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CONTINGENCY PLANNING FOR NUCLEAR PLANTS: AN APPROACH FOR USE IN INDUSTRIAL PLANTS AND HARZADOUS PRODUCTS STORAGE FACILITIES

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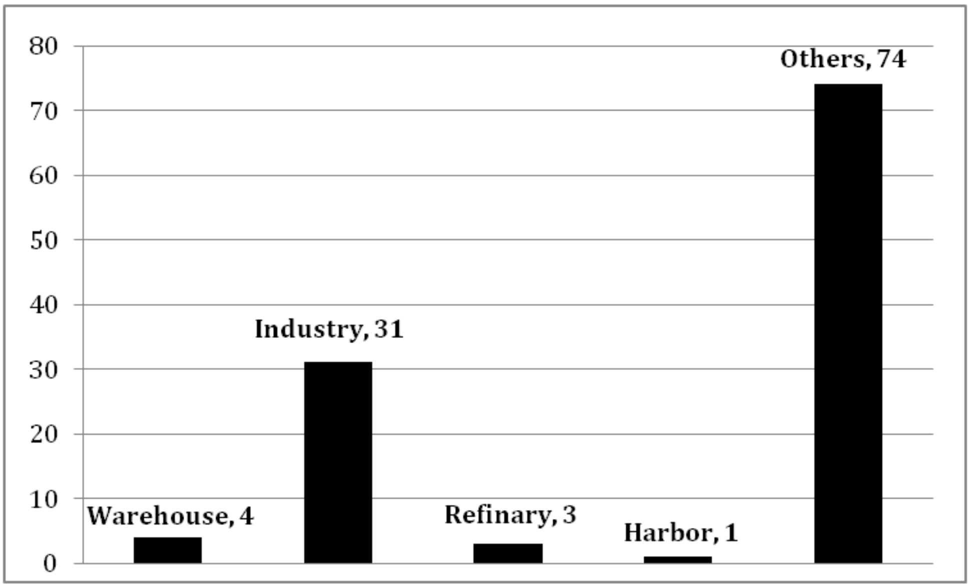
1. INTRODUCTION

When an earthquake stroke Lisbon in 1755, followed by a tsunami and a great fire, Marquis of Pombal implemented a framework to assist victims, tackle the fires that followed the quake, provide physical protection to heritage and disease control, among other actions. This pioneering coordination action was deployed during the emergency involving several actors within their jurisdiction, but without prior planning.

Population and income growth in modern society brought about a growing demand for industrial products with increasingly high-added technology as a result of the scientific and technological development leading to the advancement of industrial processes. These processes use, produce and store hazardous products, such as corrosive, toxic, flammable, radioactive or explosive chemicals. According to Veyret (2013), the main risk sources in an industrial plant are explosion, leakage with toxic chemicals release, or fire. This also applies to storage facilities. Picture 1 presents the absolute number of accidents involving hazardous products per area, according to Brasil (2014). In this picture, the column “Others” represents accidents involving pipelines, watercrafts, fuel stations, highways and others unspecified in the data source.



Picture 1: Absolute Number of Accidents with Hazardous Products per area in Brazil

Industrial development has, in fact, brought risks to society which added on to the risks arising from isolated natural phenomena or even those that can cause a technology-related accident. Veyret (2013) emphasizes that "*It is no longer only nature that engenders greater risk, it is first and foremost, science and technique"* (our translation).

Beck (2011) questions:

> How threats and risks that are systematically co-produced in the late modernization process can be avoided, minimized, dramatized, channeled and, when brought to light as latent side effects, be isolated and redistributed in such a way they do not undermine the modernization process or the boundaries of what is (ecologically, clinically, psychologically or socially) "acceptable"? (our translation).

For strategic and infrastructure reasons, industrial clusters and logistics companies that store hazardous products, hereinafter called facilities, have been set up near urban centers or became the agent of an uncontrolled population growth around them.

According to Piquet (1998),

> In theory, the city is the locus of industrial activity because, as an agglomeration of people it (…) presents itself as a consumer market at the same time it supplies the labor market". The author also points out that "large enterprises become attraction points to migrant labor, which inevitably leads to the appearance of so-called satellite towns or free cities (our translation).

This association between risks and population in a potentially affected area where, in most cases, the population is unaware of risks and protective actions, demands integrated actions from facilities, public authorities and community members so as to mitigate the effects of technological disasters.

It is the responsibility of facilities, agencies of protection and civil defense and other support agencies to draw up integrated contingency plans for the response and the protection of employees and the surrounding population in cases of an accident with potential to release harmful chemicals beyond facility boundaries.

According to Kletz (2013), the Bhopal accident in India involving methyl isocyanate leakage from a pesticide factory in December, 1984, *“revealed the need for companies to collaborate with local authorities and emergency services in drawing up plans to deal with the emergencies”*(our translation). Many of the facilities today have their own internal health and safety services to cope with fires and other emergency situations within their sites.

In Brazil, when accidents involving hazardous products release, the municipal government, through the Municipal Coordination of Civil Defense (COMDECS) is the first line of response in the disaster area, and they may receive additional support from the state and national spheres, as well from private organizations.

Therefore, it is necessary to organize a controlled and coordinated interaction through a Contingency Plan, which will establish the roles and responsibilities of each agent and also of the surrounding population in the effort to mitigate the effects caused by disasters.

The main goals of response actions should be restoring control of in-site situation, preventing and mitigating the consequences of the accident. The actions, whenever possible, must be planned to be triggered in a preventive and anticipatory manner, that is, in the threat prior to the accident. A worth mentioning concept is emphasized by the International Atomic Energy Agency (IAEA): a public action shall do more good than harm.

According to Veyret (2013), *"a zero risk does not exist, therefore risk management is mandatory”*(our translation). A Contingency Plan should define the structure of the organization, its procedures and the necessary resources for accident response.

For this reason, the purpose of this paper is establishing a basic system model for the development of contingency plans for emergencies. This includes the identification of agents involved in aid and assistance planning, pointing out communication chains among them, the delegation of action coordination and control, as well as the composition and structure of crisis centers equipped with physical and technological resources, the development of emergency procedures, the training of the teams involved, drill planning, and a policy for interactions with community members and the media in the course of a crisis.

This paper aims at proposing actions in case an emergency affects the surroundings areas to the accident site. The outlined propositions are not to be adopted only under nuclear or radiological emergencies, since Brazil has specific legislation for this purpose, as established in the Brazilian Nuclear Program Protection System (SIPRON), in addition to the structures and contingency plans currently implemented, validated and periodically tested.

2. RESPONSE ACTIONS ACCORDING TO EMERGENCY CHARACTERIZATION

Firstly, a Risk Analysis Study of the facility must be developed to identify, through various available tools, risk situations present at the facility, assessing their frequency and severity.

Thereon, potential scenarios with harmful product release to the environment can be drawn, considering its range and the most extreme weather conditions. Based on these estimates, an impact analysis for such scenarios should be conducted, in order to identify potentially exposed communities, with particular attention paid to the most vulnerable populations such as children, the elderly in nursing homes, inpatients that are not ready to be discharged, and inmates at prisons and police stations. Highways, railways, waterways, airways, rivers, lakes, lagoons, and the sea in the area may contribute to the expansion of the affected region.

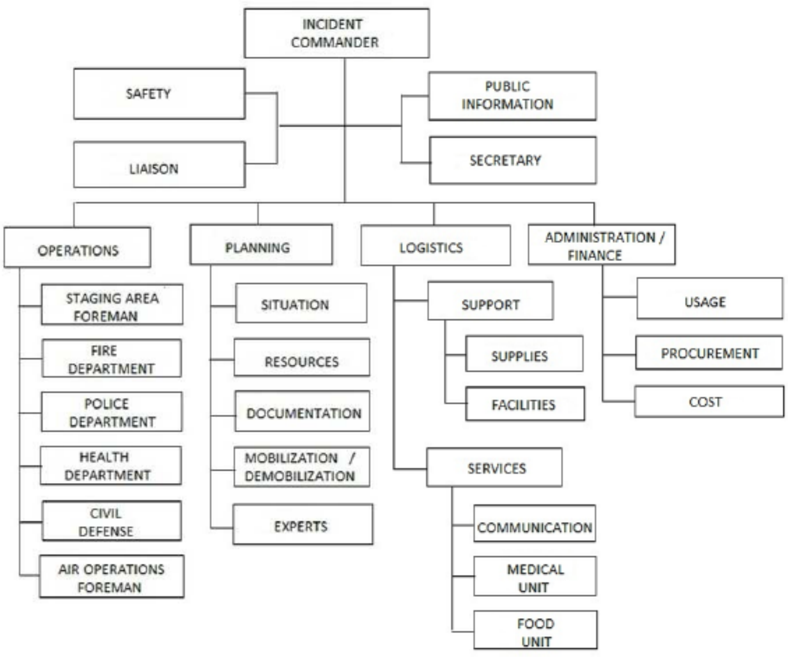
Based on the impacts listed in the risk study, response actions will be outlined in order to protect employees, the general public, the environment and, consequently, the personnel who will participate in the response, which may include, depending on the accident scenario, municipal, state and national civil defense, fire brigades, health services, military forces and road police, port captaincy and official environmental authorities, among others.

The contingency plan should establish different response actions depending on the emergency category declared by the facility, in compliance with its procedures. According to Oliveira (2010), "*it is critical to have a previously standardized, tested and trained system of coordination, command and control, favoring the better management of a critical situation*"(our translation).

The Incident Command System (ICS) is a management tool to standardize response actions and it is a good example of a system that has been developed and is adopted in Brazil and other countries.

Oliveira (2010) considers the ICS as a consistent and standardized model of disaster management system, to be employed in disasters of any source, size, configuration or complexity, which allows the three governmental spheres (federal, state and municipal) to act in an integrated manner, aligned with the private sector and non-governmental organizations.

The Picture 2 presents a standardized chart of ICS.



Picture 2: Standardized chart of ICS, extracted from Oliveira (2010)

3. PRESENTING A CONTINGENCY PLAN

The actions that are in charge of an accident condition facility must be contained in a procedure entitled Internal Contingency Plan (PCI), and external actions should be in another procedure entitled External Contingency Planning (PCE). In the model used at Almirante Álvaro Alberto Nuclear Power Station in Brazil, the utility the Eletrobras Eletronuclear S.A. has developed the Local Emergency Plan (PEL), which describes actions performed within the site. The Off-Site Emergency Plan of the State of Rio de Janeiro was developed to be used in case of a Nuclear Emergency within the premises of CNAAA Station, and it is available at http://www.defesacivil.angra.rj.gov.br/download/PEE_Final_Aprovado_24-01-2008.PDF.

Both PCI and PCE should be formal documents with revision and distribution control, and must contain basic requirements for their activation, implementation, training and simulation.

To prevent PCI from becoming too voluminous, the development of specific procedures at the facilities must be encouraged, detailing the actions for each department involved in the emergency, such as operations, maintenance, property security, industrial or medical safety, among other applicable ones, in accordance with the guidelines established in the PCI.

A similar routine must be adopted with regard to the recommended actions of the PCE, where the institutions involved must develop their own Complementary Contingency Plans (PCC) detailing their actions in response to an emergency within their scope of action.

In addition to the volume reduction of the plans, this systematic will facilitate the process of issuing and approving revisions to the improvement of the emergency response.

A collegiate composed of facility representatives and more response-oriented external organizations for the development of the PCE must be created.

4. BASIC CONTENT OF A CONTINGENCY PLAN

The contingency plan must define the following actions and features:

- Roles and responsibilities of response personnel;
- Complementary plans of the institutions involved;
- Notification and alarm system for the local population;
- Channel of communication with the media;
- Evacuation plans;
- Temporary shelters;
- Registering the local residents in the surrounding area;
- Medical and social assistance;
- Training and educational campaigns for the population;
- Training with drill exercises.

4.1 Identification and Categorization of Emergencies at the Facility

According to Veyret (2013), *"In regard to industrial risk, all possible risk sources and disruption scenarios must be identified and listed"* (our translation).

An industrial facility that handles hazardous products should have instrumentation and control networks with the purpose of providing operators with information on parameters (temperature, pressure, fluid flow, tank levels, chemicals concentrations, among others) arising from the various operational processes through indicators, recorders, controllers, logical, interlocks and alarms for the correct operation of the plant but also provide signals to actuate the safety systems.

Kletz (2013) points out that *"Only few accidents started with a sudden failure of a main component. Most of them were triggered by the failure of a smaller component, a damaged or uncalibrated instrument, an incorrect or poor procedure, or the failure to perform actions described in procedures or good engineering practices"* (our translation).

As aforementioned, a risk analysis study of a new facility or one already in operation is the starting point in the identification and categorization process for emergencies.

For plant processes and services, there are available tools for risk analysis with qualitative techniques, such as Hazard and Operability Studies (Hazop) and Preliminary Analysis of Hazards (APP) and *"What If",* amongst other techniques, will allow both the previous selection of the most appropriate course of actions and the estimation of the resources required.

The first steps for the definition of Emergency Action Levels (EAL) are the construction of scenarios and the postulation of possible accident triggers. An EAL is the combination of parameter values of the process with a defined operational condition of the facility. This can indicate an abnormal situation that may cause or contribute to an undesired release of hazardous material to the environment. Facilities may have different emergency categories depending on the EALs determined in the risk study.

Different response actions may also be established in the Contingency Plan for distinct categories. The categorization of emergencies should be incorporated into the operating procedures of the facility and operators should be trained in simulated during drill exercises, so that they are able to identify operational problems and categorize the emergencies appropriately.

A storage unit for hazardous products is generally much less complex than an industrial facility but it must also have sensors so that the emergencies are categorized according to parameter values and response actions are established.

It is worth mentioning that although a storage unit may be less complex than an industrial one, the potential risk of storage unit can by far exceed that of an industrial facility and, therefore, risk analysis studies and the preparation of a contingency plan are also required.

4.2. Assignment of off-site agents

Assigning a collegiate is an initiative that should come from the municipal government through the structure of the civil defense office, jointly with the facility management or the environmental regulator. In addition to the development of a PCE, the collegiate will be responsible for the initial approval of the plan and its subsequent reviews, which will be issued in order to include improvements. Distribution to the involved agencies should be kept under control as to ensure they all keep a copy of the most up-to-date review. According to Kletz (2013), *"A continuous auditing effort is needed to make sure that procedures are maintain"* (our translation).

Once response actions and the involved response personnel have been preliminarily established, the collegiate must assign an institution to coordinate such actions. As far as practicably possible, this institution should be tailored to respond to most emergencies that might occur in a plant at risk of hazardous substance releases. It must offer a minimum local structure and capacity to rapidly activate staff and readily deploy the necessary means defined in the PCE. Even when it comes to nuclear and radiological emergencies, the IAEA (2003) recommends full engagement of organizations in charge of conventional emergencies.

4.3. Internal and external coordination centers and response operations control

What would such center be called? Emergency Center or Crisis Center? For this purpose, the denomination of a command station for the development of response operations lacks a clear definition of what an emergency or a crisis is.

According to Forni (2013), *"The terms crisis and emergency have sometimes been used interchangeably, but they do not share the same meaning. An emergency involves the sudden interruption of normal operations due to failure, technical accident or even natural disasters "* (our translation). The author adds that:

> Crisis have a different severity potential. Whereas emergencies usually interrupt operations in a recoverable way, a crisis interrupts the system or interferes with normal activities, undermining the business and, in more severe cases, the survival of the organization (our translation).

Even more so, "one can even conceive an emergency with crisis inducing elements.

According to Couto & Soares (2013), crisis is a:

> Complex phenomenon with multiple possible sources, either internal or external to the country, which is characterized by a state of great tension, with high probability of aggravation — and the risk of serious consequences that cannot be clearly anticipated in the course of its evolution (our translation).

On the other hand, Oliveira (2010) describes an emergency as a situation that " *can be routinely serviced*" (our translation) and a critical situation as "*a scenario in which risk characteristics require, in addition to an immediate intervention of appropriately equipped skilled personnel, a non-routine organizational approach for the integrated management of response actions*" (our translation) .

As the purpose of this study is supporting facilities in their response to technology-related disasters, the effects of which go far beyond their boundaries, the term crisis center will be used.

The crisis center for coordination and emergency control must be located outside the expected range area for the worst threat, under the most unfavorable weather conditions, as close as possible to the technical center, equipped with dedicated resources of redundant communication, computers, appropriate infrastructure for long-term use, media accessibility and power supply autonomy.

This center should be coordinated by the member of the institution assigned by the PCE for this position, with decision-making power and ability.

The center must have a "crisis chamber" where the representatives of the institutions involved will gather. It must also be equipped with multimedia resources and reliable independent communication systems, in addition to a room where classified topics can be discussed and another one for the administrative support group.

4.4. Role and liability of the response personnel involved

PCE should establish, in a clear and unambiguous way, the roles and responsibilities of each agent. For the facility internal actions, the response line must classify the emergency, protect employees, service providers, and visitors, or even have them evacuated if necessary, and notify external agencies of the emergency classification.

Once the external response personnel have been engaged, they must set up the crisis center, support the facility in any demand that may arise, and perform the actions listed in the PCE with the purpose of notifying the population of the surrounding areas, protecting the population as well as their properties, installing temporary shelters if necessary, providing medical aid, setting up road, waterway and airway blocks wherever applicable, in addition to protecting the environment, among other actions aligned with the PCE.

As soon as external agencies have been activated, they must allocate response personnel and the necessary resources for the performance of their roles; their representative at the crisis center must be fully aware of his responsibilities, liability and capability for decision-making.

4.5 Setting up an information center

According to Forni (2013), communication management is one of the processes that integrates and permeates all stages of a crisis.

The information center must be set up, whenever possible, near the crisis center as to allow internal controlled interactions, functioning as a spokesperson, and keeping participants focused on emergency response operations.

Technological advancements in communications dictate that this information center is equipped with internet resources, radio, television, and videoconference receiving equipment, wire line and mobile telephone communication systems, as well as multimedia systems.

The information center must have at least two main environment: a reserved area where members can gather and communicate with both facility and the crisis center, enabling the elaboration of media releases; and another area designed for the interaction with the media and society representatives, which should be equipped with sound and multimedia systems, and wireless internet.

4.6. Communication with external response personnel

In order to put the PCE into practice at the facility when there is an ongoing emergency situation, there must be a plan for notification calls and to convene the response personnel that compose the crisis center. Independent communication means are necessary.

Due to the high personnel turnover in public offices, one must say that a successful call plan is reliant on an efficient systematics to keep contact files up-to-date. Files updating is the crisis center coordinator responsibility.

Frequent test calls must be carried out, some of which unannounced. Not all tests must necessarily require response personnel to move to their pre-established emergency response station. A record of the assistance time and response team transportation must be kept at all times. The crisis center coordinator must do an analysis result of each communication test in order to identify areas for improvement. Communication means must be compatible.

4.7 Facility internal communication systems

If a PCI emergency category occurs, and if it requires the performance of action by both facility staff and on-site service providers, plant personnel must be warned by an alarm sound system preferably composed by alarm tones and a voice channel for the broadcasting of specific messages which should be previously written and included in the procedures. The procedures must indicate the person responsible for message broadcasting. The sound alarm system must be exclusively used for emergency situations, while avoiding its use in any other type of institutional message. It should have a protective mechanism to keep it from being inappropriately activated by unauthorized personnel, and the activation should occur within a restricted access area. The system requires periodic tests in order to both verify its proper range and operability, and keep employees familiar with the emergency signals. A message indicating the performance of an emergency alarm test must be previously broadcast. This system must have an available redundancy, which can be operated from one or more vehicles equipped with sound systems with the same emergency tones, as well as a voice channel. All newly hired employees must be introduced to this system during their initial training.

4.8 Establishing an evacuation plan within the plant

In an emergency situation, as defined in the PCI, which requires facility evacuation by employees, service providers and visitors, it is necessary to identify escape routes and their signaling, meeting and boarding points for evacuation, as well as providing communication systems and transportation infrastructure to move people from the risk area to a safe rescue area.

Depending on the type of accident, certain escape routes listed in the PCI might be blocked, therefore alternative ones should be considered. In the event of an accident, the facility must assure that meeting and boarding points are safe. Meteorological data along with local or remote surveillance shall help deciding on the safety conditions of such areas. Similarly to the notification system, the meeting points should also be introduced to all newly hired employees during their initial training. Internal scheduled or unannounced evacuation drills should be planned and carried out.

4.9 Establishing an evacuation plan for the surrounding population

In an emergency situation, as defined in the PCE, which requires evacuation of the population from surrounding areas, it is necessary to identify escape routes and their signaling, meeting and boarding points for evacuation, as well as the aforementioned notification system and transportation infrastructure to move people from a risk area to a rescue area. Depending on the type of accident, certain escape routes listed in the contingency plan might be blocked, therefore alternative routes should be considered. In the event of an accident, the facility must assure that meeting and boarding points are safe. Meteorological data along with local or remote surveillance shall help deciding on the safety conditions of such areas. Similarly to the notification system, the meeting points should also be introduced to the local surrounding population, and evacuation drills must be scheduled.

4.10 Emergency training

For operators and other response teams that perform field tasks during an emergency, training on the specific procedures for emergency situations should be delivered on a frequent basis. Internal drills involving plant employees, including non-operational personnel (ie, maintenance and administration teams) must be based on likely scenarios and carried out on a yearly basis.

4.11 Developing drill scenarios

A drill scenario is an emergency operational condition or a sequence of conditions that are likely to occur and might put the facility, employees, local population, and the environment at risk. Even low probability scenarios must be contemplated in drills. In addition to the conditions indicated in item 4.1, external operational experience regarding accidents that occurred in similar facilities may be used in the development of scenarios. It is worth noting that the scenarios are not always going to be triggered at the plant and the emergency operational conditions for such drills will be tested through the messages exchanged between the operator and emergency teams.

Since the scope of this paper is proposing a contingency planning model aiming at emergencies involving release to external areas, drill scenarios should be designed to contemplate the external actions listed in the PCE, so that the involved institutions can develop their assistance capacity. In such scenarios, environmental, social, meteorological, and mobility adverse conditions must be drilled in order to introduce extreme conditions such as flooding, road blocks, power loss, telecommunication systems failure, among other adverse conditions, with the purpose of performing response actions. In such drills, the information center must be also involved in the elaboration of press releases and interaction with the press.

4.12 Awareness campaign for the surrounding population

In order to adopt a self-protective behavior, the surrounding population does not need to have deep technical knowledge on the threats posed by the facility. Local residents must trust the authorities in charge of the protective measures. The plan will indicate the communication means to be used from the facility/crisis center to the population, as well as the messages that will be broadcast, and the actions to be taken by the population according to the conveyed message. The promotion of periodic campaigns to raise awareness among local residents is at the discretion of one institution or a group of institutions involved in the plan. These campaigns may consist of lectures followed by the distribution of educational guides at schools, community centers, churches and clubs within the area that is likely to be affected.

5. CONCLUSION

The proposed model herein described for the elaboration of a contingency plan must be adapted for each situation according to the type of facility activity, its location, the conditions of the surrounding areas and preexistent local response structure for natural disasters and emergency situations. Nevertheless, some concepts must be met. The response actions described and the contingency plan are aimed at doing more good than harm to employees and local residents. The levels of emergency action, which are the triggers for contingency plans, must be precise because if, on one hand, they might trigger the plan with anticipatory actions, which is desirable, on the other hand they should not promote unnecessary actions that lead to peace disturbance or, even worse, bring panic to local residents. It is crucial that the involved response personnel interact with each other. Communication channels must keep information and the use of technology constantly up-to-date, including social medias. In the development of procedures and complementary plans, interaction will assure compliance with the PCE in such a way that there are no overlapping activities or gaps in response actions.

Meetings must be regularly carried out due to personnel turnover, especially in public offices, in order to maintain the standardization of knowledge. At each change of administration, in either state or municipal sphere, it is mandatory to carry out of a meeting with all actors with this purpose.

Interaction amongst local industrial facilities, even taking into account the distinct threats they pose, is desirable. If possible, they should integrate each other's plan with the purpose of helping with the contingency plan and estimating the impact on their own activity.

It is crucial to continuously train all involved response personnel, carrying out drills that mimic as closely as possible real potential conditions disturbing as minimally as possible local residents' routine. The community must be a partner of the plan, being aware of their role in it, and knowing that it is conceived for their own protection. Educational campaigns are key for such engagement.

If facilities give proper emphasis on preventive actions, the probability of a contingency plan being triggered is minimized. Nevertheless, human and material resources must always be ready and in conditions for prompt use whenever necessary.

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