Prerequisites of a NaTech event at a production gas well in Romania

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Abstract. This paper describes the need for NaTech risk approach in the extraction and transport activities involving potentially hazardous substances, such as natural gas. Considering the increasing trend in frquency of extreme natural phenomena, industrial facilities are becoming increasingly vulnerable. This makes the scientists focus on predicting such phenomena and on reducing the vulnerability of elements exposed to risk. There are many such international pursuits supporting the extended evaluation studies of NaTech risks, both during the activities performed on the industrial site but especially before their design. NaTech type events, already occuring in the natural gas extraction industry, are an undeniable argument in favour of repetition probability, especially in areas at risk to occurrence of natural phenomena (especially the instability of the land).
Key Words: NaTech risk, pipeline, landslide, natural gas.

Introduction. Natural disasters are wide-spread, geological and meteorological phenomena which usually occur unexpectedly (or slowly – like the drought) and have major consequences in the environment or population, in some cases requiring huge efforts to get through it (Young et al 2004).

When there are industrial sites in an area sensitive to natural disasters, NaTech risks (NAtural hazard triggering TECHnological disasters) may occur. One of the first studies referring to the link between natural and technological disasters was performed by Showalter & Myers (1992), although the frequency of NaTech disasters started to increase since 1980. They introduced the NaTech term to describe a technological disaster induced by a natural disaster. Later on Clerc & Le Claire (1994) made a classification of NaTech disasters and underlined the close connection between a natural and a technological disaster. They emphasized as well that chemical and radioactive substances added to a natural disaster may cause major negative effects on population and environment and may worsen the situation (Galderisi et al 2008).

There are more and more proves related to natural disasters which contributed to multiple and simultaneous industrial accidents, like, for instance, power failure in large areas, flooding caused by dams damage, accidental petroleum substances spills, gas emissions, fires or blow-outs which include harmful substances (petrochemical, pharmaceuticals, pesticides, etc.) stored in stable enclosures and from oil and gas transmission installations (Cruz & Steinberg 2006). As NaTech risks are very complex, they are very difficult to study. Usually the events generated by such risks have been analyzed separately and not as a joint disaster, as, in fact, they most often occur. It is pretty difficult to develop methods and procedures to assess NaTech events considering their complexity. As related to their complexity, it is the result of various hazard sources – natural and technological – which could have a major impact and which can act differently, simultaneously and in relatively short period of time (Galderisi et al 2008).The cumulative effect of such disasters may have important consequences on the population and environment, as well as economic consequence (Girgin & Krausmann 2013), especially for the communities that are not prepared for disasters of such magnitude (Ozunu et al 2011).

As compared to industrial accidents, NaTech accidents effects can be amplified by the following situations:

- safety and reduction measures that are not operational at an optimum level due to the natural event;
- spills of multiple simultaneous hazardous substances;

- the emergency response to hazardous substances spills is affected by the natural disaster, or the latter may amplify their effects;

- the recovery following the hazardous substances spills may be significantly slowed down by the impact of the natural disaster, or the recovery after the disaster may be slowed down even by such spills (Cruz 2012).

Therefore, the emergency preventive actions and planning are essential to NaTech type disaster prevention and to attenuation of their consequences. This is the reason why areas which are at risk to such type of accidents should be identified. Moreover, such risks should be systematically assessed by competent authorities (Girgin & Krausmann 2013).

Prerequisites for extending the NaTech risk assessment studies. During the last two decades the frequency and importance of NaTech disasters increased, and their important repercussions have an impact at local, regional or even international level (EEA Tehnical report 2010). Moreover, an increase of this type of disaster is foreseen due to increase of natural hazards frequency (Figure 1) as a result of climate change, of increased industrialization and due to increasing vulnerability of the society (Girgin & Krausmann 2013).

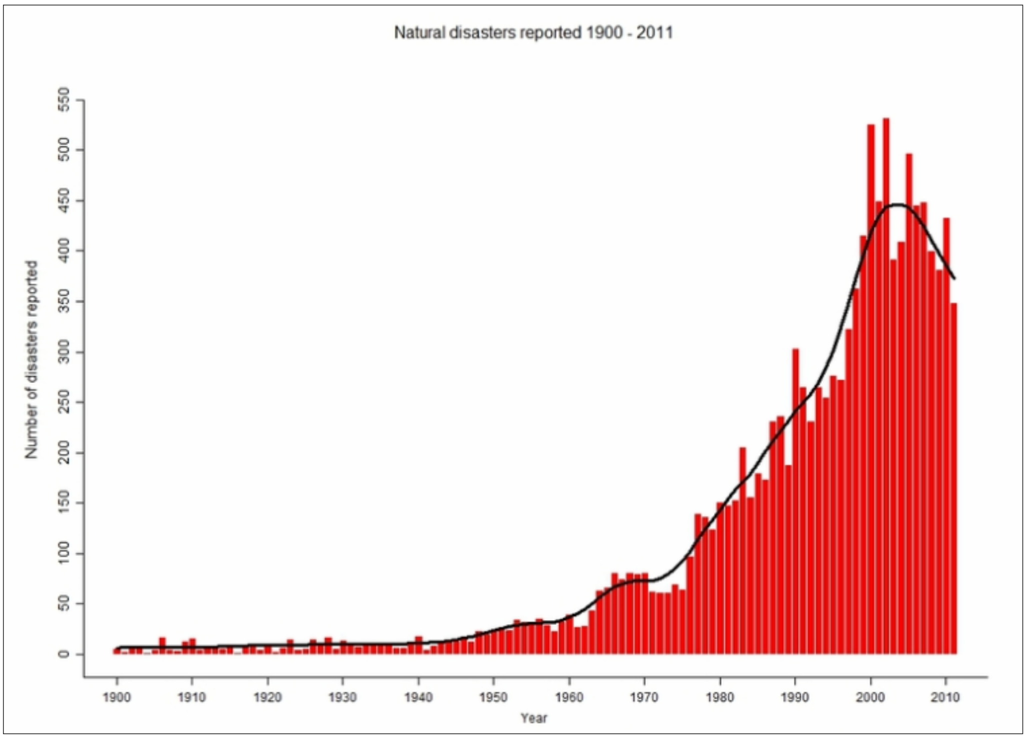

Figure 1. The number of worldwide natural disasters and their evolution between 1900-2011 (www.emdat.be).

Although the professional literature presents a great number of natural disasters which contributed to accidents involving hazardous substances, only during the last years they started to be treated as related events (Girgin & Krausmann 2013). A few recent examples of NaTech type are:

- 2002 – flooding in the Czech Republic causing 400 kg chloride spill from Spolana Chemical Works in Labe river from Neratovice, Prague;

- 2003 – Tokachi-oki, Japan, earthquake which initiated a major fire in an oil refinery, which resulted in major structural damages at 45 oil tanks of the refinery;

- 2004 – Sumatra earthquake and tsunami which caused the spill of 8000 m^3 of oil from the oil storage of Pertaminain Kreugn Raya Bay, Banda Aceh (Cruz & Okada 2008);

- 2005 – Katrina and Rita hurricanes in USA causing the spill of over 200 hazardous substances from industrial sites and over 400 oil and gas spills;

- 2011 – The Great East Japan earthquake and the tsunami it triggered caused the spill of hundreds of hazardous substances and oil and gas spills which resulted in many fires and blow-outs which, at their turn, created domino effects. Besides that, the natural risk action caused the most important nuclear accident in the history of Japan, which had a huge social and economic impact (Cruz 2012).

Considering the history of NaTech type accidents, their major impact and increasing frequency, the scientists are more and more focused on the attempt to forecast and analyze such type of disasters. Thus, many authors developed various NaTech risk assessment methodologies. For example, Cruz & Okada (2008) developed a qualitative Natech risk screening methodology at local level, while Girgin & Krausmann (2013) developed an index method regarding mainly NaTech risks at regional level or even national level. Girgin & Krausmann (2013) suggested a qualitative screening tool using a multi-criteria decision model. These studies offered as well a case study related to NaTech maps for individual and societal risk related to industrial sites, which have been obtained using an extended version of the ARIPAR software. Nevertheless, for the time being there is no consolidated methodology available for the assessment or mapping of NaTech risks. Recent studies show that no NaTech risk maps are available for the EU and the OECD member states. And where such maps are available, the NaTech risk maps are in fact simple overlaps of natural hazard maps and technological hazard maps, which do not consider the specific characteristics of the sites or the hazards interactions. Therefore, there is obvious the need of a mapping methodology for NaTech risks (Girgin & Krausmann 2013).

The natural gas and the NaTech risks. Once the global industrialization is increasing the resources demand, such as oil and gas, is increasing quickly (Zhang et al 2014). Currently the natural gas is one of the most important energy sources (Han & Weng 2011); its consumption exceeds 20% of the total energy consumption in the European Union (Ma et al 2013).

One of the most practical, economic and efficient method to transport hazardous and flammable substances like natural gas (for which railway or even road transportation is most of the time impossible) is by pipeline (Brito & Almeida 2009). Nevertheless, most of the time the pipeline gas leakage risk results in important consequences from many points of view.

Natural gas leakages from cracks or sectioning of the transmission pipeline or gas extraction pipeline can cause death, big economic losses and environment damages. Considering the inflammable, explosive and diffuse nature of the gas and of its constituents (like hydrogen sulphide, mercaptans, etc.) systematic or accidental release in air creates a hazardous situation, which could cause blow-outs and fires. The factors which have an important contribution to gas pipeline accidents are: external interference, erosion, technological defects and construction defects, natural disasters and other unknown causes (Batziasa et al 2011). Thus, when the area where a production well or a gas transmission pipeline is sensitive to landslide occurrence, the opportunity for NaTech risks occurrence has to be carefully monitored. Compared to other risks of disaster (like earthquakes of flooding) landslides can be foreseen, as their initiation is preceded by an increase in the stress state within the potentially sliding earth body, and the stress state can be assessed and monitored.

The safety of buried pipelines as related to instability phenomena like landslides draw particular attention lately. Due to land instability the pipeline is frequently deformed, which can result in local plastic collapse or deformations in critical areas.

NaTech accidents at buried pipes in landslide sensitive areas have been quite frequent lately (Zheng et al 2012). Like, for instance, the gas supply pipeline to Eregli Steel Factory from Turkey which was affected by a landslide close to Hendek. The landslide produced the pipeline sectioning which caused a fire that was extinguished only after 3 days (Yesilnacar & Topal 2005).

Another example is in Zhejiang, China, where between 2008–2009 two accidents of this type occurred. The first one in Yuyao town, where the maximum displacement was about 1.9 m. The affected part of the pipeline was,fortunately, detected and replaced in due course before any spill. The second accident was in Ningbo town where the pipeline blew out. Further inspection showed that the soil has accumulated on the hillside and the respective pipeline segment and the soil around it were significantly displaced during the landslide (Zheng et al 2012).

The NaTech type accidents probability in areas sensitive to landslides where transmission pipelines or production gathering pipelines are buried is especially high and more complex when such phenomena can be induced by other natural phenomena. Therefore, the analysis of NaTech risk generated by land instability is especially important for life, goods and environment safety. For maximum efficiency they should be performed before placing the industrial sites in areas that are subject to natural risk.

Case study: prerequisites of a NaTech risk event at a production gas well in Romania*.* Our study refers to a production gas well in Romania which was affected by a landslide. The scope of the study is to demonstrate that NaTech risk analysis has to be one of the main factors in achieving any industrial site from the design phase, so providing the conditions for a sustainable development. Moreover, these analyses should be periodically updated in order to take the required preventive measures to reduce significantly the possibility of occurrence of NaTech accidents during the operation at the site.

General overview. Strong gas emissions have been pointed out at a gas production well site of Romania, inside the site enclosure as well as behind the casing. Following the production casing integrity tests, by specific methods, it was found a deviation of the well casing. Therefore an assessment project was initiated. During the assessment works have been performed in order to remove the stress and it was found that both production casings were deteriorated down at 18 m. During the performance of these works a sliding plan was identified.

Following such events it was decided that a technological plan for reduction of the negative impact on the technological process and on the environment has to be applied. As the repair of the damaged casing did not pay the foreseen results, the initial well was abandoned and a new production well not affected by natural risks was drilledconcurrently. It should be mentioned that the lithological sequence of the stripped area included vegetable soil below which there are laminated, compact grey marls. Inside this bed a sliding plan was identified, a sliding that is very active, by a displacement of about 0.5 m/24h.

Considering the very high risk present during the performance of works, all preventive measures have been taken to avoid human accidents and fires.

After the well was declared abandoned the environment reclamation works have been performed, which included land leveling, coverage with fertile soil and remediation to the initial productive and ecological parameters.

NaTech risk assessment - geomorphological risk assessment. In order to identify the natural context of landslide, the risk source acting on the production well, as described above, we assessed the geomorphological risk in that area.

The achievement of risk maps is useful for application of preventive measures against possible disasters which could result from land sliding. Moreover, they can contribute significantly in making rational decisions on the site location, performance of drilling works, etc. without jeopardizing the slope stability. The importance of elaboration of risk maps on the slope stability derives from the fact that Romania has vast areas with high land sliding potential, areas that are overlapping with high seismic potential areas, which increases even more the risk. The risk of disasters produced by the landslides is sustained by the large number of economic and social objectives that frequently affected or threatened by this phenomenon.

Methodology. Geomorphological risk assessment in the analyzed area was based on a methodology which overlaps a number of environment layers using GIS software. In this case the involved layers are described by geology, contour lines, relief parameters (declivity, the depth of fragmentation, slope exposure), hydrographic network and its density, current geomorphological processes, use of land, etc.

After gathering the data base the score for every layer shall be established, according to the regulatory provisions in force and to the specific conditions of every areaunder study, in order to obtain geomorphological processes sensitivity indices, and based on which the geomorphological risk range will be established.

The calculation mentioned above is possible because the data are in raster format and the operations are performed at pixel level,with the size of 100 x 100 m, which allows for a real and punctual sizing of the phenomena.

Resulting values are centralized on a single map which provides a general assessment of the geomorphological potential, of the surface stability as related to natural equilibrium, and of the risk level involved by the business activity.

The probability maps for generation of geomorphological risk phenomena in the studied area were established in accordance with the regulation GT 019-98. "Guide for elaboration of slopes land sliding risk maps in order to secure stability of constructions."

The input data for elaboration of maps are lithological, geomorphological, structural, hydroclimatic, hydrogeological, seismic and anthroposilvan data.

The indices for calculation of coefficients were estimated according to the methodological guide.

Calculation formula for environment risk coefficient is the following:

$Km = K_n*K_b/6*(K_c+K_d+K_e+K_f+K_g)$, where:

K_a = lithological criterion, K_b = geomorphological criterion, K_c = structural criterion, K_d = hydrological and climatecriteria, K_e = hydrogeological criterion, K_f = seismic criterion, K_g = anthropogenous and sylvan criteria.

For the geomorphological criterion, in compliance with GT 019-98 regulation, the following have been considered: slope, display, depth of relief fragmentation.

Results and Discussion. Following the application of the above mentioned methodology the landslide potential map for the area of interest was generated (Figure 2), where the risk is presented from minimum to maximum.

As shown in Figure 2, the site where the production well is located corresponds to an area of average and very high probability of landslide generation. This is the reason why the instability processes were active in the area and affected the production well.

The results show the importance of elaboration, updating and consideration of geomorphological risk maps before locating the industrial sites, due to the possibility of NaTech risk occurrence.

Although the relief does not instantaneously react to the environmental changes, the geomorphological processes, once unleashed, represent a high destroying potential on long term with consequences mostly exceeding the intervention possibilities under technical-economical aspects. The probability of some risks experienced by the human society becomes a certainty once the geomorphological processes are unleashed

While locating a geomorphological risk, one can take into consideration the fact that the places where such phenomena were produced, are the first to be affected, even on the same areas and for the same causes. This does not mean that the relatively stable territories cannot by affected by geomorphological processes of risk. On the contrary, investigations should be carried out on such lands in order to prevent or limit such processes. The early identification of geomorphological processes and taking into account any sign in the field, followed by objective measures, are designed to prevent the decrease of the slope stability (Cioacă 2006).

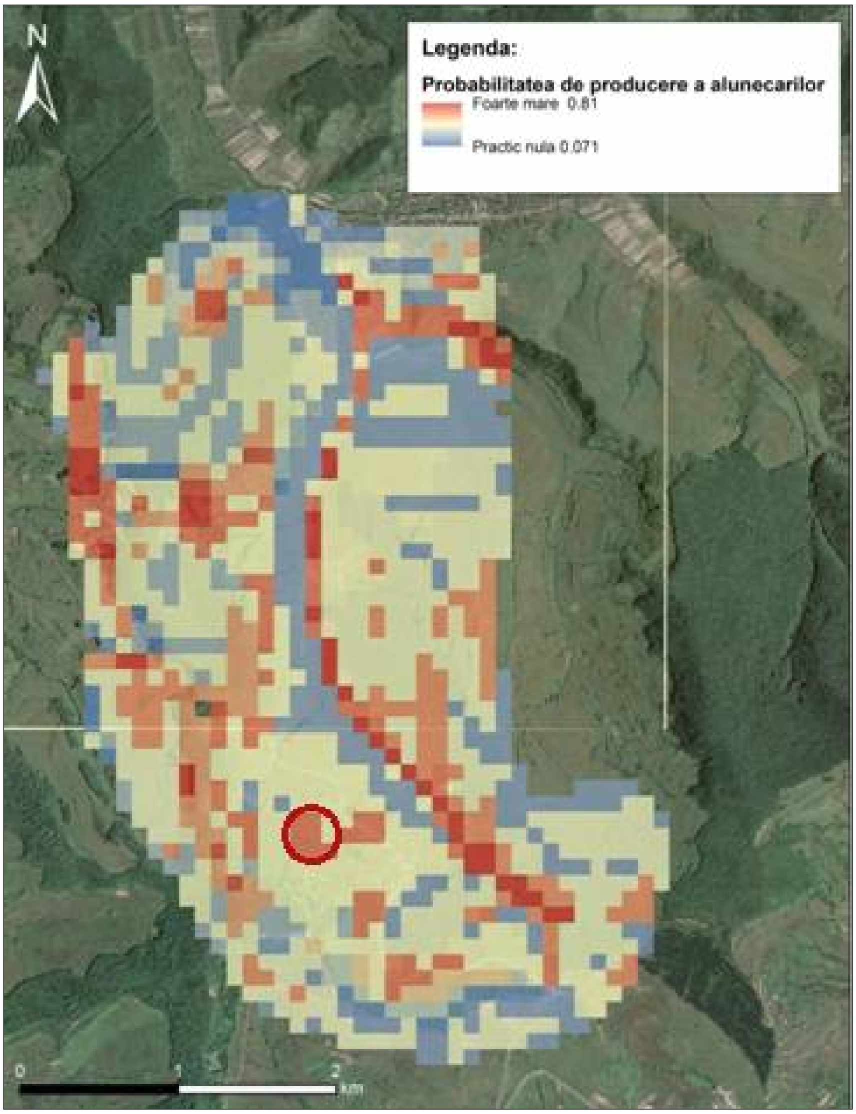

Figure 2. Landslide generation potential map for the area of interest.

Conclusions. This paper brings a noticeable contribution regarding the necessity for an integrated study of NaTech risk over an industrial site. In this case, the work refers to a production well for natural gas in Romania that is affected by a landslide.

The results of the analysis show that due to the location and the geological structure, the production well was significantly affected by the landslide. This situation could have been avoided if a regularly updated NaTech risk analysis had been existed. The absence of well-structured legislation on preventing and mitigating the NaTech risks may lead to such accidents, which is why the remedy of this gap is required.Moreover, it is important to refer to the “lessonslearned" from the accidents of this type, based on a library available for this purpose, and to initiate a sustained public awareness and information campaign about the risks and gravitygenerated by the NaTech accidents.

The NaTech risk assessment related to industrial risk in the area of natural gas production is a requirement given the current reality: more and more frequent natural phenomena, vulnerable production equipment and structures. This view is already proven by the already developed events.

The risk management within a company requires adequate management of all risks within the company, based on riskanalysis (the existence of a "Risk Register") and optimal decisions so as to reach a final control of them.

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