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Analysis of the possibility of characterizing the hazard for activities in areas of iron ore tailings dams

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SUMMARY

This dissertation aimed to reflect on the possibility of characterizing the hazards of activities carried out in areas with iron ore tailings dams. Recent years have been marked by major environmental disasters, with recent dam failures causing significant environmental, social, and economic changes. The iron ore tailings dam failures in Mariana in 2015 and Brumadinho in 2019 are prime examples of these changes. These scenarios have raised awareness of the need for preventive or corrective interventions in these structures, given the uncertainty surrounding their stability. Therefore, this dissertation aimed to analyze the possibility of characterizing the hazards of activities carried out in these areas for workers performing preventive and/or corrective interventions, given the imminent risks to their lives.

Keywords: Dams, Dam Safety, Danger. Characterization Analysis of

ABSTRACT

This dissertation aimed to reflect on the possibility of characterizing the hazard for activities developed in areas of iron ore tailings dams. The last few years have been marked by major environmental disasters, the recent cases of rupture of iron ore tailings dams have caused major changes in the environmental, social and economic spheres. The rupture of iron ore tailings dams that occurred in Mariana in 2015 and Brumadinho in 2019 are expressive examples of these changes. These scenarios drew attention to the need for preventive or corrective interventions by these structures, in view of the uncertainty of their stability. Thus, the present dissertation aimed to analyze the possibility of characterizing dangerousness in activities developed in the areas of iron ore tailings dams for workers who perform preventive and/or corrective interventions in these areas, in view of the imminent risk to life to which they are exposed.
Keyword: Dams, Dam Safety, Analysis of Hazard Characterization.

1 INTRODUCTION

This dissertation was developed with the aim of presenting the possibility of characterization of the hazard for activities carried out in tailings dam areas of iron ore at risk. There are many cases of instability and ruptures in these structures, as occurred at the Fundão dam of the Samarco Mining Company in Mariana-MG, on November 5, 2015 and in Brumadinho on January 25, 2019, which caused countless material and environmental losses and the death of hundreds of people.

According to the Dam Safety Report (2019, p. 28) from the National Water Agency (ANA), 19,338 dams are registered in Brazil, of which 1,096 are classified simultaneously as a Category of High Associated Risks and Potential Damages.

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Every day, several preventive or corrective activities are carried out by a large number of workers with the aim of ensuring the safety of these structures, being exposed to an area with high risk potential, being monitored and/or controlled, but not eliminated in their entirety.

Dangerousness is defined as the quality of something that is dangerous or risky for life, a term widely used in the field of health and safety at work, indicating activities or functions that pose an imminent risk to life during their performance. According to with the regulation of labor rights approved by the Ministry of Labor and Employment in Brazil, the hazard pay must be paid to the worker who performs dangerous tasks that may put his life at risk. The assumptions that specify the rules of this labor law are provided for between articles 193 and 196 of the Consolidation of Labor Laws (CLT), through decree law no. 5,452, of May 1, 1943).

Thus, the work plan will be divided into four parts, summarized below.

Initially, the conceptual aspects of dams will be addressed, with emphasis on systemic vision of security management of this structure in view of the existence of measures monitoring and control in the absence of risk elimination.

In a second moment, the institute of dangerousness will be analyzed, conceptualizing and characterizing the activities classified based on art 193 of the CLT as well as Standard Regulatory NR 16.

The third part of this research will discuss health and safety standards. of the work, presenting the historical and conceptual notions and applicable legislation, as well as the hierarchy of risk controls with the aim of demonstrating elimination as the solution more effective in controlling risks.

Finally, the possibility of characterizing the dangerousness for the activities in areas of iron ore tailings dams given the potential risk to life, given the existence of control measures and the lack of measures to eliminate risk situation, as well as a parameter for characterization.

2 BASIC CONCEPTUAL ASPECTS ABOUT DAMS

The mining sector in Brazil represents an important part of the country's economy through national and international marketing. Therefore, given the enormous volume of residual materials generated from the ore extraction and processing process

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made of iron, mineral waste containment dams represent one of the most popular techniques by miners and geotechnicians.

Until the 15th century, the generation of waste by mining companies and the impacts resulting from their disposal in the environment were considered negligible. However, with the introduction of steam power and the significant increase in capacity processing of minerals of economic interest, the generation of waste increased significantly, and are then sent to rivers or watercourses. According to DUARTE *et* al., (2008), tailings dams in Brazil appeared before the gold rush North American, whose gold mining activity began with the Passage Mine, in Mariana. Tailings dam (figure 01) is an earthen structure built with the aim of contain the residues from the final iron ore beneficiation process. This reject is a material that has no greater economic value. However, for safeguards environmental must be properly stored.

Figure 01 – Raising of the Itabiruçu Dam Itabira / MG.
Source: MORAIS, 2019.

In the process of generating waste, called ore beneficiation, the The amount of waste generated is very high, and disposal is done depending on the objectives economic aspects of the mining company, on the surface, or linked to the ore extraction process underground or open-air. In general, there are two types of waste produced by mining activities, waste and tailings.

According to a report by the National Mining Agency (2019), Brazil has 19,388 mining structures, power generation and water storage, of this total, Minas Gerais is the state with the largest mining industrial hub, and consequently, with the largest

number of dams located in Brazil.

In Brazil, there was an advance in legislation aimed at dams, with the creation of a Policy National Dam Safety Law (PNSB - Law 14,006), which came into force in the year 2020. The regulatory advances occurred after the Fundão dam collapse. According to the National Human Rights Council (2017), on November 5, 2015, the dam of Fundão, located in the Germano industrial unit, in the Bento Rodrigues subdistrict, in Municipality of Mariana, in the Central Region of Minas Gerais/Brazil, broke, causing a flood of mud and mining waste that caused the destruction of the subdistrict, left 17 dead and more than 600 homeless and displaced, in addition to other socioeconomic impacts and environmental.

3 SYSTEMIC VIEW ON TAILINGS DAM SAFETY IRON ORE

3.1 Risk Management in Dams: Methodologies and Controls

Existing

The study of the risk imposed and the analysis of the consequences resulting from a rupture, in any type of dam, are basic assumptions in the discussion on risk management. One of these consequences to be analyzed is the loss of human lives for which requires a fatality estimate study. If there is even one death caused by errors in a dam, is enough to classify it as a disaster. It is essential that, by force increasingly growing society, the establishment of legislation and standards, dams operate with the highest possible level of security, that is, with a minimum acceptable risk by society. The National Dam Safety Policy (PNSB) through the Law 14,066/20, establishes a series of obligations for the entrepreneur who manages these structures. Among the entrepreneur's obligations, the requirement to notify in a manner immediately the supervisory body, the environmental body and the civil protection and defense body any alteration of the safety conditions of the dam structures that could result in an accident or disaster.

In activities carried out in areas with various dams, the mechanisms are management and control of existing risks, with the aim of carrying out an analysis geotechnical assessment of the safety conditions of structures, with the aim of identifying anomalies in the structural part that may generate a risk of rupture, as well as define actions to be implemented, which can be either preventive or corrective in nature.

Dam safety can be achieved by relying on three basic pillars: safety structural, monitoring and emergency management. Monitoring is necessary to know if a structure or equipment is in acceptable safety conditions or meets to the criteria and standards for which it was designed.

The monitoring process is done through visual inspection in the field or by instrumentation. Monitoring through instrumentation aims to alert about conditions that may favor the occurrence of anomalies in the behavior of the dam: constructive pore pressures, slope instability, carried out using piezometers installed along the dams.

Another security measure adopted is the decharacterization process, works of containment and reinforcement of dams. According to the National Mining Agency, the dam uncharacterized is a structure that does not permanently receive waste and/or sediments arising from its activities and which ceases to possess or exercise the function of a dam.

After the major disasters that have occurred in recent times, controls are becoming increasingly increasingly improved and technological, with the aim of having greater efficiency in the process of management. The management of risks implemented to ensure the stability of these structures are characterized as control mechanisms. To ensure the effectiveness of these mechanisms, it is necessary to have the presence of professionals from different areas who are daily exposed in these high-risk areas. These professionals are faced with a controlled and managed risk situation, once exposed in the risk zone, elimination is something nonexistent.

3.2 Historical Incidents Involving Iron Ore Tailings Dams Iron

Brazil has recorded major tragedies involving the collapse of tailings dams. iron ore. In 2015, Brazilians witnessed the worst environmental crime in the history of country. The collapse of the Samarco dams in Minas Gerais caused enormous destruction in several cities in the region, in addition to having harmed the aquatic life of the Rio Doce.

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Figure 03: Aerial image of the Bento Rodrigues district, after the Fundão dam collapse.

Source: CRUZ, 2019.

The dam collapse in Brumadinho on January 25, 2019 was the biggest workplace accident in Brazil in terms of loss of human lives and the second biggest disaster industrial disaster of the century. It was one of the biggest environmental disasters in the country's mining industry, after of the dam collapse in Mariana. Controlled by Vale SA, the dam in tailings dam called Córrego do Feijão Mine, was classified as "low risk" and "high potential for damage" by the company. Accumulating the tailings of an iron mine, It was located on the Ferro-Carvão stream, in the Córrego do Feijão region, in the municipality of Brumadinho, state of Minas Gerais.

Figure 04: Rupture of the Vale dam at the Córrego do Feijão Mine, in Brumadinho.

Font: G1 MINAS, 2019.

After the latest episodes of rupture of these structures, this type of activity began to have stricter security policies and a series of obligations for the entrepreneur

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that manages these structures and ensures greater security in order to avoid new ruptures, mining companies have been acting with various preventive and/or corrective measures, performed by countless workers exposed daily in areas of potential risk. The existence of measures adopted after the disasters occurred demonstrates the fragility existing in these structures and the absence of control mechanisms capable of eliminating these workers in the risk zone.

4 HAZARD ALLOWANCE

4.1 Concepts of the Hazard Addition

The word dangerousness, as defined in the dictionary, means quality of that which is dangerous or harmful to life. Labor laws indicate that professional has the right to extra remuneration, due to the high risk he is exposed to develop their work activities, thus being a way of compensating for the risk to to the life and physical integrity of the worker. Therefore, the hazard pay bonus constitutes a amount due to the employee when he is exposed to danger when performing his duties work activities, such as permanent contact with risk. Activities defined as risk are exposed in article 193 of the Consolidation of Labor Laws (CLT) which brings as arduous, unhealthy or dangerous activities, this means that when a worker carries out an activity that exposes him to a constant risk of death, gives him the right to receive, in addition to the salary, the aforementioned additional amount, on the same premise, removing this right when the same worker is not exposed to risk, or even if his task no longer offers risk.

4.2 Criteria Adopted to Characterize Danger – No. 16

Regulatory Standard number 16 lists the dangerous activities and operations, presenting us with an annex with all the activities as well as the justification for the respective additional. The NR brings with it a broad and complex definitions of activities, but we can note that the classification of dangerousness can be subjective, thus requiring analysis techniques. To characterize the activity as dangerous, a technical analysis will be necessary and the preparation of a report confirming the presence of the risk, with such a need precisely because the framework is subjective, having to be affirmed through the case concrete and the real existing risks.

Regarding the obligation to prepare this report, the CLT itself provides for its obligation so that the dangerousness can be characterized or de-characterized, as set out in

article 195 of the Consolidation of Labor Laws (CLT), the characterization and classification of unhealthiness and dangerousness, according to the norms of the Ministry of Labor, will be carried out through expertise carried out by the Occupational Physician or Occupational Engineer, registered with the Ministry of Labor. The CLT indicates that such activities are considered dangerous activities which imply a high risk due to permanent exposure, therefore understood if there is no legal concept that deals with the applicability of dangerousness in practice, dealing with a subjective issue of qualitative and quantitative analysis in the work environment.

5 OCCUPATIONAL SAFETY AND MEDICINE: OBJECTIVE OF SAFETY AND OCCUPATIONAL MEDICINE AND APPLICABLE STANDARDS

Until the beginning of the 18th century, there was no concern for the health of workers, for there are few reports of workplace accidents. However, with the advent of the Industrial Revolution and new industrial processes, the consequent modernization of machines meant that the emergence of diseases or accidents resulting from work caused by the activity labor. As a result of this fact, the law began to determine certain minimum conditions that should be observed by companies. According to Martins (2012), security and occupational medicine is the branch of labor law that is based on the guarantee of protection of the health of workers at the place of service provision or, even, the right to dignified recovery when they are no longer able to work.

As Nascimento (2010) describes, safety and medicine applied to work has its own objective, which can be summarized, following Simonin, as follows: way: a) man-machine complex, in view of the constant modifications of the latter, causing all sorts of damage to those who handled them, requiring a corrective order physiological, biological, psychological and technical; b) worker-environment complex, taking into account that the workplace is a source of various risks and dangers, which must be avoided, both in concerning the construction of the establishment, in its material aspect, as in relation to implementation of sanitary technical resources by engineers, chemists and toxicologists; c) worker-employer team, understanding psychological factors of productivity, relevant to sphere of human relations in the company and the consideration of the worker as a being endowed with needs and at the same time subject to ethical, moral and spiritual factors; e) complex worker-community, which enters the field of social security, given the need to suppress or reduce the worker's uncertainty regarding certain contingencies that affect him or her the future and risks of work.

From then on, occupational safety and medicine, as means of protecting the

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man, increasingly penetrates society, to demand greater respect and care for health of those who move the machines and give life to the company.

The Brazilian legal system deals with the rules relating to this subject in articles 154 to 201 of the CLT, which were edited by Law No. 6,514-1977, in addition to Ordinance No. 3,214-1978 of the MTE. Based on the provisions of NR-1, the Regulatory Standards, relating to Occupational Health and Safety are mandatory for private companies, public bodies and by public bodies of direct and indirect administration, as well as by bodies of Legislative and Judicial Branches that have employees governed by the CLT.

The CLT establishes in articles 157 and 158 rules to be observed by companies (employers) and employees, respectively.

> Art. 157. It is up to companies:
> I- comply with and enforce occupational health and safety standards;
> II- instruct employees, through service orders, when precautions to be taken to avoid workplace accidents or illnesses occupational;
> III – adopt the measures determined by the regional body competent;
> IV – facilitate the exercise of supervision by the competent authority.
> Art. 158 - Employees are responsible for:
> I - observe occupational health and safety standards, including those instructions referred to in item II of the previous article;
> II - collaborate with the company in applying the provisions of this Chapter.
> Sole paragraph - The unjustified refusal of the employee constitutes a wrongful act:
> a) compliance with the instructions issued by the employer in the form of item II of the previous article;
> b) the use of personal protective equipment provided by enterprise.

The Constitution of the Federative Republic of Brazil, approved on October 5th of 1988, more precisely in its article 7, XXII, modified the orientation of the standards constitutional, giving specific treatment to the social rights of employees urban and rural, as well as others that aim to improve their social condition.

> Art. 7º Urban and rural workers have the rights, in addition to others that aim to improve their social condition:
> [...]
> XXII – reduction of risks inherent to work, through standards of health, hygiene and safety;

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> [...]
>
> XXIII – additional remuneration for arduous, unhealthy or dangerous activities, as provided by law;
>
> [...]
>
> XXVIII – insurance against work accidents, at the employer's expense, without exclude the compensation to which he is obliged, when he commits fraud or blame;

5.1 Hierarchy of Risk Controls

The hierarchy of control is a methodology used to determine what should be implemented and effective solutions in risk control represented as follows:

Figure 05: Risk control hierarchy.

Source: NIOSH (National Institute for Occupational Safety and Health)

The idea behind hierarchy (figure 05) is that methods at the top of the graph are more effective in protecting those at the base. So, in general terms, it is known that ways to control risks are numerous, but we need to list those that are more important than others and apply according to the scale. At the top of the inverted pyramid, there is elimination and then followed by replacement.

Eliminating risk is the best scenario, but although it is the most effective in reducing of risks, are more difficult to implement into an existing process. In this way, we identify that the management of the risks to which workers are exposed can be controlled or eliminated. Control is achieved through the implementation of measures, whether engineering, administrative or use of PPE (Personal Protective Equipment).

Critically analyzing, elimination is the best situation in the search for protection.

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of the workers, this is because it is removed from the action of the exposing agent. This measure control measures are often difficult to implement, given that the
despite the fact that work processes are increasingly keeping up with the advancement of technology, direct human action is essential.

POSSIBILITY OF CHARACTERIZING DANGEROUSNESS FOR 6 ACTIVITIES IN IRON ORE TAILINGS DAM AREAS

6.1 Exposure of Workers to Work Activities in Dam Areas Due to the Absence of Risk Elimination Measures

Activities in iron ore tailings dam areas have become commonplace.
and necessary after the history of tragedies that have occurred in recent years. This type of activity gained a more critical look accompanied by new, more severe and greater legislation monitoring by public authorities. Aiming to guarantee greater security for these structures and ensuring that new disasters do not occur, mining companies have been adopting a series of monitoring, control, construction and maintenance activities in its structures. These are daily interventions that occur either preventively or corrective.

Figure 06: Water level monitoring.
Source: Vale, 2020.

Among the monitoring and control actions, we can verify measures in the sphere geotechnics through monitoring of the structural conditions of dams through
data analysis using piezometers, a device for measuring static or
compressibility of liquids is widely used in earth and concrete dams and
also in the monitoring of slopes and embankments. Other measures adopted are the activities of maintenance of structures, and these are broken down into a series of activities: construction, mischaracterization, reinforcement, etc.

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Figure 07 – Construction of the concrete containment located 6 km downstream of the Sul Superior dam, in Baron of Cocais.

Source: Vale, 2019.

The main factor behind these measures is the existence of professionals from different areas facing to these activities. Given the range of activities developed in these structures, it is non-existent control measures that completely eliminate the exposure of professionals in these areas to the lack of control measures that certify the safety conditions of these structures. There are many professionals who face their work journeys daily of these structures, acting either preventively or correctively.

With the advent of recent times, a range of activities began to be adopted in these structures and the number of professionals facing these automatically increased activities. Technological means are increasingly implemented, but they still do not reach the all the processes carried out, in order to eliminate human presence in the interventions daily executed.

6.2 Analysis of the Possibility of Characterizing Danger

To analyze the possibility of characterizing dangerousness, it is necessary that we can understand the standard that regulates this institute as well as the legal provision. The standard regulatory NR 16, belongs to the set of regulatory standards created by Ministry of Labor and Employment through Ordinance 3,214, of July 8, 1978, and deals with specific form of classifications and measures that must be adopted by companies in terms of refers to dangerous activities and operations.

Critically analyzing the aforementioned standard, a recent change in the standard is noted

concerning activities characterized as dangerous. ORDINANCE No. 1,885 OF 02 DECEMBER 2013 brought new regulations characterizing Activities and dangerous operations with exposure to robberies or other types of physical violence in professional activities of personal or property security, such as dangerous activities, such as:

> ORDINANCE No. 1,885 OF DECEMBER 2, 2013 (DOU of 12/03/2013 - Section 1 - page 102) Approves Annex 3 - Hazardous activities and operations with exposure to robbery or other types of physical violence in professional activities personal or property security - of Regulatory Standard No. 16 - Activities and dangerous operations. THE MINISTER OF STATE FOR LABOR AND EMPLOYMENT, in the exercise of the powers conferred upon it by item II of the sole paragraph of art. 87 of the Federal Constitution and articles 155 and 200 of the Consolidation of Labor Laws - CLT, approved by Decree-Law No. 5,452 of May 1, 1943, resolves:
> Art. 1 Approve Annex 3 - Dangerous activities and operations with exposure to theft or other types of physical violence in professional personal security activities or patrimonial - of Regulatory Standard No. 16 - Activities and operations dangerous, with the wording contained in the Annex to this Ordinance.

Clearly, we can see that the aforementioned standard has been undergoing changes according to changes that have occurred in the labor scenario and social context since its creation in 1978. One of the major changes that began to receive a more critical look was the activities carried out in dam areas. It is clear that after the significant number of breaking of these structures, a critical look was turned to this type of activity, through stricter legislation and greater public authority involvement in monitoring these structures. The fact is that to ensure greater security in order to avoid new ruptures, mining companies have been acting strongly with preventive and corrective measures, and behind this effort, we come across thousands of workers with this mission, many of sometimes in lands of “mine” fields. The existence of measures adopted after the tragedies that occurred demonstrates the fragility of these structures and the absence of mechanisms capable of eliminating these workers from the risk zone.

The decharacterization of dangerousness can only be done through the preparation of technical report, which must necessarily be prepared by an occupational physician or occupational safety engineer, taking into account the neutralization/elimination of existing risk condition. Every day, several activities are carried out in the area of dams, and despite the safety level of these structures having increased in the face of events occurred, there is no means of completely eliminating the exposure of workers in activities

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monitoring, control, maintenance, etc., of these areas.

As provided for in art. 193 of the CLT, activities or operations are considered dangerous, in accordance with the regulations approved by the Ministry of Labor and Employment, those that, by their nature or working methods, imply a significant risk due to of permanent exposure of the worker, despite the same standard referring to what the activities classified as dangerous, in view of all the above, it is clear that possibility of a new inclusion of activities carried out in dam areas as dangerous activities, as occurred in the activities of security guards, which began to integrate into this category, the activities of dams in view of the history and their assumption of a new vision about this possibility.

6.3 Criteria and Parameters for Characterization

Given this possibility, it is necessary to establish criteria for the aforementioned characterization. In light of article 193 of the CLT, as well as provided in the regulatory standard NR 16, we verified possible systematic criteria and parameters for the aforementioned characterization, let's see:

> Art. 193. “Dangerous activities or operations are considered, in the form of regulations approved by the Ministry of Labor and Employment, those that, by their nature or working methods, imply a significant risk due to permanent exposure of the worker”.

Two points are worth highlighting in the caput of Art. 193, namely: **Accentuated risk** x **Permanent exhibition.** These two pillars are clearly the criteria as well as parameters for a possible characterization. Given a series of measures implemented After tragedies involving collapse, mining companies are increasingly seeking, even if slowly, to remove workers from the danger zone, or spot zone as they call it.

Law 12,334/2010, which established the National Dam Safety Policy, defined obligations and procedures to be followed to ensure compliance with standards of dam safety, in order to reduce the possibility of accidents and their consequences. The regulations and safety standards to be met vary depending on the category of risk and potential damage associated with the dam in the event of a rupture, thus requiring its classification, which is also a requirement for verifying its classification within the scope of the Law.

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Figure 08: Risk level classification of Vale mining dams

Source: Vale 2020.

In this sense, in an attempt to characterize the danger of these activities, it is necessary to check the level of risk to which these structures fit as well as the time of exposure, mode and type of activities carried out by these workers. To this end, it is a joint analysis of the dam regulatory bodies is necessary, as well as a technical analysis by experts, with the aim of classifying the activities carried out as dangerous.

7 FINAL CONSIDERATIONS

Activity in iron ore tailings dams, despite their criticality, passed gaining notoriety after the disasters that occurred at the Fundão and Brumadinho dams.

After these events, the legislation dealing with these activities became more strict as well as inspections, and what can be seen is the need to implement preventive or corrective measures in existing structures. Various activities are carried out daily, and in the face of these activities developed the presence of several professionals is something common and constant.

Critically analyzing the institute of dangerousness, this deals with the quality of what is dangerous or harmful to life. Labor laws indicate that the professional has the right to extra remuneration, due to the high risk he takes to develop his work activities, thus being a way of compensating for the risk to life and integrity worker's physics.

Although regulatory standard NR 16 through Annex V does not characterize

dam activities as dangerous, it is clear when drawing a parallel between the provisions of art. 193 of the CLT regarding the characterization, as well as the risk that this activity represents. Just as happened with the property surveillance activities that in 2012 began to to integrate the list of dangerous activities, nothing prevents us from seeing the activities of dams like that are dangerous and can cause harm to the lives of those exposed daily.

In fact, safety measures at dams are becoming increasingly effective, but they have a risk management and control role, but in most cases they do not eliminates workers from the exposure radius, and this can be seen in a wide range of activities carried out in these structures, whether for preventive or corrective purposes.

Finally, for a possible characterization, it is first necessary to include this activity in the list provided in NR 16, as well as a criterion for characterization. Two pillars are fundamental to the feat, and it is worth highlighting these two points in the caput of Art. 193, being them: *Accentuated risk vs. permanent exposure.* These two pillars are clearly the criteria as well as parameters for possible characterization.

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