

Hence, a company that will carry out an environmental risk activity must fulfill the requirements to have an environmental license granted, since the prevention principle includes a prior verification that it is difficult or even impossible to repair the environment [5].

That is to say: once the damage is done, environmental repair implies an excessive burden or impossibility. That is why the prevention is understood as the immediate interruption of certain activities with potential hazard to the environment.

What differentiates prevention and precaution is precisely the possible outcome. The prevention principle has more scope than the precautionary principle and thus is a more realistic and less abstract measure [5].

3.4. The application of precaution and prevention to radioactive waste management

The precautionary principle weighs the risk of damage and the uncertainty about it – which does not apply to the prevention principle, since it is not applicable to uncertainties. When using these principles in risk management of radioactive waste, three aspects should be taken into account, namely [7]:

(i) Weigh the cost-effectiveness and the pros and cons of the measures to be adopted.

(ii) Study the acceptance of radioactive waste risk in society.

(iii) Take proportional (not excessive) precautionary measures and implement all preventive measures against risks that exceed the acceptable level.

Risk management has a direct impact on the consideration of effective measures and decision-making to preserve the environment. In this matter, the first mentioned aspect involves the cost-benefit of using the precautionary principle. For instance, a geographic location for radioactive waste disposal may have several benefits today, but in the future, its cost may become unaffordable [8]. This is a legitimate problem in radioactive waste management, such as the disposal of disused sealed radioactive sources, for instance, which rely on the presence of geological barriers to contain the high radioactivity.

An issue like this can even affect the decision on the risk of using or not using nuclear energy, as it produces waste that needs proper treatment [9]. In these high-cost cases (financial aspect), to balance the cost-benefit binomial, the authorities must adopt measures that bring great environmental and social benefits [8,9]. It should be observed that the balance has many more problems on the cost side than on the benefit side.

The environmental instrument that best translates these principles is licensing, as it analyzes the impact activity precisely through risk management. In other words, licensing is risk management itself. It is an administrative procedure implemented by the environmental authority in Brazil, which is the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) and, for nuclear matters, the National Nuclear Energy Commission (CNEN).

The licensing procedure is a set of acts that are executed by the public body, such as the presentation of documents, requests, requirements, etc. In this procedure, depending on the complexity of the environmental impact, more thorough multidisciplinary studies are conducted. The studies, therefore, guide the risk management in licensing.

In radioactive waste management, the public body can authorize, for example, the operation of a machine that uses a sealed radioactive source. However, this authorization is granted with requirements, e.g., protecting the source with specific barriers and notifying the public body if the source becomes disused. The environmental license is full of conditions, so much so that it is revoked if the requirements are no longer met. There is no such thing as a “right to pollute”.

In some cases, all license requirements are met, but the economic agent still causes damage. In this situation, the polluting agent is responsible, as Brazilian Environmental Law adopts the Theory of Full Risk, according to which the agent is fully responsible for the risk regardless of fault.

It can also be noticed that the precautionary and prevention principles are supported by Law, but not necessarily applied by legal means in the risk management of radioactive waste. There are also technical mechanisms that implement these principles in risk assessment, such as the Environmental Impact Assessment (EIA) and its Environmental Impact Report (RIMA), prepared prior to the installation license for an activity with radioactive and nuclear material or any activity that represents a risk to the environment.

In this regard, principle 17 of the 1992 Rio Declaration provides for Environmental Impact Assessment as a risk management instrument to protect against activities that may cause significant environmental impact:

> Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are **likely to have a significant adverse impact on the environment** and are subject to a decision of a competent national authority. [3]

With regard specifically to risk management of radioactive waste, Agenda 21 has an entire chapter committed to promoting the safe and environmentally sound management of radioactive wastes (Chapter 22), clearly mentioning the need for a precautionary approach in environmental studies:

> 22.5. States, in cooperation with relevant international organizations, where appropriate, should:
> (…) b. Encourage the London Dumping Convention to expedite work to complete studies on replacing the current voluntary moratorium on disposal of low-level radioactive wastes at sea by a ban, **taking into account the precautionary approach**, with a view to taking a well informed and timely decision on the issue;
> c. Not promote or allow the storage or disposal of high-level, intermediate-level and lowlevel radioactive wastes near the marine environment unless they determine that scientific evidence, consistent with the applicable internationally agreed principles and guidelines, shows that such storage or disposal poses no unacceptable risk to people and the marine environment or does not interfere with other legitimate uses of the sea, making, in the process of consideration, **appropriate use of the concept of the precautionary approach**; (…) [4]

In Brazil, such instruments were established by the National Environmental Policy and by the Resolution No. 01/1986 of the National Council for the Environment (CONAMA), according to

which activities with an environmental impact – i.e., a modification caused by human action in the environment properties – require an Environmental Impact Assessment (art. 1 and art. 2).

Additionally, in that CONAMA Resolution, there are general guidelines for carrying out the Environmental Impact Assessment (art. 5), as well as the minimum technical activities necessary for the assessment (art. 6).

The Environmental Impact Assessment and the Environmental Impact Report were later cited by art. 225, § 1, item IV, of the Brazilian Constitution, which states that the Public Power must require a prior environmental impact study for work/activity with potential for environmental degradation.

CONAMA Resolution No. 01/1986, in its art. 11, § 2, also provides for the mandatory designation of public hearings in the environmental licensing process, with the participation of communities that are affected by or interested in the activity [10,11].

That brings us to the second aspect of applying the precautionary and prevention principles in risk management of radioactive waste, that is, the social acceptance of risk. In fact, CONAMA issued Resolution No. 09/1987, specifically about the community participation through a public hearing during the environmental licensing process. The acceptance of radioactive and nuclear risk by society is influenced by subjective facets, often based on prejudice and lack of information on the subject. Accordingly, public participation has a fundamental role of involving and educating the interested or affected community [8].

Regarding appropriate implementation of precautionary and preventive measures, which is the third aspect of using the precautionary and prevention principles in risk management, it is worth noting that, currently, the effects of human behavior are difficult to predict and measure, as many of them occur over the long term. This means that uncertainty must be incorporated into the reasoning when deciding on the obligation to protect the environment. Consequently, the management of radioactive waste risks must consider the abstract risk in addition to the concrete risk, in accordance with constitutional norms [8].

To illustrate the difference between precautionary and prevention principles applied to radioactive waste, the main risks in radioactive waste management and the respective legal preventive and precautionary measures, at each stage of the management process, are presented in Table 1:

Table 1: Precaution and prevention measures in radioactive waste management.

Stage	Main risk	Preventive measure	Precautionary measure
Characterization	Worker exposure	Wear personal protective clothing and equipment	--
Treatment	Dispersion of radioactive material	Immobilize liquid radioactive waste	--
Conditioning	Dispersion of radioactive material	Ensure that radiation levels on the package surface do not exceed legal limits	--
Storage	Corrosion of packaging	Isolate radioactive waste in an interim storage and/or a deep geological repository for long-term storage	--
Transportation	Loss of control; exposure of workers, members of the public and the environment	--	Track and escort shipments, pick shipping routes, train drivers
Disposal	Possible human/animal intrusions; institutional instability	--	Implement a multiple-barrier system to contain radioactive waste against uncertainty that barrier(s) will be compromised; conservative local site selection

As another example of precautionary and preventive measures, there is the Brazilian Nuclear Policy (*Política Nuclear Brasileira*), a national public program associated with nuclear risk

assessment, which includes radioactive waste and provides for precautionary and preventive measures in that matter [12].

As well as the Nuclear Policy, art. 225 of the Brazilian Constitution brings an environmental concern for future generations, called “intergenerational environmental law”. In doing so, it also attributes to the present generation the obligation of protecting the environmental against unacceptable impacts that may result in the future from activities that are performed today.

In managing the risk of radioactive waste, as seen, the immobilization of liquid radioactive waste and the isolation of high activity, radioactive waste in a deep geological repository are preventive measures, as they refer to the certainty that the radioactive waste will most likely be dispersed and cause damage above acceptable levels if these measures are not taken. On the other hand, the implementation of a multiple-barrier system in repositories to contain radioactive waste and conservative scenarios in risk assessment are precautionary measures, as there is no certainty about the possible interactions of the environment and human beings with the barriers.

4. CONCLUSION

For all the above reasons, it should be noted that, in the risk management of radioactive waste, the precautionary and prevention principles must be applied, but in efforts commensurate with the levels of risk, the levels of risk the society accepts, the costs of adopting the measures, and the uncertainty about a risk of significant damage.

Moreover, in this risk society, there is a growing demand for the use of nuclear technology. Nonetheless, with this growth comes scientific risks and uncertainties. That is why it is essential to get access to information on risk considered in different scenarios. Hence, in each scenario, the precautionary and prevention principles help authorities to respond to risks and scientific uncertainties by taking the best measures.

Radioactive waste professionals are increasingly working to resolve uncertainties, but they may exist. Thus, it is important to study case by case and keep in mind the different factors and variables. Risk management for decision-making should not be extrapolated to automatic mode, under penalty of blindly complying with the principles and disregarding the complexity of possible

results, including unsatisfactory ones. Therefore, the principles of precaution and prevention are extremely important, but always considered within a relative context, as they are not absolute.

When it comes to the use of nuclear energy, this relativization of principles is evident. Few countries do not adopt nuclear power today. Those who adopt it understand that, with the growing demand for diversification of the energy matrix, nuclear technology can enhance the production of electricity more than any other source and can be considered a clean source, since it does not emit greenhouse gases and is within the small group of industries that manage their waste from cradle to grave, in addition to having an abundant natural source with a low exploratory index.

From these findings, there is no doubt that, in order to emphasize the relevance of developing a principle-based legal framework as a foundation for decision-making in cases involving radioactive waste, it is crucial to implement effective information on risk and understand the different approaches to precautionary and preventive measures in risk management.

The challenge of the globalized scenario reveals a curious opportunity to update the approach that has been mostly used so far. Although there is already a movement towards change and a constant concern for the environment, there is still a lot to be done.

Based on national and international experience in environmental risk and radioactive waste disposal, it is possible to identify and assess the risks, knowing that the radioactive waste will most likely be dispersed and cause damage if the preventive measures are not taken.

However, there are still uncertain risks, which is why a conservative stance in modelling scenarios is used in risk assessment as a precautionary measure. Thus, it is crucial to implement effective information about risk and understand the different approaches to precautionary and preventive measures in radioactive waste risk management.

In the long term, the implementation of more public policies based on the principles of precaution and prevention for radioactive waste management provides a better systemic view of environmental risk. The appropriate (never excessive) use of these principles in risk management can offer several contributions to the environment and help to reduce environmental impacts.

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