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The precautionary principle: guidelines for its empirical application[1]

O princípio da precaução: diretrizes para sua aplicação empírica

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Abstract:

The precautionary principle is widely applied in environmental damage risk scenarios. It served and serves to direct the elaboration of important Brazilian environmental legislation. The fact is that although there is a pacified concept among the doctrinaires of Environmental Law about what the Precautionary Principle is, when its empirical application is required, a series of questions and disagreements are revealed. Therefore, this research aims to demonstrate the guidelines for the empirical application of the Precautionary Principle based on the concept established in Rio 92. It uses the exploratory methodology and inductive approach method, as well as bibliographic research as a technical procedure for doctrinal research and in legislation. It was concluded that for an approach capable of empirical application of the Precautionary Principle, it is important to initially understand its parts (risks, state of the art and economically viable measures). From the understanding of its "parts" it was possible to create a summary table with its application guidelines.

Keywords: precautionary principle; environmental law; guidelines.

Resumo:

O princípio da Precaução é amplamente aplicado em cenários de riscos de danos ambientais. Ele serviu e serve para direcionar a elaboração de importantes legislações ambientais brasileiras. O fato é que apesar de existir um conceito pacificado entre os doutrinadores do Direito Ambiental sobre o que é o Princípio da Precaução, quando se exige a sua aplicação empírica, uma série de questionamentos e discordâncias se revelam. Para tanto, a presente pesquisa objetiva demonstrar as diretrizes para a aplicação empírica do Princípio da Precaução com base no conceito firmado na Rio 92. Utiliza-se da metodologia exploratória e método de abordagem indutivo, bem como da pesquisa bibliográfica como procedimento técnico para pesquisa doutrinária e legal. Concluiu-se que para uma abordagem capaz de aplicação empírica do Princípio da

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Precaução faz-se importante inicialmente compreender suas partes (riscos, estado da técnica e medidas economicamente viáveis). A partir da compreensão de suas "partes" foi possível elaborar um quadro-resumo com suas diretrizes de aplicação.

Palavras-chave*: princípio da precaução; direito ambiental; diretrizes.*

1 Introduction

The Precautionary Principle is found as a guide for Brazilian environmental legislation, since there are determinations of the modes of protection, with the aim of preventing environmental damage. In this way, the principle is widely applied, both inspired by the development of new laws and by scenarios of risks of environmental damage when legislation does not exist and decision-making is a necessary measure.

Precaution is: precautions to be taken when there are scientific uncertainties regarding the potential environmental damage of a given activity. This definition is settled among the doctrinaires of Environmental Law, but when it comes to the application of the Principle, a series of questions and disagreements are revealed.

For this reason, the research problem of this article is: what are the guidelines for the empirical application of the Precautionary Principle? As a hypothesis for the solution of the problem, the research is based on the use of the concept of application of Principle 15 of Rio 92, as it is of international consensus, as well as to provide elements capable of helping to guide its understanding and application, which are: risk, state of the art and economically viable measures.

The objective of this research is to demonstrate the guidelines for the empirical application of the Precautionary Principle based on the concept established in Rio 92. It uses the exploratory methodology and the inductive approach method, as well as bibliographic research as a technical procedure for doctrinal and legal research.

2 The precautionary principle: its ability to approximate the present scenario to future damage

Caution comes from the Latin suffix "*cautio,"* a concept of "*care*." Precaution is, therefore, the "position prior to the guarantee or guarantee of something or, as the Latin structure proposes, it is located at a point of decision prior to prevention, a precept also present in environmental law". (Minassa, 2018).

The records of the origin of the Precautionary Principle derive from German legislation of 1959, specifically in the Law on the Peaceful Use of Nuclear Energy and Protection against Its Hazards, known as the Atomic Energy Act (*Atomgesetz*). In 1974, German environmental policy was created under the name "*vorsorgeprinzip*", as well as in the Federal Emission Protection Act (Bundes-Immissionsschutzgesetz) in view of the need for "precaution against harmful environmental effects and other risks" (Bundesministerium).

In addition, the principle has its first appearances in the Swedish Environmental Protection Act of 1969, introducing the passages of the law that state that agencies are authorized to prohibit activities in precaution against harmful effects on the environment (Sunstein, 2005, p.16).

Certainly, the origin of the Precautionary Principle is related to the events derived from the Industrial Revolution, when natural resources began to be impregnated too much in industrialization, just as fossil fuels were the main source of "energy". (United Nations Conference on Environment and Development).

In view of this, the Stockholm Convention in 1972 and then Rio in 1992 brought important discussions to the international stage around environmental protection. So much so that the concept of what the Precautionary Principle is, called nationally and internationally by environmental scholars, is derived from Principle 15 of RIO 92. (United Nations Conference on Environment and Development). Farber mentions that the best-known statement about the precautionary principle is the one found in the Rio 92 Declaration, especially in the passages: "to protect the environment, the precautionary approach must be applied according to its capabilities", and that, given "threats of serious or irreversible damage, the lack of scientific certainty should not be used as a reason to postpone costs", that is, effective measures to prevent environmental degradation." (Farber, 2015).

The Precautionary Principle is also provided for in Article 225 of the Federal Constitution, in addition to other laws: Environmental Crimes Law, Biosafety Law, National Policy Law on Climate Change, National Solid Waste Policy Law, Convention on Biological Diversity and United Nations Framework Convention on Climate Change[2].

[2] "Article 3. Parties shall take precautionary measures to anticipate, avoid or mitigate the causes of climate change and mitigate its negative effects. When threats of serious or irreversible harm arise, the lack of full scientific certainty should not be used as a reason to postpone such action, bearing in mind that policies and measures taken to address climate change must be cost-effective, in order to ensure global benefits at the lowest possible cost. To this end, these policies and measures should take into account different socio-economic contexts, be comprehensive, cover all major sources, sinks and reservoirs of greenhouse gases and adaptations, and cover all economic sectors. Stakeholders can make efforts, in cooperation, to address climate change." In: BRAZIL. **Decree No. 2.652 of 1 July 1998**.

> Article 225. Everyone has the right to an ecologically balanced environment, a common good for the population and essential for a healthy quality of life, which imposes on the Government and the community the duty to defend and preserve it for present and future generations.
> Paragraph 1 - To ensure the effectiveness of this Law, it is the responsibility of the Public Authority:
> [...]
> V – control the production, marketing and use of techniques, methods and substances that represent a risk to life, quality of life and the environment; [...]

Thus, it can be said that the Precautionary Principle is found as a guide for Brazilian environmental legislation, since there are determinations for the Government to define the forms of protection and impact assessment, with the aim of preventing environmental damage (Antunes, 2016, p. 39).

The studies present diverse and different definitions and forms of application. From the weakest to the strongest form. In the weak version, "the lack of decisive evidence of injury should not be a reason for refusing to regulate." (Sunstein, 2005, p.18). In the intermediate stage, the objective is the balance between all the different aspects involved in the specific case, favouring rationality and the compromise solution between the different actors. (Antunes, 2016, p.41) In the strong version, regulation is suggested whenever there is a possible risk, which represents an extreme action (Sunstein, 2005, p.18-24).

Due to the lack of definition, scholars determine that the Precautionary Principle is "innovative, but irresponsible, generalized, but arbitrary and meaningful, but reckless." (Dark; Burgin, 2017). Because of this, the Principle has been much criticized and because it is abstract it has important and serious difficulties of empirical application.

Precisely, this issue induces a scenario of ambiguity when experts disagree with the framework (strong, weak, moderate) to carry out risk management, which are full of uncertainties and raise questions such as those cited by the author Stirling (2010, n.p.).

> Ambiguity problems arise when experts disagree on the framework of possible options, contexts, outcomes, benefits, or harms. Like uncertainty, these cannot be reduced to risk analysis and require a plural and conditional treatment. These methods can highlight, rather than obscure, different regulatory questions, such as: "which is better?", "what is safer?", "is this safe?", "is this tolerable?" or (as is often the case) "is this worse than what we have now?"

To address the concept and application of the Precautionary Principle and to explore to present guidelines for its application, its best and most widely used definition worldwide was used, that is, Article 15 of the Rio 92 Declaration:

> Principle 15: In order to protect the environment, the **precautionary principle** should be widely observed by States, in accordance with their capabilities. Where there is a threat of serious or irreversible harm, the absence of absolute scientific certainty shall

> not be used as a reason for postponing economically viable measures to prevent environmental degradation.

Therefore, in order to activate the Precautionary Principle based on Rio 92 Principle 15, it is important to understand its composition, which is: i) threat of serious or irresistible harm, which are the risks related to the activities; ii) absence of absolute scientific certainty; (iii) economically viable measures to prevent environmental degradation.

3 The risk

Threats[3] (Adams, 2009, p. 26-40) of serious or irresistible harm are, in fact, the intrinsic risks that activities that use environmental resources have of causing harm (Luhmann, 2005, p. 144). Risks are, therefore, an uncertainty of occurrence, so uncertainty is not something (non)existent. Their dimensions or severities are not clearly indicated. The uncertain "may be a hypothesis, something that has not yet been verified or has not been verified." But, according to the Precautionary Principle, the fact that the uncertain is unknown or misunderstood indicates that it must be evaluated or investigated (Machado, 2018, p. 2188-2189).

Ben and Engelmann (2021) mention that risk refers to what is known about probabilities, which are calculated on scientific bases, and effects, which are well defined. Uncertainty, on the other hand, could be defined when, although there is confidence in the completeness and completeness of a defined set of effects, there is no theoretical or empirical basis as to the probability of the effects occurring.

Luhmann differentiates between risk and danger. Risk provides an opportunity for decision-making, because communication is focused on the future, and it is necessary to rationalize in the future without it even having happened, through a self-analysis of the system to promote the control of a certain threat. Danger represents the impossibility of anticipating, due to the lack of knowledge of the cause and consequence of a certain event (Luhmann, 2005, p. 144).

> The risks are real and unreal at the same time. On the one hand, there are the threats and destructions that are already very real: the pollution or death of waters, the disappearance of forests, the existence of new diseases, etc. On the other hand, the

[3] Threat is defined as something that could cause harm and risk is the result of multiplying the probability by the threat. If you don't know for sure what's going to happen, but you know the odds, that's risk, but if you don't even know the probabilities, it's uncertainty, then threatening. (Adams, 2009, p. 26-40)

> true social strength of the risk argument lies precisely in the dangers that are projected into the future (Machado, 2014, p.95).

Leite and Ayala summarize that Precaution can be conceptualized as the search for the elimination, in time and space, of danger, as well as in the search for protection against one's own risk and in the analysis of the harmful potential derived from the set of activities. Therefore, the principle seeks to "prevent a suspected hazard now or ensure a sufficient margin of safety of the hazard line". (Leite; Ayala, 2011, p.53-54). Machado limits the maximalist vision of Precaution by mentioning that "it is not just any risk that will trigger a control procedure, but the significant risk." (Machado, 2018, p. 2188-2189). However, to say whether a risk is significant or not, it must be known, assessed, measured and managed. Therefore, the question that arises is: what should the margin of safety be and to what risks should this margin be applied? (Sunstein, 2005, p. 119).

Defining what is meant by a hypothetical, but plausible, threat that would lead to the adoption of precautionary public policies with their correlated burdens, is an essential measure to trigger Precaution (Mota, 2008). For this to be plausible, "the specific choice of appropriate precautionary measures depends to a large extent on the *characteristics of the risk"* (in terms of likelihood, frequency, eminence, distributive injustice), as well as on the *nature of the potential harm* (whether it will affect the environment or also people, endangering life as well as health, whether or not it will affect the functioning of the economy, whether it will cross national territorial borders, whether it will be irreversible or if it will accumulate with pre-existing risks, whether there will be the possibility of notifying victims). Thus, in the assessment of the severity of risks, not only objective indicators of severity must be taken into account, but also subjective indicators of severity (Aragão, 2011-2012, p. 159-185), i.e., risk must be analyzed in all its direct and indirect facets.

The "Precautionary Principle is generally elevated to the status of an instrument for achieving sustainable development, with the task of protecting current and future generations against abstract, global, invisible, transtemporal, deferred and irreversible risks" (Engelmann; Axe; 2013). In this way, it is intended to manage unknown or uncertain risks to a certain extent, and for this it is necessary to rationalize the risks involved, according to an evaluation of the probability of occurrence associated with their magnitude. In this line, we find arguments and support to decide on the appropriate way to avoid environmental damage. (Berwig, 2014)

Giddens argues that precaution should be visionary of hypotheses of harm occurrence and that therefore precaution should be combined with the "Percentage *Principle*." Given this, it is necessary to evaluate the risks and opportunities in terms of the relationship between the costs to which one is subject and the benefits obtained (Giddens, 2010, p.85). Aragão understands that the application of the *Precautionary Principle* also has three moments that must be guided by the weighing between: advantages and disadvantages, the evaluation of social acceptability, and the choice of appropriate and proportional precautionary measures (Aragão, 2008, p.09-53).

In Germany and the United States, risk analysis is applied in three phases: *assessment*, *management* and *communication*. The *assessment* must be carried out, initially, by the legislator – in the "identification, in the abstract, of the vital risks to the community and in their graduation between residual, current and potential – but the Administration will always have an important task of assessing the potential risks, in particular". The *assessment* should take into account the reliability of the information and transparency in its disclosure to the public. In *risk management*, in its operational dimension it is exclusively administrative, but the principle obliges the legislator to establish, even if it is in the most dense way possible, the legal qualification for the interference and the essential assumptions. *Risk communication* "operates at two levels: the recipient of the authorization and the general public, within which interested persons can be selected for their proximity to the source of the risk." Either party has an interest in explaining the decision that generates the uncertainty, not only for reasons of assessing the reasonableness of the level of interference (i.e.: *quantum* of the duties of protection) required by the Administration (the recipient), but also for the knowledge of the type and degree of risk to which they are exposed (general public and interested parties in particular) (Gomes, 2013, p.199-200).

Risk Analysis and Risk Management, for Cezar and Abrantes, must be carried out in three phases: First, the *Risk Perception* is defined; Secondly, the *Risk Analysis* itself, which based on specialized technical-scientific knowledge and the prior identification of the adverse effects to be considered, a quantification of the risk is carried out by Third Parties, in possession of detailed information on the risks (perception, analysis and quantification) of the *Management* of Risks, which is the final stage of decision-making, where certain lines of action are chosen based on the results of the risk study (Cezar; Abrantes, 2003). The *perception of risks* is analysed in the light of scientific criteria of severity and also of social unacceptability. Thus, Aragão classifies them into i) objective risks, which are those risks that are scientifically high, to the extent that their severity is measurable, that is, their importance is scientifically assessable. In these, apparently, there is an awareness of the citizens (water pollution, for example); ii) subjective risks, despite being considered very low or even irrelevant by specialists, generate waves of social alarm (Aragão, 2011-2012, p. 159-185).

In the *perception of risk,* the precautionary principle could assume the following function: verified by common sense or by isolated experts, the possibility of damage considered serious or irreversible, precaution would lead to the immediate adoption of measures to prevent the expected environmental degradation" (Cezar; Abrantes, 2003). Thus, the precautionary principle implies an initial perception of risks in which there are no certainties, not even the so-called scientific perceptions.

When it comes to new technologies, the benefits are initially overestimated and the risks are underestimated. Due to the specificity required in identifying a new technology, and the abstract nature of risk anticipation, the uncertainty associated with estimating benefits may be lower initially, while uncertainty around risk may be large. Therefore, to the extent that additional information produces better estimates of both benefit (risks and benefits), as the system moves forward in search of more perfect information, the risks and benefits are indistinguishable within the limits of uncertainty (Wiesner, 2011).

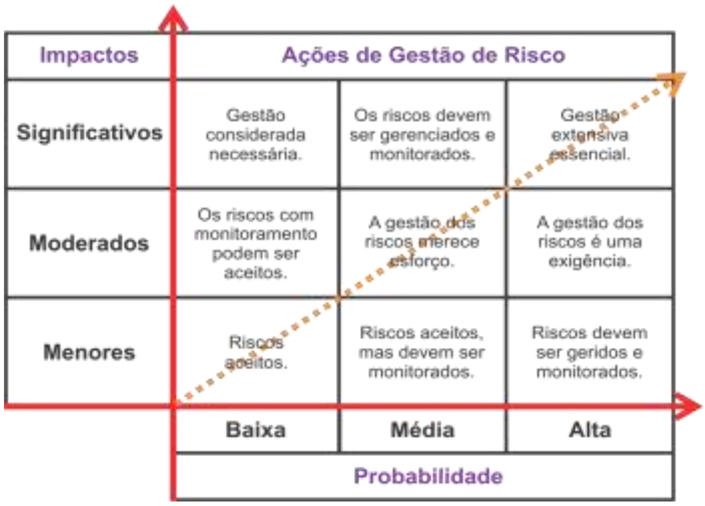
At this stage, "the first problem is nearsightedness: people often focus on the short-term and neglect the long-term, in a way that can harm their own interests." The reason is that the attempt at defense ignores the central problem, "precautions against some risks almost always create other risks" (Sunstein, 2005, p. 52-53). It is often a matter of avoiding known risks, although not unknown risks, or surprises (Antunes, 2016, p. 34).

In another example, Antunes clearly explains the necessary balance in precautionary decisions against risks:

> If, on the basis of the precautionary principle, we adopt an attitude against nuclear energy, we cannot use it against fossil fuels, as we consider nuclear energy to be a greater risk. On the other hand, if we use it against fossil fuels, because we have a well-founded fear of global warming, we cannot rebel against hydroelectric plants (Antunes, 2016, p. 32).

In this way, Pérez suggests the application *of the qualitative risk diagram* as a tool to provide useful information for risk analysis and precautionary application. In this context, visualization can help decision-makers to classify risks and consider appropriate responses. It can support decision-makers in reasoning about the Precautionary Principle and its place within the broader universe of risks (Pérez, 2010).

Perez's Risk Diagram adapted and translated into Portuguese



Source: Pérez (2010).

The diagram presented by Pérez makes an approach taking as parameters the impacts (minor, moderate and significant) and the probabilities (low, medium and high), red lines. As the impacts and probabilities increase (from the exterminated minimum to the high, the orange line) the actions for risk management also become more extensive. For example, a certain product will have its risk accepted if it has a lower impact and a low probability of causing damage. On the other hand, a product with a low probability of harm, but with a significant impact, will have actions for risk management that are considered necessary. Conversely, if the product has a low impact and high probability, risks should be managed and monitored.

It is assumed, therefore, that the relationship between the principle and the total process of Risk Analysis *is complex*, so that, in some situations, the principle reaffirms the relevance of technical-scientific knowledge for the quantification of risk, while in others, it discredits them to safeguard perceptions based on common sense. In other words, if the *Risk Analysis* indicated a high risk that an agent would cause serious or irreversible environmental damage, the Precautionary Principle could be invoked to avoid arguments that sought to delay or avoid the adoption of measures. In another interpretation, if the *Risk Analysis* presented a probability of damage close to zero. Given the uncertainty inherent in quantifying risk, it could be argued that the risk analysis concludes that there is an "absence of absolute scientific certainty" that a given agent will not cause harm. The Precautionary Principle could then be applied to prevent this Risk Analysis from pointing to a risk close to zero and being used as a reason to postpone, in the Risk Management phase, precautionary measures against an initially perceived environmental damage (Cezar; Abrantes, 2003).

What is the field of decidability in terms of the perception of risk for the application of the precautionary principle?

In the field of politics, in which a decision has to be made, without it being possible to predict its effects and implying the institutional responsibility of the rulers, which cannot be based either on risk analysis (flawed, because there is no reliable scientific data), or on common sense, which in this perspective is always wrong. Political action is always paradoxical, because it implies action that is broader than the force of uncertainty. In addition, the imposition of restrictions is required to take place even before there is absolute scientific certainty about the real threat to the environment. Therefore, plausibility, based on the scientific knowledge available at the time, is sufficient. Therefore, the Precautionary Principle brings with it a "requirement for the early calculation of potential hazards to one's health or activity, when the essential has not yet emerged" (Mota, 2008).

4 The state of the art

The Convergent Technologies programs correspond perfectly to the characteristics that distinguish contemporary technoscience from modern science: science wants to know what the world is like: to describe it, interpret it, understand it, explain it and, in the best of cases, predict *a priori* the events that will happen, as well as explain *a posteriori* those that occurred. The main goal of technoscience, on the other hand, is to "transform the world, whether natural, social, or artificial." Moreover, for a scientist, knowledge is an end in itself, while for a technoscientist it is a means to achieve other goals. The accelerated development of technoscience is related to financial incentives, since these aim to give rise to technological developments and innovations based on research, that is, transformations and not only the understanding of the world and its description (Echeverría, 2009).

In these circumstances,

> The Precautionary Principle provides a way to legitimize activities and processes that would otherwise be unacceptable. Even when the public's fear of new technologies is irrational, scientists and policymakers cannot ignore it. At least some version of the precautionary principle may seem to offer a compromise between science and democracy, assuring the public of the security of a new technology and making it more difficult for alarmists to block a new technology (Sunstein, 2005, p.54).

Of course, no one can reliably predict the unpredictable, but there are lessons to be learned from past mistakes (Stirling, 2010). The results derived from scientific uncertainty generated distrust in science after the tragedies of thalidomide, mad cow disease and Chernobyl (Sunstein, 2005, p. 54). In other words, development is a gradual process through the addition of new elements, in isolation or in combination, this is no different in the field of scientific knowledge, in which the constantly growing stock constitutes scientific knowledge and technique (Kuhn, 2017, p.60).

> - There may be uncertainties as to the origin of the damage. When there is actual and confirmed harm, but the cause is unknown, or when there is a hypothetical cause for the harm, but the causal link between the two is unclear. It is the doubts about "which", and what justifies the question: "what is the risk?"
> - There may be uncertainty as to the nature or severity of the damage. When there is no doubt that a certain activity is going to cause damage, but we do not know exactly what or how serious. It is the doubts about the "what" or the "how much" that lead to the question: "risk of what?"
> - There may be uncertainties as to the actual verification of damage. When there is not even confirmed damage yet, there are only suspicions. It is the doubts about the "if" that explain the question: "Is there even a risk? (Aragão, 2011-2012, p. 159-185)

Scientific achievements are recognized for some time by a specific scientific community, providing the basis for subsequent practice. These are open to allow further development by these science professionals. These achievements are conceived as paradigms, that is, examples that are accepted in scientific practice and that provide models from which the traditions of scientific research that will be applied later (Kuhn, 2017, p. 71) emerge.

For a better understanding "Heat, light, electricity and magnetism acquired paradigms and suddenly a whole mass of indiscriminate phenomena began to make sense". This coincided with the Industrial Revolution, a time that gave rise to the modern technical-scientific world shared today (Hacking, 2017, p.17).

Even in the information century, there are still numerous scientific uncertainties. This is justified by the fact that society is confronted with very recent and innovative substances or technologies, whose impacts are still poorly understood (nanotechnologies or genetically modified organisms, for example), but which entail risks for current and future generations. In addition, many of the new technologies have been studied only in a laboratory context, and not in a real environmental context; only on a time scale of years or decades when it should have been centuries or millennia; and only on a restricted and non-extended geographical scale (Aragão, 2011-2012, p. 159-185).

Aragão explains the differentiation between ontological, epistemological, and hermeneutic uncertainty. Ontological uncertainty derives from the complex nature of systems (ecosystems or climate systems), their scale (from the nano scale to the planetary scale, or interstellar, in the case of solar magnetic storms), their randomness (atomic risks, for the behavior of living beings or biotic communities) or their dynamic nature (ecosystems are open and dynamic systems, difficult to predict, as they evolve due to numerous factors). Epistemological uncertainty can result from the non-existence, insufficiency or incompleteness of data, or from the existence of contradictory data or even from the existence of too much data. Hermeneutical uncertainty arises from the fact that, in the face of a scarcity or excess of data, different interpretations of reality can be generated and, therefore, different visions of risk (Aragão, 2011-2012, p. 159-185).

Technological prediction can be expressed by a "numerical value or by constraints such as 'likely', 'unlikely', 'very likely', 'unlikely' or 'almost certain', according to the degree and type of relevant knowledge available and effectively employed in forecasting" (Cezar; Abrantes, 2003).

In this way, although predictions about the effects of technologies refer to natural or social events, they are not made exclusively based on scientific knowledge, they are also made based on knowledge about the functioning and failures of technologies. More specifically, technology forecasts can refer to: (i) *Operational forecasts*, which refer to the anticipations of inputs and outputs arising from the operation of mechanisms or systems of mechanisms; or the internal workings of those mechanisms or systems of mechanisms; ii) *Predictions about failures, which* indicate the forecasts of the failure of the mechanism or which products or by-products would be generated or compromised due to failures of the mechanism or any of its components; iii) *Social Impact Forecasts*, which are the forecasts of economic, social, political or cultural effects generated by the products or inputs involved in the operation of the mechanism or in its possible failure or by the environmental or health effects derived from them; iv) *Environmental Impact* Forecasts which are the forecasts of the effects on the environment generated by the outputs or inputs involved in the operation of the mechanism or in its possible failure or by the social or health effects that derive from them; v) *Predictions on Effects on Human Health*, which are the anticipation of the effects on human health generated by the products or inputs involved in the operation of the mechanism or in its possible failure or by the social or environmental effects that derive from them (Cezar; Abrantes, 2003).

The term "certainty" in the Precautionary Principle qualifies a prediction (that there will or will not be environmental damage under certain conditions). The formulation takes place in a scientific context: it is an "absolute scientific certainty". It is a matter of certainty with respect to a scientific prediction. "Having knowledge" and "being safe" seem to be closely associated knowledges. One of the strategies of the skeptic is that there is certainty in order to have knowledge. Consequently, if it is not possible to be sure; Therefore, one does not have the knowledge. Two ways to deal with this skeptical challenge would be: “To show that certainty is not a necessary condition for knowledge. Show that we can be certain about at least a subset of our beliefs and then try to extend our certainty to other beliefs” (Cezar; Abrantes, 2003).

Several contemporary epistemologists defend the first strategy: certainty would be an additional requirement to knowledge, that is, it is possible to have knowledge even if one is not sure. "Certainty would only be relevant to the statements of a subject of whom he has knowledge. But the subject can have, in fact, knowledge even if he is not sure of his belief and declares, erroneously, that he has no knowledge." The second strategy is adopted by foundationalists, for whom the notion of "certainty" is central. Therefore, it designates the position that one is justified only in beliefs and if they are "backed by solid foundations", by some indubitable "basis". The "foundationalist proposes to justify (all) our beliefs based on 'basic' beliefs that are taken as 'correct', in the sense that they are indubitable or infallible" (Cezar; Abrantes, 2003). In other words, "everything that is known and admitted as true or true, has an ultimate foundation." (Mora, 1994, p. 1163).

In a scientific context, "law" can generate different interpretations:

> That the inference that leads from the premises to the conclusion is "certain." That is, if certain propositions are admitted as premises, the observational proposition (which constitutes the prediction) necessarily follows. Here we have a logical certainty which does not guarantee, by itself, the truth value of the observational proposition. We usually mean more than merely logical certainty when we say that a prediction is "true," and this leads us to the following interpretation. That the observational proposition that constitutes the prediction is true (Mora, 1994, p. 1163).

In both interpretations, a lower "certainty" (or a higher degree of uncertainty) can be admitted, depending on the following factors:

> 1) If the inference involved in the prediction is not deductive but inductive, we have no logical certainty that the (truth of) the conclusion follows from the premises. We infer the conclusion only with a certain probability, degree of "force" or "certainty".
> 2) We are not "absolutely" sure about any proposition, including those presupposed in an inference, whether observational, nomological, or theoretical. In this case, even if the inference linking the conclusion to the premises is deductive, we cannot be sure with certainty of the (truth of) the conclusion; that is, we cannot be sure of the occurrence of the foreseen event (Cezar; Abrantes, 2003).

Factor (2) is very present. In a scientific prediction, the premises of the laws and the initial conditions are involved. Laws are "universal statements, i.e., spatio-temporal unconstrained, and initial conditions are singular statements." But it is not possible, in general, to have an "absolute" certainty about a universal proposition. They cannot be proven, but confirmed (probabilized) or falsified given empirical evidence (Cezar; Abrantes, 2003).

Therefore, the precautionary principle presupposes a scientific assessment of all verifiable and verifiable aspects of risk before taking action. Considering that "precautionary measures are always provisional", and that "they must be periodically reviewed in the light of the evolution of scientific and technical knowledge, even after the adoption of the measures, science is called upon again, this time to justify the maintenance, reinforcement or repeal of precautionary measures". In short, precautionary measures based on science and not against science, including maintenance based on scientific data (Aragão, 2011-2012, p. 159-185). Thus, "there is no absolute scientific certainty, but only paradigms, provisional scientific answers that are decisive in a precise historical epoch" (Mota, 2008).

In turn, the relevant knowledge for this type of forecasting can be constituted by:

> (a) Descriptions of specific aspects of the mechanism currently under consideration, such as the material and method used in its development.
> (b) descriptions of the environment in which the mechanism will be used or developed.
> c) Descriptions of the persons or group of persons responsible for its operationalization.
> d) Deterministic laws or scientific statistics.
> e) Statistical-technical laws.
> (f) Information on the "role" performed by a particular structure, component or person (Cezar; Abrantes, 2003).

Scientific uncertainty lies in the risks of carrying out activities that use natural resources, especially with regard to new technologies (nanotechnologies and biotechnologies). Therefore, there is a need to monitor risks, through the elucidation of the mechanisms that produce these risks, as well as a broad consideration of the possible risks to complex ecosystems (Wiesner; Bottero, 2011).

5 Economically viable measures

As has been verified, the empirical application of the Precautionary Principle includes numerous uncertainties regarding the assessment of risks, as well as scientific uncertainty, but it is also necessary to consider the economic value of the measure to be implemented for the management of the risk of environmental damage. Bearing in mind that, although there is information, this will only be possible through a certain investment, which must also be measured against the possible risks and benefits of the technology.

The Commission's Communication on the precautionary principle in relation to economically viable measures states:

> The measures taken presuppose an analysis of the advantages and burdens arising from the action or inaction. This analysis should include an economic cost/benefit analysis where appropriate and feasible. However, other methods of analysis can be considered, such as those that refer to the effectiveness and socio-economic impact of possible options. In addition, decision-making bodies may also be guided by non-economic considerations (Commission of the European Communities).

But how could the measures be quantified and what are the social limits that they entail? Precaution restores the primacy of the political in the achievement of public policies, but what is its delimitation? It is known that it must be guided by the establishment of reasonable measures and proportional economic measures to preserve environmental degradation (Mota, 2008).

As is well known, "there is no human activity that can be considered risk-free; what humanity does, in all its activities, is a cost-benefit analysis between the acceptable degree of risk and the benefit that will be derived from the activity" (Antunes, 2016. p. 38).

Sunstein criticizes cost-benefit analysis to control regulatory decisions, since this analysis does not establish a rule by which decisions should be made. Participants may choose to continue using a certain technology even when the costs outweigh the benefits. However, if they do, it should be after receiving the information offered by the cost-benefit analysis. On the other hand, if regulators choose to impose disproportionately high costs compared to the expected benefits, they must explain why they chose to do so (Sunstein, 2005, p.130).

Therefore, "the excessive cost must be weighed according to the economic reality of each country, since the environmental possibility is common to all countries, but differentiated" (Machado, 2014, p. 106). In a summary of the precautionary "doubts", Aragão summarizes that:

> The special importance of prevention in the environmental protection plan is perfectly understandable and corresponds to the popular aphorism "prevention is better than cure". Common sense dictates that, instead of accounting for the damage and trying to repair it, we should try above all to anticipate and avoid the occurrence of damage, for some very obvious reasons that range from environmental justice to simple economic rationality, including intertemporal justice (Aragão, 2011. p. 64).

In short, it can be stated that "protection measures must be proportional to the level of protection sought", stressing that we currently live in a society of risk, in which the needs of man force us to resort, more and more, to the technological advances generated by new risks (Mota, 2008).

6 Guidelines for the application of the precautionary principle

Environmental health is known to be analogous to human health and, as such, should be prioritized (Dark; Burgin, 2017). But, for this, it is necessary to draw guidelines for its applicability, moving away from the vagueness of the Precautionary Principle. In view of this, its application requires a careful analysis of the following assumptions: i) Risk; (ii) Prior art; and (iii) Economically viable measures.

As for *the risk* , it was found that it is essential that it goes through the phases of 1. *Risk Perception* is based on technical-scientific knowledge, but the participation of common sense is also decisive in deciding which effects are considered adverse. 2. *Risk Analysis* Based on specialized technical-scientific knowledge and the prior identification of the adverse effects to be considered, a quantification of the risk is carried out. 3. *Risk Management*, the final stage of decision-making, where certain lines of action are chosen based on the results provided by the Risk Analysis (Cezar/Abrantes, 2003). In addition, risk rating issues can be understood by applying *the risk diagram as a tool* to provide useful information. Visualization could help to decide on risk classification and consider appropriate responses (Pérez, 2010). In addition, the application of proportionality was also pointed out as an important understanding of the focus on risks and the production of balanced decisions in uncertainty scenarios (Gomes, 2013, p. 203).

As for the second element of the Precautionary Principle, the *State of the Question*, it was found that in view of the continuous evolution and mutation of scientific knowledge, it is not possible to apply the time factor to it, but rather to the development of technical knowledge (Commission of the European Communities). Following this, including the guidelines of *the Commission's Communication on the Precautionary Principle*, the measures to be taken must consider their i) *Temporality,* since it will last as long as there is uncertainty, changing after new discoveries of scientific knowledge; ii) *Proportionality*, which requires no more than the adequacy between the means used and the end pursued. In this sense, the third element of precaution, cost, must be weighed according to the economic reality of each country (Machado, 2014, p. 104). And, in this sense, to carry out an analysis of the advantages and burdens derived from (in)action (Commission of the European Communities).

In summary, the measures adopted based on precaution must be proportional, coherent and precarious (be periodically reviewed in the light of scientific advances and, when necessary, modified) (Aragão, 2011, p. 63). Thus, in a general view of the Precautionary Principle, it is understood that the legal delimitation of what is the "precautionary principle" is called into question by its fluid and changing nature, which requires the configuration of an application model that meets the parameters of possible certainty, decidability, reasonableness and proportionality". This definition, therefore, is essential to serve as a parameter for the decision of the courts (Mota, 2008).

The objective of resorting to the Precautionary Principle that must be understood and preserved is to raise the level of protection of the environment, public health, public safety and fundamental rights, to a level more compatible with the degree of quality currently required. It is not a question of aspiring to zero risk (even in traditional and well-experienced activities there is a certain degree of risk), but of opting for responsible development (Aragão, 2011-2012, p. 159-185).

In this regard, the *Commission's Communication on the Precautionary Principle* mentions that the Precautionary Principle includes the general principles of risk management: proportionality, non-discrimination, consistency, analysis of the advantages and burdens that may arise from action or lack of action, and analysis of scientific advances (Commission of the European Communities).

In a report on the French legislation "*Charte de l'Environnement",* approved by the Chamber of Deputies and the Senate, in Versailles in France, Machado mentions that Article 5 of this refers to the Precautionary Principle, with the following wording:

> When the occurrence of damage, even if it is uncertain in view of the state of scientific knowledge, may seriously and irreversibly affect the environment, the public authorities shall, through the application of the precautionary principle and within the scope of their powers, provide for the implementation of risk assessment procedures and the adoption of provisional and proportionate measures to prevent the occurrence of the damage (Machado, 2014, pp. 103-104).

The Charte de l'Environnement has the following requirements for its application: a) the damage resulting from an act or omission is uncertain in the face of the state of scientific knowledge; (b) there is a likelihood of serious and irreversible effects on the environment; (c) the Government will apply it to itself, businesses and citizens; (d) there are two phases in the application of the precautionary principle: in the first phase there is a mandatory nature of risk assessment procedures, and in the second phase measures are adopted to prevent the occurrence of the damage; e) the adoption of public measures is subject to a special methodology, with two aspects: temporality and proportionality (Machado, 2014, p. 104). In this way, the guidelines of French law follow in a manner similar to those found in the understanding of the elements of article 15 of the Rio Declaration, as previously substantiated. To this end, the following synoptic table is proposed:

Summary of the stages of analysis for the empirical application of the Precautionary Principle

i) RISK > PROPORTIONALITY;
1. ***Risk perception*** : technical-scientific knowledge and the participation of common sense to decide on acceptable effects.
2. ***Risk analysis*** : technical-scientific knowledge for the prior identification of adverse effects and the quantification of risk through the risk diagram ;
3. ***Risk management*** : decision-making based on proportionality, based on the results provided by the risk analysis
ii) State of the art - > PROVISIONALITY;
1. ***Temporality***, because it will last as long as there is uncertainty, changing after new discoveries of scientific knowledge;
2. ***Proportionality***, which requires nothing more than the adequacy between the means used and the end pursued.
iii) Economically viable measures - > COHERENT.
It should be weighted according to the economic reality of each country, accompanied by an analysis of the advantages and burdens resulting from action and inaction.

Source: Authors.

It is concluded, therefore, that the application of the Precautionary Principle requires a position of distancing itself from the normativist mode, from a strong positivist attachment to give consequences to what is the very subject of Law. In the application of precaution, flexibility is required (Mota, 2008) to achieve its own objective, to avoid serious environmental and human damage.

7 Final considerations

Regarding risk, it was found that it is essential that it goes through the phases of Risk Perception, Risk Analysis and Risk Management. In addition, risk rating issues can be understood by applying the risk diagram as a tool to provide useful information. Visualization could help decide on risk classification and consider appropriate responses. In addition, the application of proportionality was also noted as an important understanding of the focus on risks and the production of balanced decisions in uncertainty scenarios.

The element of the state of the art is the situation of human scientific knowledge about a given technology. This knowledge is not immutable, on the contrary, it evolves constantly and, in today's society, with unprecedented speed. Therefore, scientific knowledge is agile. Thus, "certainty" as a property of an observation of a theory or a prediction is never "absolute", but always relative to a background or past knowledge, being provisionally accepted and always subject to criticism. Therefore, when we talk about the state of the art, we must refer to the concept of provisionality. Therefore, any risk decision will take into account the state of the art and this is linked to the movements of provisionality, proportionality and monitoring.

Thus, the absence of scientific certainty is part of almost all human actions. To this end, it follows the guidelines of the Commission's Communication on the Precautionary Principle: the measures to be taken must take into account its i) Temporality, as it will last as long as there is uncertainty, changing after new discoveries of scientific knowledge; ii) Proportionality, which requires nothing more than the adequacy between the means used and the end pursued.

The third element is economically viable measures, a weighting and proportionality between the advantages of the activity and the costs of action/inaction in relation to the risks of environmental damage that materialize. In this way, the understanding of the definition of the Precautionary Principle was closed.

To this end, the hypothesis of the initial research problem was confirmed, since from the division of the Principle into elements based on the concept of Rio 92 it was possible to draw guidelines for its empirical application, which were collected in the summary table presented.

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