Post-Emergency, Multi-Hazard Health Risk Assessment in Chemical Disasters
PEC

Deliverable D.E.1

Guidelines for Early Warning System

ECHO/SUB/2015-713844-PREV11 - PEC: Post-Emergency, multi-hazard health risk assessment in Chemical disasters
Project co-funded by ECHO - Humanitarian Aid and Civil Protection

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1 INTRODUCTION

An Early Warning System is a condition, system or series of procedures indicating a potential development or impending problem. In the framework of the Multi-Hazard risk assessment, the capability to set-up an adequate Early Warning System is crucial to allow controlling and minimizing the impact of accidental scenarios on population, environment and assets.

Based on the approaches, methodologies and innovations developed during the "Post-Emergency, Multi-Hazard Health Risk Assessment in Chemical Disasters – PEC" project, this report outlines the main principles to be applied in order to develop a suitable Early Warning System, according to the characteristics and criticalities of the area under analysis.

Although the report will mainly focus on the main aspects covered by the PEC project, the approach for developing an Early Warning System has been kept as general as possible, in order to widen the applicability of the obtained results and potentially achieve the widest dissemination of the results.

In order to work-out an Early Warning System the following steps should be carried out:

- Identification of Hazards and potential Consequences;
- Taxonomy of Hazards;
- Taxonomy of Consequences;
- Planning of actions.
- Conveying the messages to the general population

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2 HAZARDS

In order to develop an appropriate Early Warning System, an extended knowledge of the potential Hazards in the area of interest is crucial in order to allow identifying potential accidental scenarios. A proper Hazard identification shall be therefore carried out in advance allowing a comprehensive definition of the dangerous situations to be included in the Early Warning System.

In the framework of the "Post-Emergency, Multi-Hazard Health Risk Assessment in Chemical Disasters – PEC" project the following Hazard taxonomy has been proposed:

- Seismic hazards (detailed in Deliverable DA2, "Hazards identification for earthquake");
- Flooding hazards (detailed in Deliverable DA3, "Hazards identification for Floods");
- Man- made hazards (detailed in Deliverable DA3, "Man-Made hazards").

2.1 Hazards identification for earthquake

The seismic hazard of an area is, in probabilistic terms, the probability of occurrence of a certain severity of the shaking. This type of assessment therefore considers only the seismic characteristics of an area and assesses the ground shaking without considering the structures that insist on the territory.

The seismic hazard analyses have improved considerably in recent years due to the development of sophisticated computer codes, which, together with the multiplied capacity of calculation of the processors now available, make these evaluations possible in a very short time and thus enable to develop models with a high degree of complexity.

An ad hoc probabilistic seismic hazard should be undertaken in order to achieve a detailed understanding of the relevant hazards.

Standard approach of the probabilistic assessment of seismic hazard (Cornell, 1968) allows to use two different models of seismic hazard: the "Poisson" (i.e. the events are independent with each other and the release mode is constant in time) and the "characteristic" pattern (which is applied to seismogenic faults for which the release of energy through earthquakes of predetermined magnitude and return period is known).

In this type of analysis the input elements are: a seismogenetic model where each zone has a rate of seismicity, a catalog of earthquakes from which completeness intervals are defined, an attenuation relationship that gives the ground shaking as a function of magnitude and epicentral distance.

A well-established standard at international level for the estimation of the seismic hazard (SSHAC, 1997) based on a logical tree approach should be followed to consider all possible alternatives in the selection of models. The epistemic uncertainties in the estimates produced from the selection of each option are to be assessed. Particular attention is to be paid to the selection of the alternative source models, in order to take into consideration the most recent and reliable research results in the field of seismotectonic.

2.2 Hazards identification for Floods

A flood hazard analysis involves the assessment of the probabilities of flooding, as well as the consequences of flooding. Floods can be caused by a number of different mechanisms, such as extreme precipitation with high intensity and prolonged duration, snow melt, coastal floodings by extreme storms and wind set-up or tsunami, and dam breaches. For a proper hazards or risk analysis, the probabilities of these events should be estimated. Typically, this is done by observational data analysis, in combination with physical-based modelling.

2.3 Man-Made Hazards

When assessing loss of containment events from a process plant, scenarios of leakage derived by causes related to human action have to be taken into account. Human action plays a crucial role in this evaluation since usually most likely causes of loss of containment are the ones related to human action.

The causes of loss of containment related to human action/presence can be divided in four main categories:

a) **Errors in design, construction, maintenance**
   Potential errors in design, construction and other phases, such as normal operation, maintenance, etc., leading to hazardous scenarios as loss of containment are related to the human action since the cause of the loss of containment is related to wrong human action (error of operator during the design, wrong action during the construction or during maintenance, etc.).
b) **Not voluntary errors by plant operators**
   One of the most likely cause of loss of containment in industrial plant is the operator error during an action that requires operator intervention: in fact manned operations with respect to unmanned operations have largest probability of failure and need to be analyzed in order to prevent potential severe damages.
c) **Sabotage**
   Sabotage is defined as a deliberate action aimed at weakening a polity or corporation through subversion, obstruction, disruption or destruction. Regarding industrial plants, usually sabotage events are voluntary actions planned and acted in order to cause loss of containment, fire or explosion.
d) **Terrorism**
   In the last years the terrorism attacks phenomenon is increased due to the general world situation. Accidents in industrial plant caused by terroristic attack have to be taken into account when assessing all the potential causes of loss of containment.

2.3.1 Errors in design, construction, maintenance (A)

In order to assess events of loss of containment from process items random ruptures, statistical databases (such as OGP Risk Assessment Data Directory or similar) are generally taken into account. Statistical databases works out historical analysis of number of failures over an extended population of process items, thus allowing to define, with a probabilistic approach, potential causes and expected frequency of occurrence.

The frequency with which a random rupture may potentially occur can be calculated through the "parts count" exercise: the method involves counting items (valves, flanges, instrument connections, vessels and other equipment) for each representative section and multiplying the number of equipment parts with generic release frequency for each component, provided by the statistical database, to obtain the total release frequency.

2.3.2 Not voluntary errors by plant operators (B)

One of the most likely causes of loss of containment in industrial plant is the operator error during an action that requires operator intervention.
In order to assess this possible source of Hazard, tasks that require operator intervention should be defined and analysed. Task analysis can be carried out with a variety of human-factor techniques; a dedicated "What-If Analysis" can prove a solid although cheap analysis technique: the "What-If Analysis" consists in a brainstorming approach during which a group of experienced people familiar with the subject process ask questions or voice concerns about possible undesired events. The purpose of a What-If Analysis is to identify hazards, hazardous situations, or specific event sequences that could produce undesirable consequences. During the analysis possible abnormal situations are identified, together with their consequences, and existing safeguards, and then alternatives for risk reduction, where obvious improvement opportunities are identified or where Safeguards are judged to be inadequate, are suggested. The method can involve examination of possible deviations from the design, construction, modification, or operating intent. It requires a basic understanding of the process intention, along with the ability to mentally combine possible deviations from the design intent that could result in an incident.

Results of the analysis are provided in tabular form, and in addition to What-If Analysis also Top Event identification and definition has been performed. Top Event is the undesired event related to the identified hazard: depending on the results of What-If Analysis it is evaluated if the consequence (the answer to the question) can result in a undesired/hazardous event; if so, the event is listed as Top Event and it will be analyzed by means of Fault Tree Analysis in order to quantify the frequency of occurrence.

2.3.3 Sabotage and Terrorism (C)

In order to develop an analysis accounting for potential hazards deriving by terrorism and sabotage, a general overview of the historical and political situation of the area of interest and relevant country is required.
Focus of the overview is to highlight local potential unrests or riots as well as general threats from terrorism aimed at defining a credible list of threats:

- Electrical Power System Sabotage;
- Internal Communication System Sabotage;
- External Communication System Sabotage;
- Water System Sabotage;
- Bomb Attack;
- Discovery of an Improvised Explosive Device (IEDs);

- Vandalism;
- Theft;
- Intruders;
- Suicide Attacks;
- Hostage/Kidnapping;
- Armed/ Terrorist attack.

Each threat of previous list have been described and analyzed in the following paragraph.

Electrical Power System Sabotage

From its earliest days, the electric power industry has been able to provide, or rapidly restore, essential services during various types of natural emergencies. Recent international developments have created a heightened threat to the nation's infrastructure from terrorist attack, including the electric power supply system. It is also evident from the various attacks carried out by terrorists groups against power systems elsewhere in the world that many such groups consider electric power systems to be on their list of potential targets. Potential terrorist attacks against electric power systems may include:

- Sabotage;
- Physical assault;
- Disruption of sensors.
- Information systems and computer networks;
- Tampering with process safety;
- Disruption of fail-safe systems;
- Indirect attacks such as disruption of water, fuel, or key personnel.

Electric power transmission and distribution systems are susceptible to attack by saboteurs and terrorists. The electrical power is generated inside the perimeter of the Plant. Selecting points for attack and estimating the consequences are within the capability of technically trained individuals in the terrorist community.

Internal/External Communication System Sabotage

Attackers have a variety of options for breaking into an industrial facility's operations: a sabotage of the Communication System is one of the most diffused. Often, communication systems are connected to corporate systems, so commonly known Windows or server vulnerabilities can open a back door into the control rooms. Internal communication is protected by the station perimeter that is a restricted area. External communication is through buried cables and satellite dishes located inside the station perimeters that is a restricted area of the Plant. Moreover, external communication to corporate systems are firewalled.

Bomb Attack

A bomb is basically some type of casing or shell that contains explosive material. The casing can be anything from a steel-walled artillery shell to a glass bottle or a sealed-shut length of lead pipe. It can even be as ordinary as a coffee tin or an automobile. Once the casing is penetrated by the force of the explosion, it will fragment outward, each piece of the shell serving as a deadly projectile. The explosive material inside the shell could be any type of high explosive.

A bomb causes damage in several different ways, depending on the point at which the explosion impacts. These different points include:

- Blast wave: When a bomb explodes, the area around the explosion becomes over-pressurized, resulting in highly compressed air particles that travel faster than the speed of sound. This wave will dissipate over time and distance and will exist only for a matter of milliseconds. This initial blast wave inflicts the most damage. When this blast wave reaches a structure or person, two things will initially happen. First, the person will feel the force of the blast, which is the primary and initial impact of the shockwave. This will damage a structure or body on impact.
- Shockwaves: After a blast wave strikes a surface or body, high-velocity shockwaves, or stress waves, will continue to pass through in the body, they travel through the organs and tissues. Shockwaves carry energy through the medium they pass through; they're supersonic and transport more energy than sound waves. Currently, there are no effective ways to prevent shockwaves from passing through protective clothing, and in some cases protective measures may even amplify the destructive effects?
- Fragmentation: When the bomb explodes, the bomb casing, as well as any additional shrapnel (nails, screws or other items included in the bomb), will be violently thrown outward and away from the explosion. When these fragments strike buildings, concrete, masonry, glass and even people, they may fragment even further and cause even more damage. This is known as secondary fragmentation.
- Fire and heat: The explosion may also create a fireball and high temperatures, which will result in burns on a human body or even cause secondary fires or explosions, depending on whether any other fuel sources or flammable materials are located near the blast.
- Blast wind: At the explosion site, a vacuum is created by the rapid outward movement of the blast. This vacuum will almost immediately refill itself with the surrounding atmosphere. This creates a very strong pull on any nearby person or structural surface after the initial push effect of the blast has been delivered. As this void is refilled, it creates a high-intensity wind that causes fragmented objects, glass and debris to be drawn back in toward the source of the explosion.

Discovery of an Improvised Explosive Device (IEDs)

An improvised explosive device (IED) attack is the use of a “homemade” bomb and/or destructive device to destroy, incapacitate, harass, or distract. IEDs are used by criminals, vandals, terrorists, suicide bombers, and insurgents. Because they are improvised, IEDs can come in many forms, ranging from a small pipe bomb to a sophisticated device capable of causing massive damage and loss of life. IEDs can be carried or delivered in a vehicle; carried, placed, or thrown by a person; delivered in a package; or concealed on the roadside.

Vandalism

The intentional destruction of property is popularly referred to as vandalism. It includes behaviour such as breaking windows, slashing tires, spray painting a wall with graffiti, and destroying a computer system through the use of a computer virus.
In this environment, vandalism is a malicious act aimed to cause damages or destruction of critical components, devices or infrastructures of the facility, and may reflect personal. The recklessness of the act imputes both intent and malice.

Theft

A “thief” is person who dishonestly appropriates property belonging to another with the intention of permanently depriving the other of it; and “thief” and “steal” shall be construed accordingly. In this case, act of robbery and theft are intended as intentional actions aimed to the robbery of critical devices inside the facility.
Infiltrators can enter the facility only by land, with the aim of stealing material and/or damaging apparatus, compromising operability of the entire plant.

Intruders

The term “intruder” is referred to a person who is present in the system and that is doing business without any documents or identification device exposed or at least clearly visible.
The reason for the lack of identification can be due to various causes: loss of recognition device (ID badge or document legally recognized), lack of board staff, unauthorized access to restricted areas, and intrusion for the purpose of sabotage or criminal act).

Suicide Attacks

Terrorist organizations may organize acts aimed to reach the highest level of destruction and injuries in the facility proximities. Subversive groups can carry out attacks with explosives, possibly from portable missile launchers or transported by local drivers, on parts of the gas pipeline or against the company, with the result of causing fires, interrupting operations of the facility or the gas pipeline, interrupting any maintenance operations underway.

Hostage/Kidnapping

Possible threats can derive from terrorist action or protests, aimed at creating a significant psychological impact on public opinion in order to receive satisfaction for any claims/requests made or in order to raise awareness in society at large of the damage that man, globalization and in particular multinational companies cause to the environment; action could also be aimed at striking at symbols of capitalism and the western lifestyle in general.
Nationally based subversive groups could use action against sites to protest against current energy policies or against major projects undertaken by the current government or, more in general, the candidates chosen by a political party.
Finally, the intense media coverage given a significant incident at a site could also provide a kick-start to launch new subversive groups in search of publicity and support in non-parliamentary environments.

Armed / Terrorist Attack

Armed attacks are terrorist acts aimed to reach the highest level of destruction and injuries in the facility proximities. Activist/Local Groups occupy facility zones and/or block access to it, in order to block operations, obtain publicity and a response to any claims made.

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3 CONSEQUENCES

Identified Hazards may lead to the development of accidental scenarios potentially impacting people, environment and assets.

The sequence of the events developing from the initiating events to the final outcomes depends on a variety of parameters, including the source of the potential hazards, the potential for release of dangerous substance, the characteristics of the released substance (toxic, flammable, pyrophoric, etc.), boundary conditions etc.

The analysis of developing accidental events can be performed by means of Event Trees Analysis. A qualitative, generic Event Tree is proposed in the following **Figure 1**. A detailed explanation of each branch in the Event Tree is provided in the following.

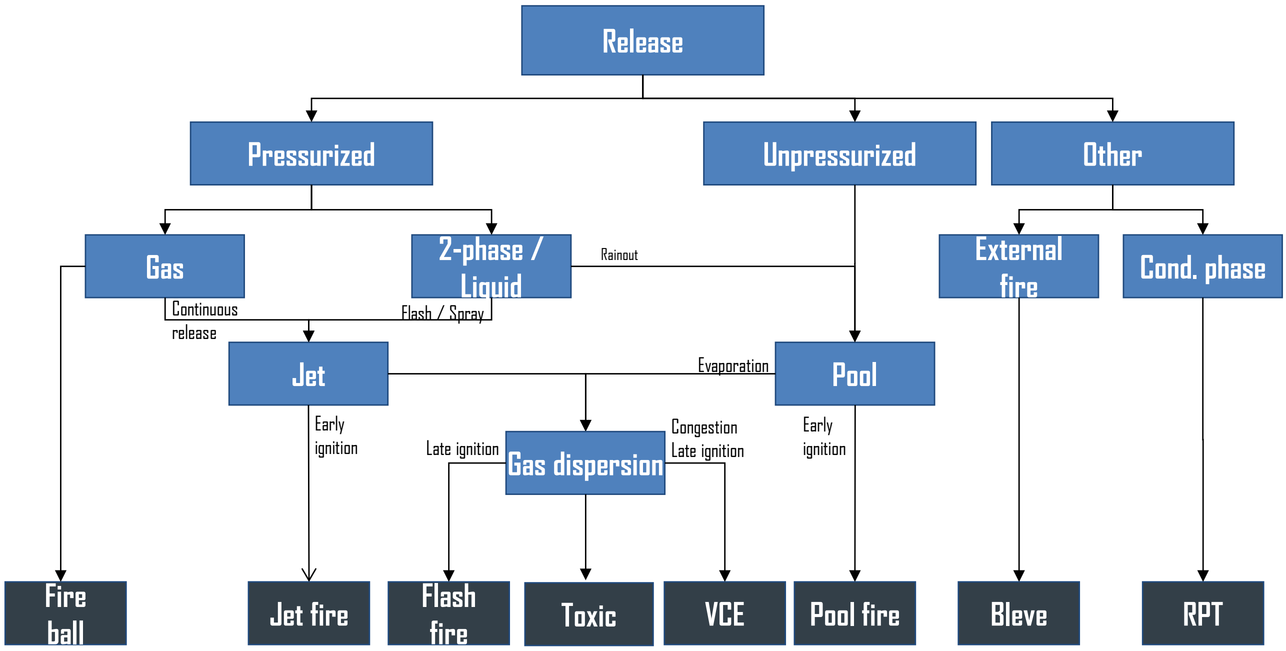

Figure 1: Generic Event tree

3.1 Taxonomy of the release

Pressurized release: this branch refers to the process/storage condition of the substance involved in the accidental scenario. If the substance is pressurized, relevant release will be driven by an initial momentum due to the difference in pressure between process/storage pressure and atmospheric pressure. The initial momentum may significantly impact on the evolution of the accidental scenario.

Unpressurized release: this branch refers to the process/storage condition of the substance involved in the accidental scenario. If the substance is not pressurized, relevant discharge will happen be gravity discharge; a lack of initial momentum is expected along with lower release rate.

Other release: this branch refers to specific events that may involve alternative accidental scenario development paths which do not fit in the Pressurized/Unpressurized branches. Two examples have been included in the generic Event Tree, although other possibilities exist based on the large variety of dangerous substances treated in the Chemical industry.

3.2 Released phase

With reference to the involved phase, the release may a **gas release**, a **2-phase release**, or a **liquid/solid** release.
Gases are characterized by the highest mobility and can quickly be dispersed in the environment; moreover, since the combustion reaction occurs in gas phase, relevant ignition is more probable than liquid or solid substance.
Liquids and solids tend to accumulate to the ground. If the initial momentum is high enough, a droplet/particle jet can be observed; settling time of the droplets/particles will depends upon relevant size. Liquids can flash or evaporate (based on the physical properties of the substance, process/storage conditions and ambient conditions) leading to the formation of gas phase.

3.3 Dispersion mechanism

With reference to the dispersion mechanism, the following events may occur:

- **Instantaneous release** of a large quantity of substance (leading, for example to a fireball);
- Momentum driven release, leading to the formation of a **Jet**. After the initial, momentum-driven phase, kinetic energy is dissipated due to friction with ambient air, and, if not ignited, jet release can lead to gas dispersion;
- Accumulation of liquid on the ground, leading to the formation of a **Pool**. Pool evaporation may lead, if not ignited, to gas dispersion of relevant vapors;
- **Dispersion of the gas** due to the action of wind and atmospheric turbulence.

3.4 Final outcomes

The following final outcomes are considered in the generic Event Tree provided in **Figure 1**:

- **Fire ball**: a fire, burning sufficiently rapidly for the burning mass to rise into the air as a cloud or ball. It is normally associated to the ignition of large amount of unmixed gas released instantaneously;
- **Jet fire**: the combustion of material emerging with significant momentum from an orifice;
- **Flash fire**: the combustion of a flammable vapor and air mixture in which flame passes through that mixture at less than sonic velocity, such that negligible damaging overpressure is generated;
- **Toxic dispersion**: dispersion of toxic material in the atmosphere;
- **Vapor Cloud Explosion (VCE)**: the explosion resulting from the ignition of a cloud of flammable vapor, gas, or mist in which flame speeds accelerate to sufficiently high velocities to produce significant overpressure;
- **Pool Fire**: turbulent diffusion fire burning above a horizontal pool of vaporizing fuel under conditions where the fuel has zero or very low initial momentum;

- **Boiling Liquid Expanding Vapor Explosion (BLEVE)**: explosion caused by the rupture of a vessel containing a pressurized liquid that has reached temperatures above its boiling point;
- **Rapid Phase Transition (RPT)**: phenomenon realized in cryogenic gas (e.g. liquefied natural gas - LNG) incidents in which the cryogenic gas vaporizes violently upon coming in contact with water.

3.5 Multi-Hazard contamination

Identified consequences can represent a further hazard for neighboring assets, potentially triggering additional events, characterized by more severe consequence.

Such an occurrence is generally referred to as a "Cascading effect".

Cascading effects may occur among scenarios belonging to the same hazard category, but multi-hazard contamination event chains are also possible (for example a man-made or a seismic event damaging a dam and causing a flooding due to the release of water contained in the basin).

Proper identification of the potential chain is also a key factor to allow working out a proper Early Warning System. Detailed approach to carry out the Multi-hazard contamination analysis is provided in Deliverable D.B.4 "Multi-Hazard contamination". Possible sequences of cascading events are identified through the application of an iterative approach (**Figure 2**).

The main steps of the methodology are detailed in the following:

- Initiating event refers to the root causes of the cascading sequences; all the initiating causes (Man Made, Seismic events and Flooding) should be included in the review;
- For each initiating event a list of potential consequences is identified and relevant type is attributed (e.g. fire event, structural damage, atmospheric dispersion etc.)
- If a new consequence type is identified, it is added to the list of "initiating event" to be reviewed for potential cascading effects (consequences);
- If the consequence type already exists in the list, relevant potential cascading sequences are already covered by the analysis; analysis is repeated for each potential consequence and for each initiating event.

An example of application of the methodology is provided in **Figure 3**.

Connectors represent potential cascading event sequences: for example, starting from a Man Made initiating event a Fire event can be configured; the cascading sequence can be further developed, moving to Structural damages, back to Fire event or to Environmental dispersion.
To ease the readability of the graph, connectors have been drawn with the same color of the relevant initiating cause.

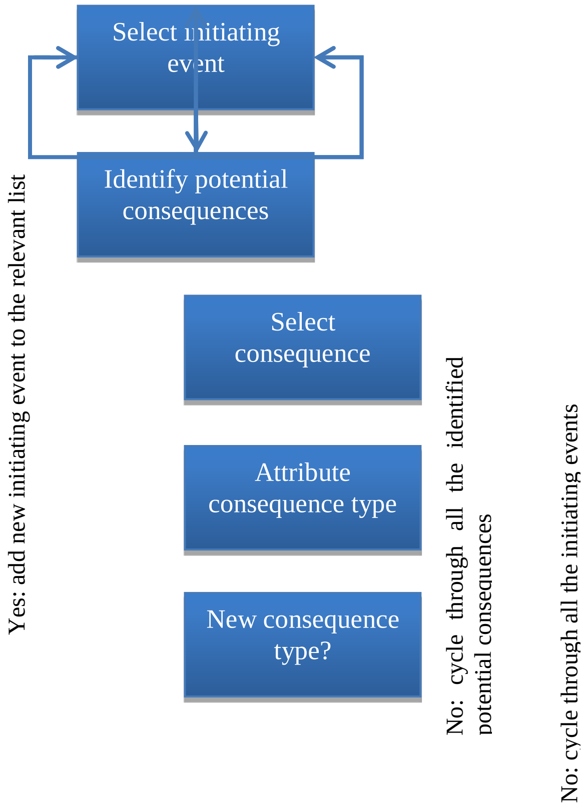

Figure 2: Workflow for potential cascading sequences identification

It is important to underline that the Map of potential cascading event sequences has been worked out as an example, considering Scenarios in the Plants included in the case studies of the "Post-Emergency, Multi-Hazard Health Risk Assessment in Chemical Disasters – PEC" project; as a consequence, alternative maps could be worked out for different scenarios through the application of the methodology detailed in **Figure 2**.

Identified connections between cascading events are defined as "potential": probability of escalation from one event to the following one depend on specific parameters which must be quantitatively assessed in order to provide a probabilistic assessment of each sequence (for example: probability of fire event depend on the type of release fluid, release rate, presence of ignition sources etc.).

Assessment of relevant probabilities is carried out in D.B.4 "Multi-Hazard contamination" by means of Dynamic Event Tree.

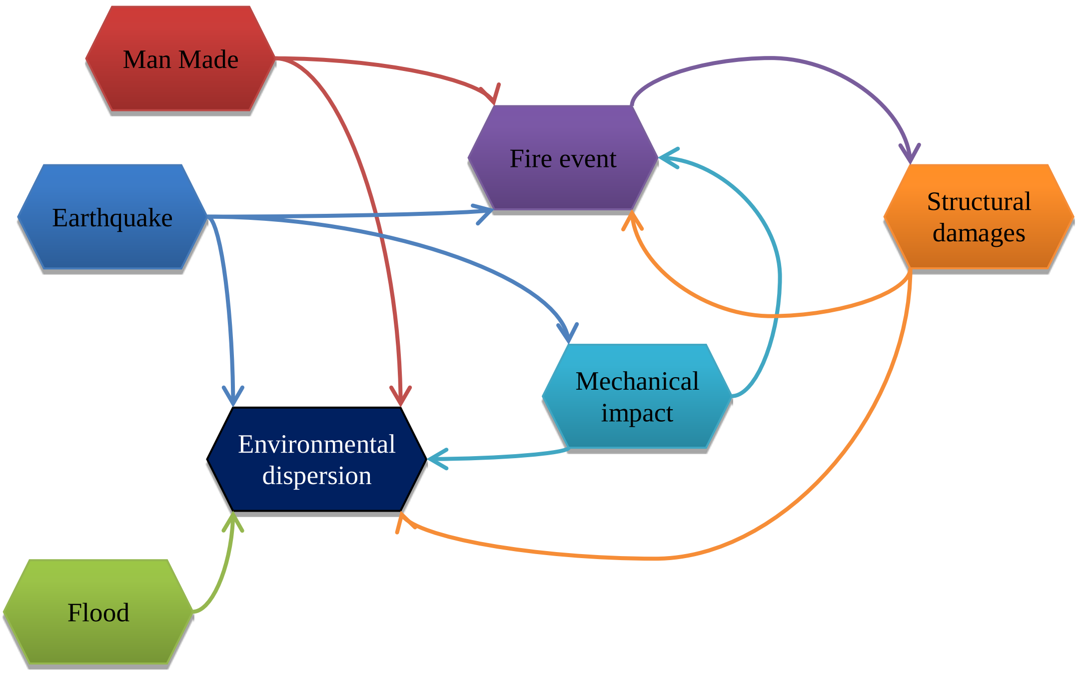

Figure 3: Map of potential cascading event sequences

4 HAZARD/CONSEQUENCE TAXONOMY FOR EARLY WARNING SYSTEM PREPARATION

The Hazard identification process and the Consequence assessment strongly depend upon the facilities under scope of work. Therefore, list of Hazards and Consequences provided in Chapters **Errore. L'origine riferimento non è stata trovata.** and 3 may results incomplete when applied to other projects, or some of the proposed items may be not applicable in other studies.

Providing guidelines for Early Warning System realization directly based on those lists could therefore lead to incomplete or over-redundant results. A taxonomy for both Hazards and Consequences classification is therefore proposed to allow the results worked out in the "Post-Emergency, Multi-Hazard Health Risk Assessment in Chemical Disasters – PEC" project to be extended to the widest range of potential application.

As far as the Hazard classification is concerned, the following taxonomy is suggested:

- **Predictable Hazard**: occurrence and timing of a specific event relevant to a Predictable Hazard can be foreseen with an elevated level of confidence by means of early warning signals or as a part of a planned activity. Examples of Predictable Hazards are: flooding due to an extended period of heavy raining, Hazardous situation during planned maintenance or activities etc.
- **Unpredictable Hazard**: Unpredictable Hazard can be identified and probabilistically characterized but occurrence and timing of a specific relevant event can not be foreseen with a sufficient level of confidence. Examples of Unpredictable Hazards are: seismic event (although the seismic risk of the area can be determined, it is not possible, at present, to anticipate an earthquake).

As far as the Consequence classification is concerned, the following taxonomy is suggested:

- **Immediate effect**: Immediate Effects cause impairment or damage since the very beginning of the event. Examples of Immediate Effects are: people hit by jet fire, structures exposed to earthquake etc.
- **Acute effect**: Acute Effects cause impairment or damage over a short period of time. Examples of Immediate Effects are: people exposed to thermal radiation or concentrated toxic gas, steel structures impinged by fire, etc.
- **Long-term effect**: Long-term Effects causes impairment or damage over an extended period of time. Typical examples of Long-term Effects are toxics accumulating in the human body and causing adverse health effect over time.

5 EARLY WARNING SYSTEM

5.1 Selection of actions

Actions to be planned in an Early Warning System depend upon the potential Hazards and Consequences to be faced during the emergency scenarios.

According to the taxonomies for Hazards and Consequences classification discussed in Chapter 4, a total of six different situations have been identified, as detailed in the following

Table 5.1: Early Warning System actions

		Consequences		
		Immediate effect	**Acute effect**	**Long-term effect**
Hazards	**Unpredictable**	Early Warning System not applicable. Relevant risk shall be managed at design level.	Exclusion zone to be set-up in the area of effect for the duration of the emergency scenario.	Monitoring campaign and remediation activities.
	Predictable	Set-up of a preventive exclusion zone for the duration of the emergency conditions. Consider process shut down.	Alert population. Preventive exclusion zone preparation. Consider process shut down.	Alert population. Preparation of Monitoring campaign and remediation activities.

The following actions are considered:

- **Exclusion zone**: dangerous area should be fenced and access to the area restricted to emergency response team. Main purpose of the Exclusion zone is limiting exposure of population to adverse health effect due to the emergency scenario. Set-up of the exclusion zone is particularly critical for those scenarios which are not self-revealing: flammable clouds or acute toxic gas clouds, for example, may not be directly sensed by the population, and the extent of the hazardous area should be defined using dedicated sensors. In order to provide an effective Early Warning System, adequate hardware should be foreseen based on the result of the risk assessment. Preventive exclusion zone can be set-up, based on information obtained from risk assessment in case of Predictable Hazards. Preventive set-up should be advisable for immediate effect (since such a scenario will not allow sufficient time after the occurrence); for acute effect allowing for a sufficient intervention time, preventive exclusion zone can be prepared but not made effective in advance, based on the associated risk level and expected impact on operability;
- **Monitoring campaign**: for long-term effects, the monitoring of key parameters is crucial to provide adequate response to the emergency. Assuming, for example, a massive release of

toxic with long-term effect on human health due to progressive accumulation, monitoring of toxic concentration allow defining restrictions to be applied to control the emergency (for example avoiding access to certain areas, avoiding herding in contaminated areas, etc.);

- **Remediation activities**: remediation activities are particularly viable for environmental damages. Contaminated areas should be re-instated by means of dedicated interventions, thus limiting the duration of the emergency scenario;
- **Population alert**: in case of Predictable Hazards, Early Warning could be in the form of Population alert. Focus of this activity should be to rise up awareness relevant to specific hazards and to suggest adequate strategies to avoid or limit the exposure;
- **Process shut-down**: in emergency situations characterized by an elevated risk ranking, preventive process shut-down could be advisable (if technically and economically feasible) in order to remove the potential source of risk for Predictable Hazards, for the duration of the identified enabling conditions.

5.2 Dissemination and communication

Effective early warnings have to be communicated and disseminated to people to ensure communities are warned in advance of impending hazardous events and to facilitate coordination and information exchange.

Proper coordination with local and (eventually) national authorities for Risk Management shall be ensured; local/national authorities shall be informed about potential hazards, relevant likelihood of occurrence and potential area of impact.

Coordination shall also achieve the definition of common actions to be timely activated in case of Early Warning.

Appropriate sources of issuing warnings and information should be identified and designated; the community is more likely to trust information from someone with a local knowledge of the area, rather than someone from a distant office who may not be as sensitive to the local needs.

Warnings may be prepared for presentation in several different formats – text, graphics, color-coded categories, audio – and should include specific actions for people to take to respond to the event. Different formats also make it easier for people with disabilities to receive and act on the warnings. All formats, however, must present the information accurately and consistently.

Dissemination is delivery of the warning messages, but communication is accomplished only after the information is received and understood. So the foundation of warning communication rests on the format and wording of the warnings, dissemination methods, education and preparedness of stakeholders, and their understanding of the risks they face.

Effective warning messages are short, concise, understandable, and actionable, answering the questions of "what?", "where?", "when?", "why?", and "how to respond?". They should also be consistent over time. Alert messages should be tailored to the specific need of intended users. The use of plain language in simple, short sentences or phrases enhances the user's understanding of the warning.

In addition, the most important information in the warning should be presented first, followed by supporting information. They should also include detailed information about the threat with recognizable or localized geographical references. Effective communication about risks and warnings requires knowledge about the recipients.

In most countries, the public is very diverse, with different backgrounds, experiences, perceptions, circumstances and priorities. Any attempts to communicate with the public must reflect this diversity. Concerns of the affected community have to be identified such that actions to protect their interest may be included in the warning messages.

There should be provisions for informing the users when the threat of hazards is over and emergency measures may be stepped down.

Communication means to meet the needs of individual communities must be put in place covering the entire affected population. These may include a variety of formats (text, graphics, audio) and a wide range of media as available (radio, telephone, Internet, pagers, sirens and visual warnings). Warnings should be disseminated over multiple channels to ensure minimum delay in delivery to the end users.

Furthermore, communication is also significantly enhanced when consistent warning information is received from multiple credible sources. Media broadcasts from local authorities and / or radio and television interviews with one or more authoritative figures can be effective in triggering response from people.

Warning communication channels should be made known to all recipients and should preferably be consistent across different types of warnings to minimize confusion or misunderstanding among users. The transmission of warning should be reliable and reception by intended users should be acknowledged. The ability to quickly adapt to emerging communication technology is becoming a key requirement. People expect to be notified about dangerous conditions on a variety of new platforms (smart phones, tablet mobile computers, etc.) via social networks, as well as older platforms (TV and radio). The popularity of platforms and social networks can change quickly, so the Early Warning System must be equally flexible in order to successfully reach as many people as possible.