WHAT IS A WORST CASE SCENARIO FOR A POTENTIAL ACCIDENT
AND HOW CAN IT BE USED?

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Several concepts have been used to describe potential serious accidents in industrial activities. Examples of these concepts are worst case scenarios, likelier-but-less-catastrophic scenarios, most credible scenarios etc.

A worst case scenario is a sequence of events/actions/accidents for a certain place (site) and time which causes the worst magnitude of an accident. Often these kind of accidents are regarded as having very low probability so as a basis for planning likelier-but-less-catastrophic scenarios are used. Clear definitions as well as guidelines for developing these scenarios are lacking. The problem is of course to find the quantitative border between “worst” and “likelier-but-less-catastrophic”. If we should use worst case all the way out through an event tree, the calculated probabilities will be difficult to grasp especially when communicating the result to different stakeholders in the society. From research in risk communication, we know that people often are more afraid of risks with low probabilities but large consequences than more credible scenarios.

It is usually not clear who is the final user of the information received from accident scenario analysis. Is it an authority with responsibility for supervision, a municipality where the site is located, or 3rd parties affected by the increased risk? All these shareholders need different kind of information both in content and depth. That is something, what people, performing accident scenario analysis, should keep in their minds.

This paper will discuss several aspects and problems related to accident scenarios. Several different approaches to the definition of worst-case scenario exist in the scientific world. The first part of the paper is a systematization of the definitions.

We will also try to make an analysis of so called Seveso Reports taken from three Swedish companies. They are all written in different ways, which makes them more useful for our final aim. In the very end we will make an attempt to write a list of recommendations for accident scenario analysis which could be used in participatory processes where many stakeholders are involved.

Finally a serious question to discuss is what the worst-case scenario approach is most useful for. Is it just a static evaluation in the report or really valuable results (information) that can be applied somehow in the decision-making process?

KEYWORDS: accident scenario, worst case scenario, risk assessment, risk management, risk communication, decision making processes, safety reports

Risk and safety are important topics in many decision making processes in our society. For example industrial installations that handle substances harmful to humans and environment had to produce safety reports and present them for evaluation to state agencies and the public. The meaning of risk presentation done in safety reports is to reveal risks using reliable methods and to gather information for rational decision making including physical planning and risk management.

There is an idea that by doing risk assessment and producing safety reports it is possible to manage risks in a better way. Another belief is that the risk estimation is a reliable risk method because mathematical statistics are used. However, there are several difficulties connected to current use of these methods. One of the difficulties is uncertainties in the probabilities estimation calculated in quantitative risk assessment methods. Other difficulties include unclear guidelines for the worst possible event and consequences of an accident.

We do claim that the “worst case” approach should not involve any notion of probability. It should be based on the accumulation of worst case assumptions and yields; in theory, the maximum loss level. The chosen worst case and following worst loss should sufficiently support any democratic decision making process, for example spatial planning.

Another important demand on risk assessment and management today is that its results should be communicated to different stakeholders. The communication aspect is stressed because of recognized importance of public participation during decision making processes. The high level of acceptance mitigates future conflicts. The experience tells us that the overuse of quantitative risk assessment methods leads to communication difficulties rather than to communication clearness; the probability concept is difficult
Several concepts have been introduced to describe a potential serious accident development during industrial activities. Examples of these concepts are the worst case scenarios, likelier-but-less catastrophic scenarios, most credible scenarios, major accident scenario, etc. The worst case scenario should be a sequence of events/actions/accidents for a certain industrial site and time that causes the worst magnitude of an accident and consequences. These kind of accidents are often regarded as having very low probability so a basis for planning likelier-but-less catastrophic scenarios are used. Clear definitions as well as guidelines for developing these scenarios are missing.

The problem is to find a border between “worst” and “likelier-but-less” catastrophic. If we would use the worst case all the way through an event tree, the calculated probabilities would be difficult to grasp – especially when communicating results to different stakeholders. An observed conclusion from conflict resolution concerning industrial sites is that involved stakeholders who have no benefit of potential risks emphasize safety issues and are afraid of risks with low probabilities but large consequences. They are not interested in probabilities or more credible scenarios.

Another question is who is a user of information gathered from safety reports. Is it an authority with a responsibility for supervision, a municipality where the site is located, or third parties affected by new hazards? All these stakeholders need different kind of information both in content and depth. This is something what people performing accident scenario analysis should keep in their minds. Additional question is for what purposes risk estimations are produced - for emergency planning, decision making, or safety?

The intention of this manuscript is to discuss aspects and problems related to the topic of accident scenarios. There are different approaches towards description of accident scenarios used today. The first part of the paper is a systematization of the definitions. We also analyse the so called Seveso reports taken from three Swedish companies. These reports are written in different ways, showing that unclear guidelines lead to problematical use of quantitative risk assessment methods. There is a discussion at the end concerning the usefulness of the worst case scenario approach. Is it just a static evaluation in the report or really valuable information that can be applied somehow in the decision-making process? Finally, there is a list of recommendations for accident scenario analysis which could be used in participatory processes where many stakeholders are involved.

ANALYSING DEMANDS ON ACCIDENTS

DESCRIPTION

The description or/and counting requirements for possible accidents are a part of safety reports required by state authorities. These requirements vary between countries and can be more or less precise. There is also a variation in terms of potential accidents that should be examined - a major accident, the worst case, a major accident scenario, or the worst case scenario.

It might be required for the safety reports to produce an analysis of an accident which has the “biggest” conceivable impact – the worst case (e.g. if all contain of a vessel blows up). The requirements can also be formulated in a way which leaves this question open. In this case the analyses are often done for more “realistic” accidents – the more probable ones with a slightly lower consequence than the worst case.

THE EU

In the EU the Seveso II Directive sets requirements on industrial operators to produce a safety report to demonstrate that they have taken all necessary measures to prevent accidents and to limit their consequences for humans and the environment. The safety report shall include a “major accident scenario”. The directive just states that a major accident shall mean an occurrence of a “major” event without defining what it is. The directive also leaves it up to each member state to choose if these major accident scenarios should be described quantitatively by their possibilities or qualitatively by the conditions under which they occur (Annex II of the Seveso II Directive).

A central part of the directive is the requirement to information public about major industrial hazards and appropriate safety measures in the event of an accident. It is based on recognition that industrial workers and the general public need to know about hazards that threaten them and about safety procedures. This is in fact the first time that the principle of “need to know” has been enshrined in European Community legislation (Mitchell 1996, part 4).

As mention above in the EU requirements vary between member states. In the United Kingdom the Seveso directive is implemented through the Control of Major Accident Hazards (COMAH) Regulations. Under these regulations there is a requirement for the safety reports for major process and storage sites to include an analysis of major accidents. Guidance from the HSE on preparing safety reports – The Safety Report Assessment Manual (SRAM) describes what means major accident.

Risk assessments carried out by operators should be proportionate to the risk of the establishment. This proportionality is interpreted by the HSE as a function of the scale of the operations, the dangerous substances handled by the site and the nature of the surrounding area (including the population density). Guidance documents for risk assessment have been issued by the HSE and EA. These publications are not very detailed and do not specify whether a quantitative of qualitative approach has to be followed or how scenarios have to be selected and modelled.

In Belgium the federal and regional authorities have jointly published an extensive guideline about content and structure of a federal safety report. This guideline suggests...
that the qualitative approach is the best way to implement the risk assessment. This model combines a detailed root cause analysis with consequence analyses. Additional guidance on risk assessment is given by the federal authority. The contents of these notes are not compulsory in nature.

In Netherlands the Hazards of Major Accidents Decree 1999 (HMAR) and amending various other decrees enact the Seveso II directive on the control of major accident hazards involving dangerous substances. The HMAR defines a major accident in the exactly same way as it is in the Seveso II directive. The risk assessment shall between others include an estimate of the probability of occurrence of the developments referred to major accidents, and an estimate of the effects of such developments outside the establishment.

THE U.S.
In the U.S. it is the Risk Management Program (RMP) issued by Environmental Protection Agency (EPA) which provides these regulations. The U.S. RMP requires to interpret a major accident and a major accident scenario as an accident/scenario which have a highest consequence, even if the probability for it is very low.

The EPA has issued detailed information in the Risk Management Program Guidance for Offsite Consequence Analysis. The offsite consequence analysis consists of two elements: a worst-case release scenario and alternative release scenarios. The worst-case scenario is defined by the EPA as the release of the largest quantity of a regulated substance from a single vessel or process line failure that results in the greatest distance to an endpoint. When describing the worst case release scenario, an owner or operator must assume the worst possible conditions with respect to wind speed and atmospheric stability, ambient temperature, height of release, and temperature of the released substance. Alternative release scenarios should be also examined. These scenarios are more likely to occur than the worst case scenario and they should be based on accident history or operator’s risk analysis. The EPA developed guidance for industry specific risk management programs for some industries.

Both worst-case and alternative release scenarios may take passive mitigation systems into consideration. Passive mitigation systems are equipment, devices or technologies that work without human, mechanical or other energy input to capture or control released substances. Dikes, building enclosures, and containment walls are examples of passive mitigation systems. Active mitigation systems such as fire sprinkler systems, water curtains, valves, scrubbers, and flares use human, mechanical or energy input. Only alternative release scenarios may take active mitigation systems into consideration.

CANADA
Canada’s authorities: Council for Reducing Major Industrial Accidents/Conseil pour la réduction des accidents industriels majeurs (CRAIM) develop a management guide for major industrial accidents intended for municipalities and industry. In the guide there is a clear definition of a worst case realise scenario as “the emission of the greatest quantity of a hazardous substance, held in the largest container, whose impact distance is the greatest. Whether the hazardous materials consist of toxic or flammable substances, conditions are preestablished to help understand the worst-case scenarios. These standard conditions concern the meteorological conditions, the duration of the loss of containment, the quantities of the product to consider, the physical conditions of the accident site, etc”.

THE SEVESO SAFETY REPORTS IN SWEDEN
Swedish law states that there is the possibility of both qualitative and quantitative analysis. Below are the analyses of three Seveso safety reports made by Swedish companies. The idea here is to study similarities and differences in the way companies understand their obligations concerning depth and width of Seveso safety reports and whether the worst case scenario approach is used. It is also of an interest to compare reports from the same or similar fields. First safety report is done by an energy company and two others are made done by petroleum companies.

PROPOSED LNG ESTABLISHMENT IN LOUDDEN, STOCKHOLM
In this case the Seveso safety report is done for a planned LNG establishment. The area of the establishment is divided into sections. The sections are chosen in order to use the template for count leakage probabilities. A section can include such activities as unloading from a boat, storage container and pumps, truck vessels, etc.

Three types of leakage are defined; small, medium, big/burst. For each defined leakage (small, medium, big/burst) there are frequencies assigned for an event; no ignition, immediately ignition and delayed ignition. The consequences of these events are assessed with the use a computer program. The leakage in a section is an internal danger. There are also external dangers such as oil fire, collision with pipe, and an accident during boat unloading.

For each section probabilities and consequences of LNG leakages are produced with the help of data obtained from a template (probabilities) and software (consequences). Consequences are assessed independently of probabilities. In the end a risk matrix with five frequency ranks (1–5) and six consequence ranks is produced in order to asses the risk level.

From the probability analyses it emerges that there are two events which can give a rise for a critical consequence – ignition in cofferdam after leakage and a large jet fire. A serious consequence is associated with a medium or large pool fire, jet fire, and flash burn in number of sections together with some external events.

Thus a fire in the cofferdam after a leakage and a large jet fire are the worst case events and medium or large
pool fire, jet fire and flash burn are the worst case consequences. According to the analyses, this gives altogether 37 different worst case scenarios. When transferred into a risk matrix, these 37 worst case scenarios are classified as significantly risky. None of them, however, are classified as unacceptable risky.

The conclusion drawn in these safety analyses states that the unwanted events that can be expected in planned LNG establishment with a “large certainty won’t influence the establishment’s surroundings and in that meaning the establishment is a safety one”.

The active and passive barriers are implicitly included in the analyses because they are taken into a consideration when describing consequences with the help of computer software. For example, the closing time of valves in a section which limits the amount of LNG coming out after leakage (e.g. broken pipe) is included when computing consequences.

TWO OIL TERMINALS IN STOCKHOLM’S AREA

In this case two Seveso safety reports for two oil terminals (Preem and Statoil) in Stockholm are examined. The safety reports are produced using the same templates to estimate probabilities and consequences. These templates are based on experience data from Swedish Petrol Institute (SPI) and Swedish Oil Ports’ Forum to estimate.

In the templates there are different working moments; boat unloading, storage, oil pumping, etc. Each working moment in its order is divided into different events. For each event there “basic” probabilities assigned. When analysing a specific establishment, these basic probabilities are adjusted to a particular situation by evaluating different factors. The factors can be procedures, instructions, equipment, working environment, etc. Possible passive and active barriers are assessed here as well. The result of the risk analyses are probabilities for events in working moments. An event with negative consequences can lead to oil discharge. Discharges are divided into four different classes according to amount of discharge oil.

Under consequence analyses several scenarios are chosen based on probabilities. According to SPI recommendation scenario’s effects, both in case of ignition or not, can be described or counted with a help of a computer program. In case of description consequences are judge with a help of diagrams for spill dimension, heat radiation etc. The template also recommends to identify if any residential areas, source of water supply etc. in the vicinity of the stalled establishment. In the end a risk matrix is produce to describe and help judge the risk level.

As mention above both Seveso safety reports for these oil terminals are using the same templates. Even if the templates are same there are differences in how they are applied. In the case of Preem Oil Terminal consequences are described. In the case of Statoil consequences are counted with software. In the Preem’s safety report there are events overfilling during unloading estimated as having high probability but less serious consequence. Events fire in connection with pipe leakage after loading or unloading and overfilling during unloading are considered being serious events with low probability. In the Statoil’s safety report there are tree scenarios identified as having highest risk potential; loss of petrol during loading a petrol truck, leakage in pipe system and overfilling of a tank. In the report the overfilling is chosen as a “worst case scenario” compare to Preem’s report which doesn’t state a worst case scenario.

DISCUSSION AND CONCLUSION

In the beginning of this part we would like to stress out the progress report from Buncefield Storage Depot Investigation. This report verifies that the “realistic” worst case scenario was used in the risk assessment but the event which later caused the incident was dismissed as having a very low probability.

The disaster in Buncefield was caused due to an alarm system failure during filling of a tank. Several levels of control did not show that the tank was full and petrol was leaking over the roof of a tank. After being mixed with air a dense flammable cloud was formed and exploded. This operation is widely counted as one of the weakest parts in the chain; this is also stated in two Seveso reports from oil companies mentioned above.

The Buncefield disaster put into the question the meaning of risk assessment as it is done nowadays. For example the emergency planning and spatial planning are now discussed frequently in connection to similar establishments. Likelihood for an accident as the one in Buncefield is very low according to quantitative risk assessment but the fact is that it has happened with devastating effects on surrounding area.

The importance of worst case scenario approach is also stressed in OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response. This document recommends for emergency planning to identify possible impacts on the assumption of the worst case and the most probable accident scenarios.

One of the mistakes done during risk assessments is that the possible accidents are approached using statistical methods, i.e. being perceived as stochastic. We argue that the possible accidents shouldn’t be assessed using statistical methods. The worst case approach as it is used in the U.S. gives a better starting point for emergency planning, spatial planning, and for mitigating possible effects – for example using effective passive barriers. The worst case approach is also easier to communicate and mediate to stakeholders due to its transparency – it is more useful in democratic decision making processes.

The conclusion which can be drawn from examination of the three safety reports mentioned above is that they are not in compliance with the purpose for which they are produced. Especially LNG safety report led to even bigger suspiciousness between stakeholders. Safety is not an invert risk. The aim of risk/safety assessment
should be to find cause effect chains which could lead to an accident and to improve mitigation methods for potential accidents, i.e. using effective passive barriers.

RECOMMENDED PRINCIPLES FOR POSSIBLE ACCIDENTS DESCRIPTION AND MANAGEMENT

In the end we present a list of recommendations for accident scenario analysis which could be used in participatory processes involving different stakeholders.

1. Develop a transparent and realistic emergency plan which is transparent and easy to communicate. The capacity to handle a potential accident is of a highest importance. Do not hide possible uncertainties.

2. Chose the worst case scenario with the worst thinkable consequences as an accident scenario, not the one with lesser consequences just because circumstances and/or calculations show that the worst one seems to be not realistic enough.

3. Do not underestimate the information gained from the worst case scenarios. When deciding upon different accident scenarios, do not underestimate the worst one. If you do neglect the potential worst case as unrealistic due to low probabilities, other stakeholders can focus on consequences.

4. Keep in mind that a quantitative risk assessment is not a certain method and that the potential worst accident is not a stochastic variable. This means that the worst accident will happen, we only do not know when.

5. Do not underestimate a human factor or an act of terror.

6. Put more time to lessen eventual consequences and emergency planning by improving preventative measures than counting possibilities.

7. If stakeholders bring up questions about possible consequences and emergency planning, give them a credit for it and let them be involved in planning and communication.

8. Safety is not an invert risk. The aim of risk management is to understand possible circumstances which could lead to the worst possible accident in analysed site and to prevent them. Be aware of complexity. The better you understand the circumstances leading to a possible accident, the better risk management will be.

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