The deficiencies of the emergency action planning for dams in Brazil

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Abstract

The Emergency Action Planning for Dams (EAP) is an instrument of the National Dam Safety Policy, by legal imposition. Brazilian law, regarding the content of the EAP is in accordance with international guidelines on the subject, requiring a number of strategies, actions and procedures, based on scenario studies that minimize or neutralize the impacts caused by the breach of a dam. The EAP fails, however, when it does not prescribe adequate control mechanisms of such content. Confidence in the righteousness of the entrepreneur, or his fear of a sanction, may charge a high price in case of accident or disaster with avoidable human, economic and environmental losses.
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1 Introduction

Engineering was not yet able to develop a technique that ensures full security to dams and maybe it never will. There are variables related to the project and foundations, to the used material and to the speed or filling conditions that, individually or conjunctly, make immunity to risk an unrealizable wish. This does not mean that it is not possible to develop careful projects and effective controls on the stages of execution and of loading that significantly reduce the possibilities of occurrence (JANSEN, 1980). The economic logic that leads to the reduction of costs, either by the selection of projects with outdated or uncertified technology, or by the selection of inferior materials or the hiring of skilled labor, however, is the cause of a significant number of dam breaches (VEESAERT; CARDIA; TSUZUKI, 2005).

Reducing the risk of breaching, by adopting good engineering practices ranging from the project to the maintenance of structures, going through its execution, is the duty of the entrepreneur. As it is not always possible to fully ensure that an event will not happen, two measures should be adopted. Firstly, there should exist a strict security control system executed by the means of auscultation and visual monitoring instruments. Secondly, there should be a reliable emergency plan based on realistic studies of scenarios with dam breach and a flood map that consider the possible extent - not only probable – of the social, economic and environmental impacts generated by the wave and the material released by the event (VEESAERT; CARDIA; TSUZUKI, 2005, p. 5).

The plan, periodically revised, should also contain the establishment of procedures that enable fast communication to potentially affected population and the evacuation of the area, so that there are no victims or at least that their number is reduced (ALMEIDA; VISEU, 1997). It seems obvious, although the obvious is not always observed, that projects cannot be ordered nor the definition and implementation of safety actions should be entrusted to technicians without expertise in the

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subject or with little experience in the field (VEESAERT; CARDIA; TSUZUKI, 2005, p. 4).

Dam safety was inserted in the Brazilian political agenda only in this century, though it was already a subject of discussion among engineering and geotechnics professionals in the 1980s (FRANCO, 2008). The first federal law that was dedicated to this subject was promulgated on 20 September 2010, Law No. 12.334 (BRASIL, 2010), and it has been regulated two years later. This legislative neglect deserves a more dedicated study. In this study, however, efforts will be made to the legal examination of one of the instruments of the Dam Safety Plan, provided in that Law: the Emergency Action Plan (EAP), and with a larger cut to the structures employed for the containment of mining waste. A review of the literature on the subject will be made with the comparative and critical analysis of the Brazilian legislation, focusing on tailings dam.

2 Dam, risk and associated potential damage

Law No. 12.334/2010, a late product of international and domestic concerns about dam safety, established the National Dam Safety Policy (PNSB) and created the National Dam Safety Information System (SNISB). According to this law, "dam" should be understood as any structure on a permanent or temporary watercourse for containment purposes or accumulation of liquid substances or mixtures of liquids and solids, including the impoundment and the associated structures (BRASIL, 2012, Art. 2, I)[1].

Such structures should be classified by the inspection agents by risk category, for associated potential damage and for their volume. The classification per risk category in high, medium or low takes into account structural and functional aspects of the dam, its technical characteristics, its condition and the compliance with the Dam Safety Plan[2]. Regarding the classification per category of associated potential damage, also in high, medium or low, it considers the potential of loss of human life and the economic, social and environmental impacts resulting from dam breach[3]. There is also the classification regarding their volume[4]. The general classification criteria were entrusted to the National Council of Water Resources (CNRH) to establish (BRASIL, 2010, Art. 7, §§ 1 and 2), which occurred with the CNRH Resolution No. 143/2012 (BRASIL, 2012a).

According to the Resolution, dams must be classified in every five years by the supervisory agencies, taking advantage of the information provided by the entrepreneur himself. If the entrepreneur, however, does not provide the information, even on certain criteria specified in the ordinances, the supervisory agency should apply to him the maximum score for all criteria or for the missing ones (BRASIL, 2012a, Art. 4, § 3, Art. 5, § 4). In the case of tailings dam, the entrepreneur is the responsible for registering it, even if it is under construction or disabled, in the system of the Annual Mining Report - RAL, available on

1 The Law did not include in its normative framework the massifs lower than 15 meters, reservoirs lower than 3,000,000 m³ and the ones with the category of low associated potential damage, in economic, social, environmental or loss of human life terms (BRASIL, 2010 Art. 1, sole paragraph). Exclusion is problematic because a large percentage of incidents with fatalities is due to structures that are not included in its normativity (FRANCO, 2008).

2 Besides complementary technical criteria set by supervisory agencies, these should be taken into account: a) the technical characteristics such as height of the impoundment, crowning length, material and construction time, type of foundation and recurrence time of the flow of the spillway design; b) the condition of the dam, the reliability of the overflowing and collection structures, lock, percolation, deformations and consolidations, and deterioration of slopes; c) the security plan to discuss the existence of project documentation, the organizational structure and qualification of the technical staff of dam safety, the procedures for safety inspections and for monitoring, operational rule of the dam discharge devices and safety inspection reports with analysis and interpretation (BRASIL, 2012a, Art. 4).

3 Criteria to be used for the classification regarding the potential damage associated with the affected area are the existence of: a) downstream population with potential loss of human lives; b) housing units or urban or communitarian equipment; c) infrastructure or services; d) existence of essential public services equipment; e) existence of protected areas defined in legislation; f) nature of the waste or deposited waste; and g) volume (BRASIL, 2012a, Art. 5).

4 For the classification regarding the volume of the reservoir for disposal of mineral and/or industrial waste, it is considered: a) too small: reservoir with total volume lower than or exceeding 500 thousand cubic meters; b) small: reservoir with total volume exceeding 500 thousand and lower than or equal to 5 million cubic meters; c) medium: reservoir with total volume exceeding 5 million cubic meters and lower than or equal to 25 million cubic meters; d) large: reservoir with total volume exceeding 25 million and lower than or equal to 50 million cubic meters; and e) very large: reservoir with total volume exceeding 50 million cubic meters (BRASIL, 2012a, Art. 6).

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the website of the DNPM (BRASIL, 2012b, Art 3). According to the Ordinance DNPM 416, the DNPM "may, at any time and with proper justification, ask the entrepreneur to rectify his registration in the referred system." (BRASIL, 2012b, Art. 4, § 1).

Here is a delicate issue of the normative discipline, for it is guided in the self-declaration of the entrepreneurial on the conditions of dam safety. It is assumed that the supervisory agencies will inspect the veracity and technical relevance of the information provided in order to validate or rectify them. In practice, it is not what happens. It lacks technicians and techniques to do it.

3 The emergency action plan

Even if precaution is taken in the project, construction and monitoring of a dam, there is always room for an accident or a disaster to happen. This possibility has led governments and international organizations to demand, each one with the power that they have, from the *jus cogens* to the persuasive appeal, that those responsible for dams must have a plan for dealing with emergency situations. In the United States, where this subject has occupied the political agenda, especially since the late 1970s, the lack of an emergency plan compromises the planning of a construction or enterprise, and may lead to its embargo (ESTADOS UNIDOS, 2004). The requirements of a plan that presents clear elements of planning, coordination and responsibility in relation to contingencies of a disaster also makes up the normative repertoire of several countries since at least the 1990s (COLLISCHONN; TUCCI, 1997).

There are several documents and norms that prescribe the minimum content of such a plan. The Bureau of Reclamation (1999), for example, recommends that a number of contingency procedures should be adopted for a hypothetical breach of the dam that can ensure, if the event becomes real, the smallest impact on the environment, economy and people. It is essential, therefore, that studies of the various possible scenarios be conducted, including the most onerous ones, evaluating the time in which the flood wave caused by the breach could reach the flood-prone areas. The number of people at risk for each scenario should be estimated by using empirical equations to calculate the probable number of fatalities, as well as should be established an efficient dam alert system and the uncertainties of the event should be assessed, including the ones of the estimates (BUREAU OF RECLAMATION, 1999).

Law No. 12.334/2010, in this line, established as a tool of the National Dam Safety Policy, the Dam Safety Plan that, among various requirements, requires the entrepreneur to elaborate an Emergency Action Plan[5]. Except for dams classified as high associated potential damage, the Law entrusted the supervisory agency with the extension of the obligation to other associated potential damage levels and according to the risk category of structures (BRASIL, 2010, Arts. 6, II.; 8, VII, 11). Since there are various supervisory agencies[6], it is common that there is incidence of more than one ordinance or regulation of the same dam.

In the case of mining, for example, there will be the discipline of the environmental licensing agency and of the DNPM, and only one or both may require the completion of the emergency action plan, according to their risk and damage frameworks. The ordinance of the mining autarky does not establish other requirements in addition to the high associated potential damage, although it admits the hypothesis that it could be formally requested by it (BRASIL, 2013, Art. 4), it can be assumed that to other levels of damage and risk categories. The ordinance does not expressly say that nor it is known that it had required it excluding the case of the DPA.

The EAP, although it is a technical document, should be written in a way of allowing an easy understanding of those who read it. Its elaboration is a task of the entrepreneur, who must entrust it with engineers or engineering firms with domain and experience in dam safety which must

5 The Brazilian legislator was inspired by the recommendations of the Federal Emergency Management Agency (FEMA) and of the Federal Energy Regulatory Commission (FERC): UEMURA 2009.

6 According to Art. 5 of Law No. 12.334/2010, supervisory agencies, without loss of the supervision actions of environmental agencies that are members of the National Environment System (Sisnama) are: I - the entity that bestowed the right to use of the water resources, observed the area of the body of water, when the object is of accumulation of water, except for the purpose of hydroelectric use; II – the one which bestowed or authorized the use of the hydraulic potential, in the case of preponderant use for the purpose of hydroelectric generation; III - the bestower of mining rights for the purpose of final or temporary disposal of waste; and IV - the entity that provided the environmental license for installation and operation for disposal purposes of industrial waste (BRASIL, 2010).

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have experts in hydrology, hydraulics, geotechnics and monitoring dams (SILVEIRA; MACHADO, 2005). The legislation requires that the technician responsible for the elaboration of the plan must be registered at the Regional Council of Engineering and Agronomy - CREA, with professional assignments for the project or construction or operation or maintenance of dams compatible with those defined by the Federal Council of Engineering, Architecture and Agronomy - CONFEA (BRASIL, 2013, Art. 13). This is a way of ensuring adequate technical knowledge and responsibility.

The plan must establish the actions to be performed in an emergency situation, including preventive and corrective procedures, in addition to dissemination and warning to potentially affected communities (BRASIL, 2010, Art. 12; 2013, Art. 3). It is necessary that the plan contains information related to both its assumptions of prevention, as to the procedures for its implementation. The assumptions of prevention refer, on the one hand, to the guarantees of the reliability of the dam structure and its monitoring by means of appropriate equipment and instruments; and on the other hand, to studies of possible scenarios in the case of spillage of large flows. There still should be included an adequate system of advertisement of the plan and training of employees, communities and civil servants involved.

The instrumentation of technical auscultation of the dam, and especially the study of scenarios, establish the rescue operation areas and the mitigation of impacts in case something wrong happens. This action makes up the procedures of implementation, through the clear allocation of responsibilities and decision-making, of communication and warning of the potentially affected, of articulation with the government, especially with civil defense, as well as of removal of humans, animals, equipment and materials at risk, by appropriate means of transport (SILVEIRA; MACHADO, 2005).

The Brazilian legislation has incorporated these recommendations. In the case of the Tailings Dam Emergency Action Plan (PAEBM), it should be composed by, at least: a) general information about the dam on its content, associated structures, location and access; b) general responsibilities (of the entrepreneur; of the supervisor and his substitute, formally designated, trained and qualified to coordinate emergency actions; for notification, evacuation, continuity and closure of emergencies); c) criteria and detection tools, evaluation and classification of emergency situations, assigning a security team to perform them; d) preventive and corrective procedures to be adopted in emergency situations; e) analysis of the study of scenarios including the possible downstream impacts, resulting from a hypothetical dam breach, with its associated map of georeferenced scenarios; f) strategy and means of fast and effective dissemination and warning for the potentially affected communities in an emergency situation and for the competent authorities, and it should always contain a flowchart and the notification procedures with phones, when appropriate, of the competent authorities. (BRASIL, 2013, Art. 6) [7].

The clear definition of the strategies that should be adopted, including by the means of the alert system to the potentially affected population, and the geographic or spatial availability of resources that can be used opportunely to prevent or reduce as far as possible the economic, environmental and human losses, as well as a practical scheme of evacuation of downstream inhabited areas, with assignment of the respective responsible and the chaining of actions, are essential to the success of an emergency plan.

The effectiveness of the plan, if needed to be used, is still dependent on a study of the scenarios, able to adequately characterize the possible occurrences due to a possible dam breach. The analyzed scenarios and the study's methods should be included in the PAEBM, as well as the map of scenarios which comprises the georeferenced geographical demarcation of the potentially affected areas by the possible associated scenarios. (BRASIL, 2013, Art. 2, XII and XIII).

But none of this will work if the document is not publicized and if a network of integration is not created with the government, and especially with the organs of civil defense so that timely

7 In its annexes and appendices, the training records of the EAP state: description of the available means and resources to be used in emergency situations, such as materials, equipment and tools, their location and how to obtain them; declaration form of start and closure of the emergency situation. In the case of Risk 1, it must contain the copy of the Regular Safety Inspection Extract of the Dam, which detected the emergency situation; when in Risk 2, the copy of the Special Safety Inspection Extract of the Dam, which extinguished or controlled the anomaly, containing, in any case, the emergency event's closure report. They must also contain the PAEBM update control form and the list of the competent authorities that received the PAEBM with the respective protocols (BRASIL, 2013).

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rescue measures are taken. The Brazilian legislation, attentive to this matter, requires that, in addition to being inserted into the PSBM (volume V), available to the authorities, physical copies of the plan must be delivered to the affected prefectures and the municipal and state civil defenses, as well as a digital copy for the CENAD through the electronic website of the referred Center[8]. These copies should be available, also included to public consultation, in the referred locations and in the entrepreneur's office at the dam, and if an office does not exist, in the beneficiation plant, in the mine office, in the regional or entrepreneur's headquarters, whichever is closer to the dam (BRASIL, 2012b, Art. 8, § 1; 2013 Arts. 7, § 2, and 8). When the authorities request clarification on the content of the PAEBM, according to the Ordinance DNPM, the entrepreneurs should provide additional information (BRASIL, 2013, Art. 7, caput and § 2). Two observations should be made on this matter.

The first one is that the list of authorities to whom the plan should be submitted is not limited only to those mentioned. The Ordinance DNPM 526/2013 seems to leave it open to the entrepreneur to choose to which other authorities the plan should be sent: "The PAEBM must contain in its annexes the list of public authorities that will receive a copy of the Plan" (BRASIL, 2013, Art. 7, § 3). The wording is ambiguous. In fact, any competent authority may require a physical or digital copy of the plan, as well as require additional information. Law No. 12.334/2010 obliges the forwarding to the competent authorities. The Ordinance only exemplifies and does not specify who is competent to automatically receive, or by request, the EAP (BRASIL, 2010, Art. 11, sole paragraph).

The second observation has to do with this statement. If the Ordinance of the DNPM gives the authorities the power to require clarification, it can be assumed that, minimally, these authorities should assess the appropriateness of the measures contained therein. The studies and scenario maps should be analyzed with due care so as to identify eventual incompleteness or inconsistencies. This is not about a merely formal control but a meritorious one. In fact, it would not be necessary that the police power was prescribed there, for it is the result of general safety obligation imposed on the Government and, in particular, of the licenses of the activity, both environmental and mining.

The normative wording seems to exclude these authorities both in the automatic reception of the PAEBM, and in its analysis, however it is a habit. Whoever grants or licenses an environmental activity and that is socially impactful should ensure that the risks and damage do not happen or, once happened, should produce the lower potential human, environmental and economic losses. The silence of the literalness does not deprive them from the responsibility by omission. It is better, then, that they have the initiative of demanding the delivery of the plan and that they conduct an appropriate examination of its contents.

Not only the organs of civil defense should analyze the plan. They do it - or should do it - regarding the adequacy of the measures of warning and alarms, rescue and evacuation, but they do not have structure nor allocation for the examination of the EAP assumptions, such as the general conditions of the structure and of the scenario studies. This is a task that must be performed by the federal and state competent organs, including the DNPM in the case of tailings dams or ore residue.

4 Review and training of the EAP

The formal and material integrity of the plan requires the contemporaneity of its content and the knowledge of all involved, from the employees of the entrepreneur to the public servants in charge of analyzing it or implementing its actions, when necessary, and of course, the possible affected by an accident or disaster. The plan must therefore contain the formal designation of a coordinator and his substitute, trained and qualified to coordinate the procedures described therein, as well as the establishment of frequent internal training on preventive and corrective actions, keeping records of these activities. The plan should also contain all the technical information necessary so that the organs of civil defense promote training and emergency simulations, together with the prefectures. When formally requested, the entrepreneur must act in conjunction with such organs or entities to carry out the training and simulations.

8 After the delivery of the PAEBM to the authorities, according to the Ordinance DNPM, the respective receipt protocols should be filed as Annexes and Appendices of the PAEBM. (BRASIL, 2013, Art. 7, § 4). It is a preventive measure of responsibility, including and especially for the entrepreneur.

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The knowledge of the plan content is intensified by the event simulations, an opportunity that serves to test the diagnosis itself and established emergency measures. There are several exercises and training forums suggested in the literature. In the United States, the Federal Emergency Management Agency - FEMA provides two large groups of exercises: one, oriented to discussion; other, of a more operational nature. In the first group are included seminars, workshops, tabletop exercises or TTX and games, seeking to bring together the company's employees, consultants and public authorities in order to know and to give them the knowledge of the responsibilities and procedures established in the plan. In a game, operations are simulated involving two or more teams in an environment, generally competitive, making use of the rules, procedures and information to describe a real or hypothetical situation and test, validate or revise what is established in the plan.

In the second group are the drills, the functional and the full-scale exercises. The drills involve a trivial emergency simulation procedure or of little expression, so, for example, to validate procedures, to practice or to maintain abilities, to evaluate the effectiveness of existing media in the plan and to refine methods and processes. The functional exercise aims at evaluating the skills and the degree of effectiveness of tasks involving groups or various functions, primarily of the people performing tasks regarding management, direction, command and control, trying to improve their coordination and response skills. The activities are conducted in real time and in a real environment, therefore under tension, although the movement of personnel and equipment is normally simulated. Finally, the full-scale exercise involves various agencies, organizations and competences in order to evaluate the multiple aspects and activities described in the plan, particularly at the operational level. The activities, including the mobilization of people and equipment, are usually conducted in real time and in a tense environment as close as possible of a real situation (ESTADOS UNIDOS, 2013).

These exercises and training, both possible and necessary, must involve the downstream community, as well as those responsible for other dams. The release date and time can also be made by the main local media (SILVEIRA; MACHADO, 2005).

The dam may undergo changes over time, and it is likely that the social, economic and environmental conditions downstream of the dam may also undergo changes. It is necessary, therefore, that there is validity of the elaborated plans, requiring periodic reviews. In the case of tailings dam, for example, it is up to the entrepreneur to revise it: a) at the completion of each Dam Safety Periodic Review, as Art. 16 of the Ordinance DNPM 416, on 03 September 2012, by technical team described in Article 17 of that Ordinance; or b) whenever there is any change in the means and resources available to be used in emergencies. The plan review, obviously, implies in the updating of the study and map scenarios with proper reassessment of occupations downstream and of potential impacts associated with them.

5 Emergency situations

"Emergency situations" are those that resulting from adverse events may affect the safety of the dam and cause damage to its structural and operational integrity, to the preservation of life, to health, to property and to the environment. The Ordinance DNPM 526, regarding tailings dams, considers that an emergency situation is initiated whenever the security of the structure is potentially compromised or when there is a special inspection of the dam safety, by findings in periodic analysis, of anomalies that result in maximum score of ten points in any column of the Conservation Status table regarding the Risk Category of the Tailings Dam, according to the legislation[9] (BRASIL, 2013, Art. 15). Therefore, it is a critical situation or nearly so.

There are three emergency levels, according to the norm of the mining autarky: a) level 1 or state of readiness, in the event characterized by manageable adverse situation and by remediable structural problems; b) level 2 or state of alertness, defined by the not extinct adverse situation or uncontrolled and structural impairment not remedied. In this level it must be framed the dams that showed anomalies with maximum score of ten points, according to the risk calculation, whose interventions have not solved them; and c) level 3 or state of emergency: in cases where the structural dam safety has been severely and irreversibly affected, and the breaching is imminent or is already ongoing.

9 These parameters are established in Annex I of Resolution CNRH No. 143/2012 and in Annex IV of the Ordinance DNPM No. 416/2012 (BRASIL, 2012a and b).

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It is the duty of the coordinator of the emergency action plan, together with the security team of tailings dams, to identify, evaluate and classify the emergency situation, thus performing the actions described herein. Then, the coordinator must communicate the emergency situation to the local, state and national civil defenses and the DNPM, being himself at the disposal of the authorities for information and measures that they may deem necessary.

Regarding level 3 of emergency situations, the priority must be to immediately communicate the situation to the people who may potentially be affected, and to promptly remove them. In the self-rescue region, understood as the area downstream of the dam that does not allow a timely intervention by the competent authorities, it is the entrepreneur's duty to immediately inform the population through alert systems and warnings contained on the plan. Presumably, to meet the normative teleology, the established means are efficient enough to meet the need of rapidly spreading knowledge to the possible affected, according to the magnitude of the event. Hence the importance of the study and the map of scenarios to establish, with possible accuracy and the necessary seriousness, the developments that can happen with a possible dam breach, identifying the potentially affected areas and communities.

6 Study of scenarios and dam break

In the study of scenarios, it should be considered, within the line of possible causality and in technical and mathematical basis, the worst or more serious scenario. One has to assess, for example, if a dam built in the course of a tributary or in which it pours its body of water cannot have its reservoir spread across the main river, compromising the integrity of the drainage basin and the integrity of whom live in its shores; or if the disruption will cause a domino effect on other existing structures in the course of those rivers with the collapse of the entire system and the aggravation of the impacts of the flood wave. It should always be considered that the discharges and the resulting levels derived from the spill of the deposited material may be much higher than the natural maximum, reaching spaces and communities that would be safe from the historic river floods (MORRIS; GALLAND, 2000; COLLISCHONN; TUCCI, 1997, p. 191). The study of scenarios should follow four basic steps: a) preparation of the breach hydrograph, b) propagation of the flood wave, c) preparation of flood maps and d) elaboration of the emergency action plan or contingency plans (ICOLD, 1998).

The flood simulations are subjected to high uncertainty and inaccuracy levels, identified as sensitivity factors to the results, e.g., the cause of the breaching, the width and time of formation of the breach gap, the determination of the discharge of peak flow or the maximum discharge due to rupture (related to the height of the dam, the length of the crest, the type and volume of the waste or tailings), calculated in diverse forms (MORRIS; GALLAND, 2000); study of the hydrological and geological and geotechnical conditions; geometry of the sections of the river and the valley, roughness coefficient (Manning's n coefficient), material collected by the flood, mathematical representation of the dam and of the flood-prone areas and flow regime (ALMEIDA; FRANCO, 1994). The simulation of the formation of the gap can be made by various methods such as hydrograph of the estimated breach, predetermined evolution of the gap, evolution by simplified erosion and evolution by complete erosion, each one with its shortcomings and its own contexts of application (COLLISCHONN; TUCCI, 1997, p. 192).

To estimate the time for emptying the reservoir, simplified models of hydrograph can be used such as the simplified triangular and the parabolic (WALTHER, 2000). Therefore, there are also several approaches to determine the maximum flows, whose mistake or impropriety may result in a wrong definition of the flow rate of the waste and of the potential for flooding of downstream areas (MORRIS, GALLAND, 2000). There are several numerical models used for simulating the dam break wave such as the FLDWAV and the SMPBRK, developed by the National Weather Service of the United States, the DAMBRK, of the Boss International, the DWAF-DAMBRK, of South Africa, the MIKE 11, of Denmark, the FLORIS, of the ETH Zurich and the CLIV PLUS, of the Hydraulics Technology Center Foundation (UEMURA, 2009).

In general, it is customary to divide them into four groups: simplified models, hydrological models, one-dimensional hydrodynamic models

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and two-dimensional hydrodynamic models. The latter two are more used and the preference is for the one best suited to the dam conditions, topography and hydrography. If, for example, the downstream valley comprises a meaningful occupation and it is not a rugged terrain to the point of allowing a flow of the wave in the same direction of that imposed by the main bed of the watercourse, the one-dimensional simulation is adequate. For areas containing mainly floodplains and watercourses with abrupt transitions or with the presence of bridges or other hydraulic structures, the two-dimensional hydrodynamic models are more suitable (MORRIS; GALLAND, 2000).

The propagation of the hydrograph, in turn, is simulated by three main methods: shock fitting (calculation that takes into account the discontinuity between two or more sections that apply to the equations of Saint-Venant, located by area of primary and secondary shock), pseudo-viscosity (dissipates the shock on a greater region) and weak or conservative solutions of the equations of Saint-Venant or shock capturing or through computation (does not give special treatment to shock) (MACCHIONE; MORELLI, 2003). It matters little whether the approach is one or two-dimensional, because the equations of Saint-Venant, which form a system of partial differential of the first order, non-linear and of the hyperbolic type, in its complete form, do not admit analytical solution, being resolved by three distinct techniques, of the characteristics, of the finite difference and of the finite element (CHAUDHRY, 2008).

In practice, the dam break method has been frequently used, which takes advantage of "complete one-dimensional equations" of Saint-Venant, associated with the "equations of rapidly varied flow"[10], adopting the predetermined evolution of the gap, calculated by the formation time, final base width and shape of the gap. These are important elements for the simulation test: the water level of the reservoir, as well as the use of the hydrological method (the water line on the dam is considered horizontal, used to calculate a quota/area curve), for the hypothesis of slow formation of the gap, and of the hydrodynamic (the roughness coefficients are analyzed in each cross subsection wherein the reservoir is divided), when the formation is rapid or immediate (DRESSLER, 1954; FREAD, 1977; IERVOLINO et al., 2010). Propagation studies focus on the series of tributary flows, the records of natural floods and of extreme flows, taking several cross sections along the river to characterize the topography. One tries to predict the flood's profile, the time of arrival of the waves at different locations downstream and hydrographs in certain areas (SYLVESTRE; SYLVESTRE, 2002).

Such variation of analysis and technical assessment should be subjected to a strict control by the government. The supervisory agency has to rely on professionals able to examine the studies conducted by the entrepreneur and to point them corrections when necessary. The Brazilian legislation at this point is weak, for it does not create mechanisms that allow an accurate examination of EAP prepared by the entrepreneur. It is only a duty to deliver the document to some public authorities and to provide additional information. Everything will depend on a serious compliance policy and environmental safety of the entrepreneur or of his fear that the noncompliance with the norm, when occurring an accident or disaster, might be costly. This situation relies too much in the corporate self-control, which can cost human lives and economic and environmental damage, always tragic and, what is worse, avoidable.

7 Conclusions

The Emergency Action Plan (EAP) is an instrument of the National Dam Safety Policy, established by the Law No. 12.334/2010. According to the Law, it should be developed whenever the dam is classified as of associated high potential damage, entrusting the supervisory agencies, notably environmental and mining, with the establishment of additional obligation.

In the EAP, it should be listed the people responsible for its preparation and implementation; detection, evaluation, classification and treatment of emergency situations mechanisms; the scenario study analysis including the potential impacts downstream, resulting from a hypothetical dam breach, with its associated map of georeferenced

10 Where there are bridges, dams and waterfalls, the equations of Saint Venant do not apply. The empirical quota/discharge equations apply as the spillways equation. The hypercritical flow transition points of and to subcritical also cannot count on Saint Venant, and are evaluated by the flow equations in critical regime (p. 196). There is a frequent use for this purpose of the numerical model FLDWAV, developed by the National Weather Service, and of the software FLDAT (NWS Flood Wave Analysis Tool) (SYLVESTRE; SYLVESTRE, 2002).

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scenarios; as well as the dissemination and alertness tools to potentially affected communities and to the competent authorities.

The EAP is prepared by the entrepreneur and submitted to the government. The legislation is flawed at this point, since it establishes its sending only to the prefectures, civil defense agencies and CENAD, entrusting the entrepreneur, in the case of the Ordinance DNPM 526/2013, with the possibility of sending it to other public authorities. This flaw undermines the power of supervising the content of the EAP and a close examination of the provisions and applied technical calculations, and can rebound his ability of successfully confront emergency situations. The environmental agencies and the mining autarky should examine the assumptions and technical definitions, entrusting the prefectures and the civil defense with the examination of the adequacy of the proposed emergency measures. Nevertheless, none of this is done.

One trusts that the entrepreneur, in good faith or fear regarding the penalties that he may suffer by the noncompliance with the norms, especially in the case of a dam breaching, eventually meet the legal requirements. This belief, however, may charge a high price in human, environmental and economic losses.

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As deficiências do plano de ação emergencial das barragens no Brasil

Resumo

O Plano de Ação Emergencial (PAE) é instrumento da Política Nacional de Segurança de Barragem, por imposição legal. A legislação brasileira, no tocante ao conteúdo do PAE, está em sintonia com os parâmetros internacionais sobre o assunto, exigindo uma série de estratégias, ações e procedimentos, baseados em estudos de cenários, que minimizem ou neutralizem os impactos gerados pelo rompimento de uma barragem. É falha, porém, quando não prescreve mecanismos adequados de controle desse conteúdo. A confiança na boa fé do empreendedor, ou no seu temor da sanção, pode cobrar um preço alto em caso de acidente ou desastre com perdas humanas, econômicas e ambientais evitáveis.
Palavras-chave: Plano de Ação Emergencial. Segurança de barragem. Direito ao meio ambiente ecologicamente equilibrado.

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