Impact of Natural Hazards on Chemical Installations in Switzerland between 1991 and 2008

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Cover photo	Flooded industrial district on the Reuss plain (Schattdorf UR), August 2005. Source: Swiss Air Force

Bern, December 2010

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1 Introduction

The Swiss Federal Office for the Environment FOEN represents Switzerland in the "Working Group on Chemical Accidents" (WGCA) of the OECD, which manages the project "Control of Impact of Natural Hazards on Chemical Installations" running between 2009 and 2012 (OECD 2009). In this context, the FOEN provided a first overview of this problem throughout Switzerland, inter alia through preliminary work done by the Department of Geography at the University of Zurich (Leuschner 2008). In particular, establishments with a chemical hazard potential in areas possibly exposed to different types of natural hazards were identified and the past experiences of proprietors and authorities analyzed based on case studies.

In a second step, the FOEN examined the actual impact of natural hazard events on chemical installations which are subject to the Ordinance on Protection against Major Accidents of 1991 (Major Accidents Ordinance, MAO) in collaboration with the Department of Geography at the University of Bern. Thereby, the focus was put on a quantitative evaluation of the experiences gained in this field in Switzerland during the last years. The results of the study are presented in this report.

2 Problem Statement

The main objective of the present study was to find out what role natural hazard events have played in causing major accidents in establishments with a chemical hazard potential in Switzerland so far.

To get an answer to this leading question, the following subquestions were identified and analyzed:

- Which establishments with a chemical hazard potential that are subject to the Ordinance on Protection against Major Accidents were actually affected by which types of natural hazard events in the last years?
- What effects did the natural hazard events have on these establishments?
- Were dangerous substances, preparations or special wastes released from the installations?

  If not: By what means a release could be prevented (location of hazard potential, safety measures, emergency organization)?
- What additional damages arose from these releases?
- What conclusions can be drawn from these experiences?

3 Data

The following data were used for the present study:

a) The Federal Risk Register according to the Ordinance on Protection against Major Accidents (Eidgenössischer Risikokataster, hereinafter referred to as ERKAS) as of December 2005 for establishments with a chemical hazard potential. Before conducting the survey, the entries were synchronized with the new data from 2009.

   The collection of the ERKAS data is regulated by Swiss law. Since 1996, information about the establishments subject to the Ordinance on Protection against Major Accidents has been recorded by the competent cantonal authorities. These data are periodically collected by the FOEN and then stored in a database on a national level. The risk register essentially contains the contact details, the current state of implementation of the MAO and an overview of the hazard potentials and risks on the premises of each establishment. The data are spatially referenced and can therefore easily be integrated into a GIS.
   At the end of 2005, 2189 establishments with a chemical hazard potential existed in Switzerland, all of which had prepared a summary report according to the Major Accidents Ordinance. Furthermore, 177 establishments had to carry out an additional risk assessment and produce a risk report since serious harm to the public or damage to the environment was to be expected in case of a major accident. (Leuschner 2008)

b) The Swiss flood and landslide damage database of the Swiss Federal Institute for Forest, Snow and Landscape Research WSL, extract of the category industrial buildings for the years 1991 to 2008 with the following data fields: date of the event, process, affected canton and municipality, name of the decisive river, coordinates of the main damage point and information about its accuracy, remarks. Totally, the extract contained 1216 entries.

   The WSL has been systematically collecting information on flood, debris flow and landslide damage in Switzerland in a batabase since 1972. Since 2002, rockfall damages have also been integrated. The estimated direct financial damage as well as fatalities and injured people have been documented using press articles as a main source of information. (Hilker, Badoux, Hegg 2009)

c) The Swiss avalanche damage database of the Institute for Snow and Avalanche Research SLF, extract for the years 1991 to 2006 with the following data fields: avalanche number, date of event, affected municipality, coordinates of the avalanche starting and deposition zone, kind of damage (building, object, vegetation, livestock or personal). Totally, the extract contained 3432 entries.

   Since 1945 all the reported avalanches that had caused any damage have been registered in the avalanche damage archive (Ammann 2003).

4 Event Analysis

4.1 Determination of Potentially Affected Establishments

To identify the establishments that had potentially been affected by natural hazard events during the last years, the locations of the ERKAS establishments were compared with the areas exposed to natural hazards events according to the Swiss flood and landslide damage database and the Swiss avalanche damage database, respectively.
For the determination of the establishments potentially affected by flood, debris flow, landslide or rockfall, the remarks field of the database was essential. In the best case, the name of an affected establishment was already given there. Often, however, it was just mentioned that an industrial area in a certain place had been affected. So it had to be checked with the help of aerial photographs and a phone directory whether any ERKAS establishments were located in this particular area and if they could possibly have been affected by the hazard event. Only in few cases, the coordinates of the main damage point could be directly compared with the coordinates of the ERKAS establishments in ArcGIS, as often the accuracy of the damage point was not good enough.
In contrast, the establishments potentially affected by avalanches could be all identified by means of a GIS-based analysis, because the accuracy of the avalanche coordinates was much better. The coordinates of the avalanche starting and deposition zones served for the generation of a spatially referenced line shapefile, which was buffered with different distances and then overlaid with the 150 m buffers of the ERKAS point data set.

After these examinations, all the records of both the Swiss flood and landslide damage database and the Swiss avalanche damage database were assigned to one of the three following classes:

- almost certainly relevant
- needs to be clarified
- rather not affected

Only the entries in the first two classes were used for further investigations. After synchronizing them with the current ERKAS data to eliminate possible errors, 154 potential cases of damage in 149 possibly affected establishments were identified.
The exact period to be considered in the study was primarily determined by the availability of the data used. Therefore, investigations were limited to the period from 1991 (the year of the adoption of the Major Accidents Ordinance) to 2006 (availability of avalanche damage data) and 2008 (availability of flood and landslide damage data), respectively.

4.2 Survey

To find out which companies had in fact been affected by natural hazard events and to get more information about those cases, an online survey was conducted among the 149 potentially affected establishments. For this purpose, the SharePoint platform of the FOEN was used.
For each of the 154 potential events of damage, a case number was distributed. Each potentially affected establishment received a letter with information about the study, its case number - or numbers in case of multiple mentions -, details about the event to investigate (process type, date), the survey workflow, the link to the online survey and the password. The survey was running for one month.
In Figure 1, the survey questions and workflow are shown. The user is automatically guided through the survey depending on his answers as illustrated in the graphic.

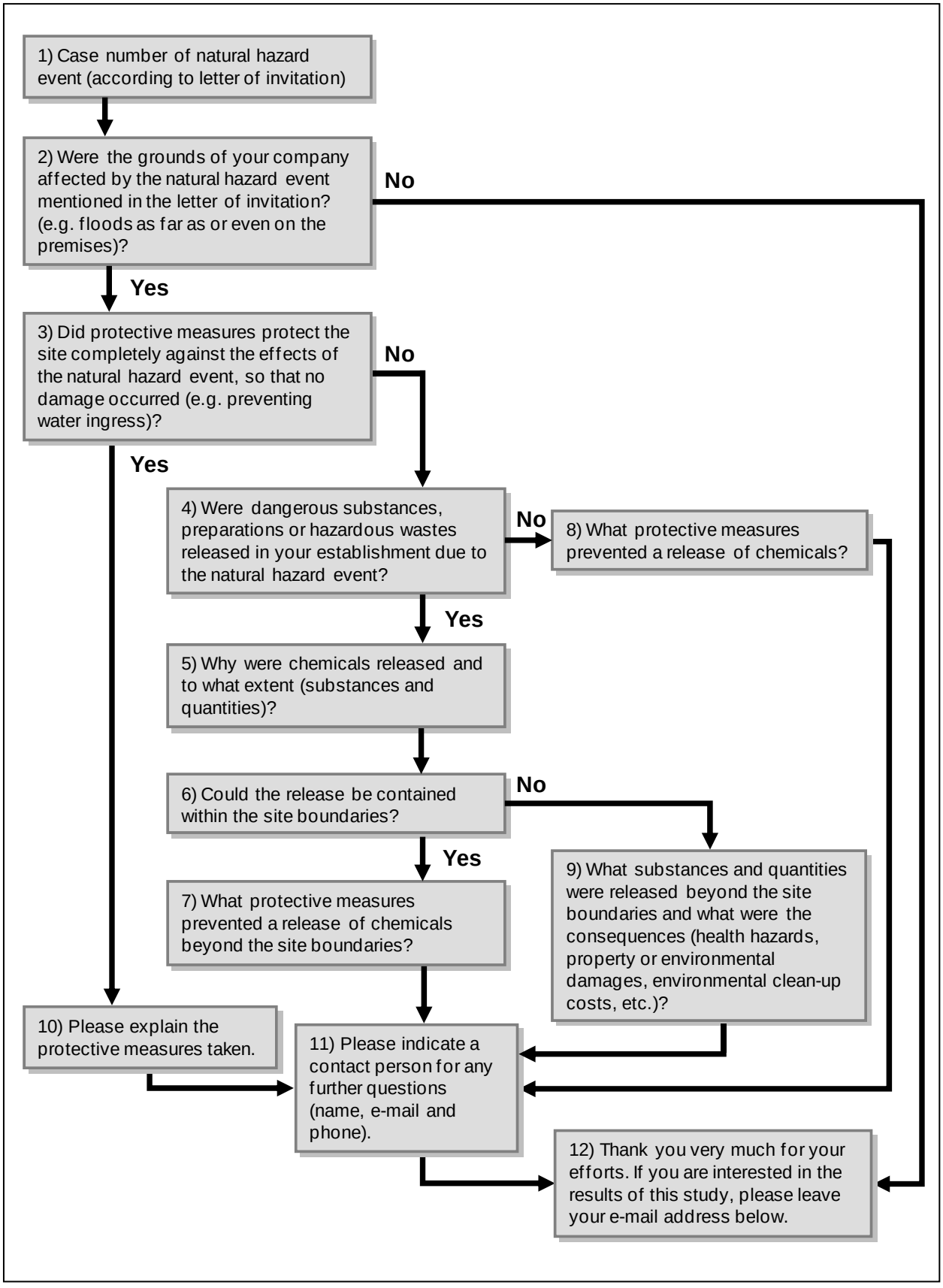

Figure 1: Survey workflow

4.3 Results of the Survey

General results

68 of 154 potentially affected cases could be clarified by the survey, which corresponds to a response rate of 44%. As mentioned above, ERKAS 2005 contains 2189 establishments with a chemical hazard potential, so roughly 7% of all the companies were questioned and 3% actually responded to the survey.

In Figure 2, an overview of the results is shown. The numbers in the blue boxes indicate the number of responses for the corresponding questions. The results of the single questions are presented in detail hereafter.

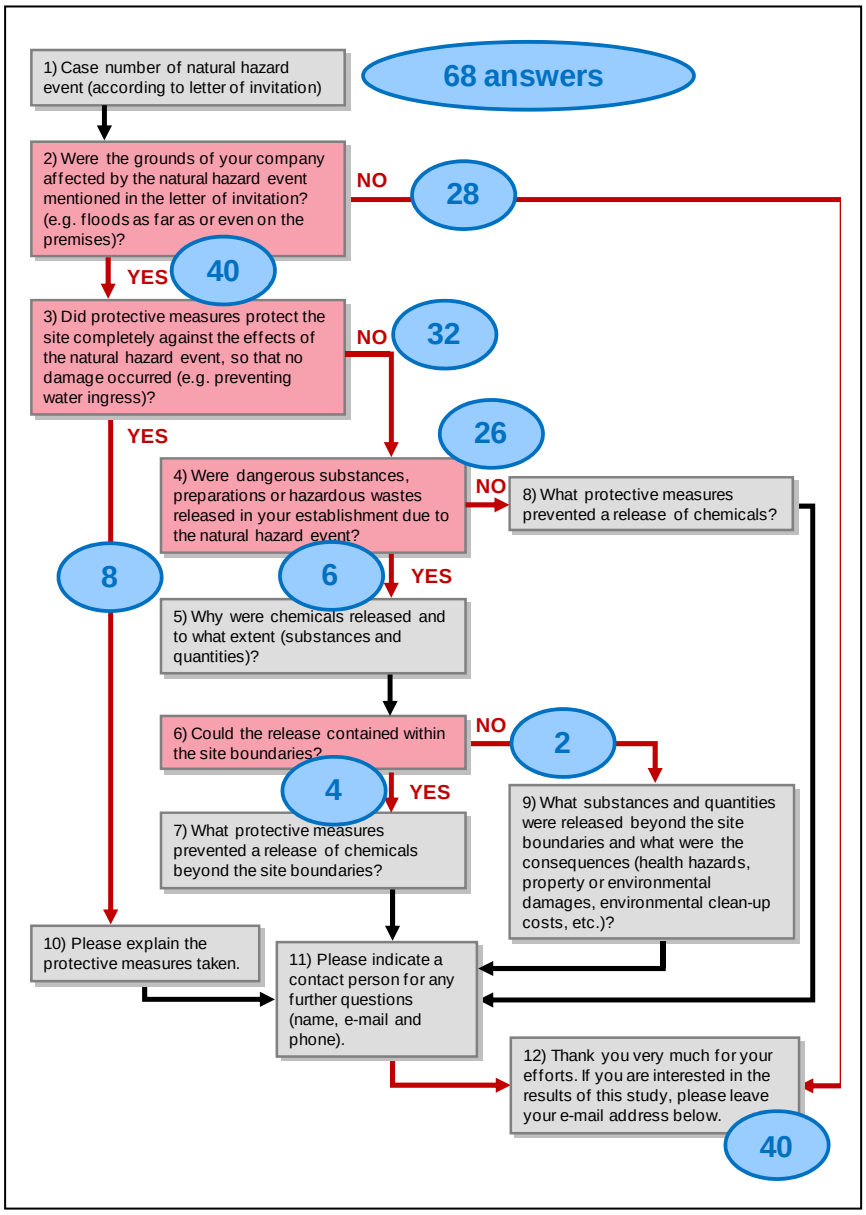

Figure 2: Overview of results

Question 2: Were the grounds of your company affected by the natural hazard event mentioned in the letter of invitation? (e. g. floods as far as or even on the premises)?

In 40 of the 68 cases from which an answer had been got, the establishments were in fact affected by the mentioned natural hazard event, as is illustrated in
Figure 3. This means that about 2% of all the ERKAS establishments were actually located in areas exposed to natural hazard events. It can be assumed that rather the affected establishments responded to the survey, since an answer was got by most of the cases in the category “almost certainly relevant”.

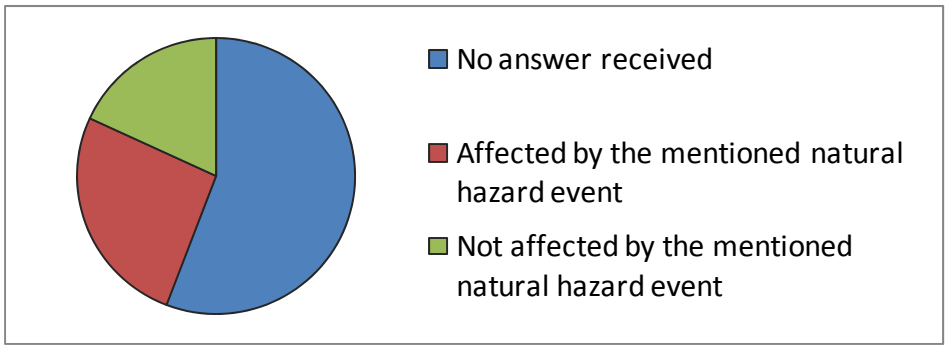

Figure 3: Overview of the 154 potentially affected establishments

Even though a few establishments were considered to be potentially affected by debris flow, slope failure, landslide and avalanches, the survey showed that in fact none of them had been affected by one of the mentioned hazard events. So it turned out that all of the 40 confirmed cases were exclusively affected by flood events. The precise distribution of the potentially and actually dangerous natural hazards for the establishment participating in the survey can be seen in Figure 4.

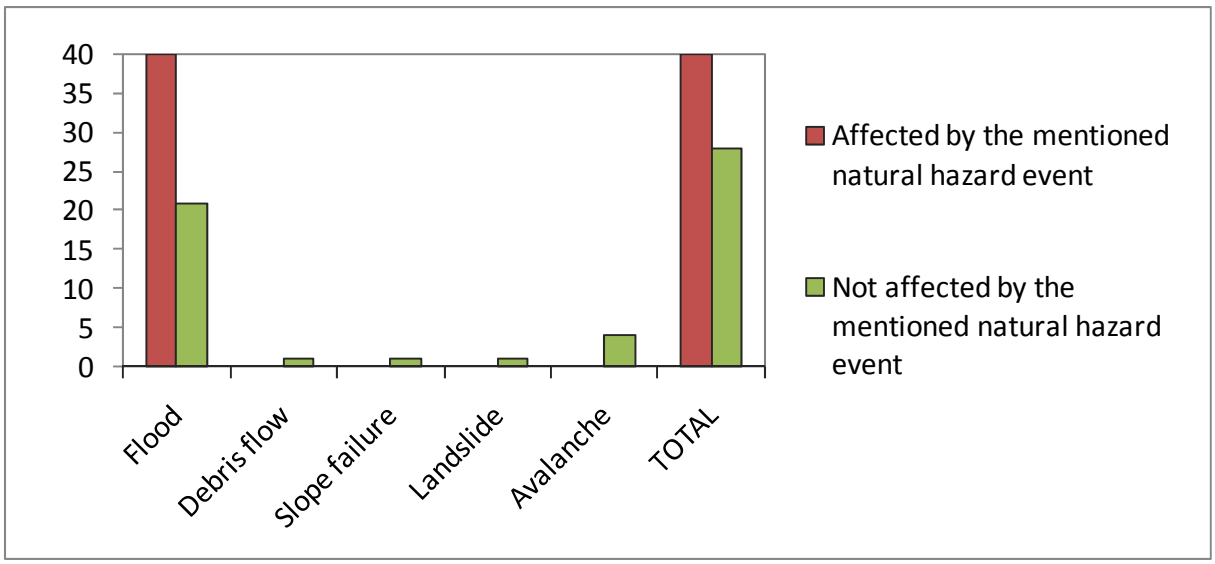

Figure 4: Companies participating in the survey grouped according to exposure to different natural hazards

This finding coincides with Leuschner's statement (2008) that floods are the most important natural hazard relating to establishments with a chemical hazard potential. She claims that floods with a return period of 500 years pose a potential threat to 45% of the establishments and that still 33% of the companies are potentially at risk by floods with a return period of 100 years. Moreover, according to Leuschner, 30% of the establishments are potentially threatened by slope failures, 15% by rockfall and approximately 3% by debris flows and avalanches. In this study, four cases with a potential risk for avalanches and one case with a potential risk for each debris flows, slope failures and landslides were detected for the establishments participating in the survey, but none of the identified establishments had actually been affected by the corresponding hazard event.
So Leuschner's work can be verified insofar as water hazards in fact being the decisive natural hazard. But her results clearly seem to overestimate the risk, considering that in fact 2% of all the existing 2189 ERKAS enterprises were affected by flood events during the last 20 years. The same is true for slope failures and rockfall events.

Question 3: Did protective measures protect the site completely against the effects of the natural hazard event, so that no damage occurred (e.g. preventing water ingress)?

8 of the 40 affected establishments were completely protected against the effects of the flood event. In 32 cases, however, damage was caused (see Figure 5). This corresponds to approximately 1.5% of all the ERKAS establishments.

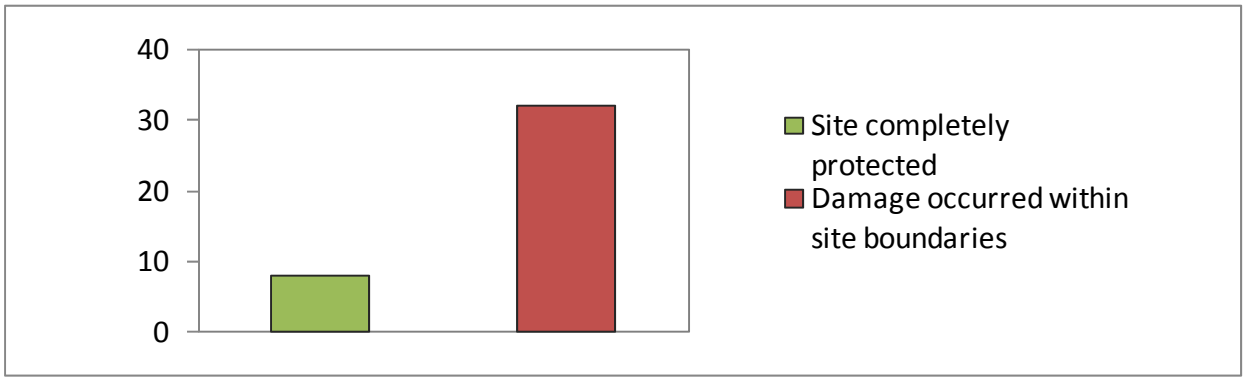

Figure 5: Affected establishments with and without damage

Question 10: Please explain the protective measures taken.

This was an open question, so several protective measures could be mentioned in free text. For this reason, the total number of answers exceeds the number of the 8 questioned establishments. The different answers were grouped thematically in order to facilitate evaluation. An overview of the protective measures taken is shown in Figure 6.

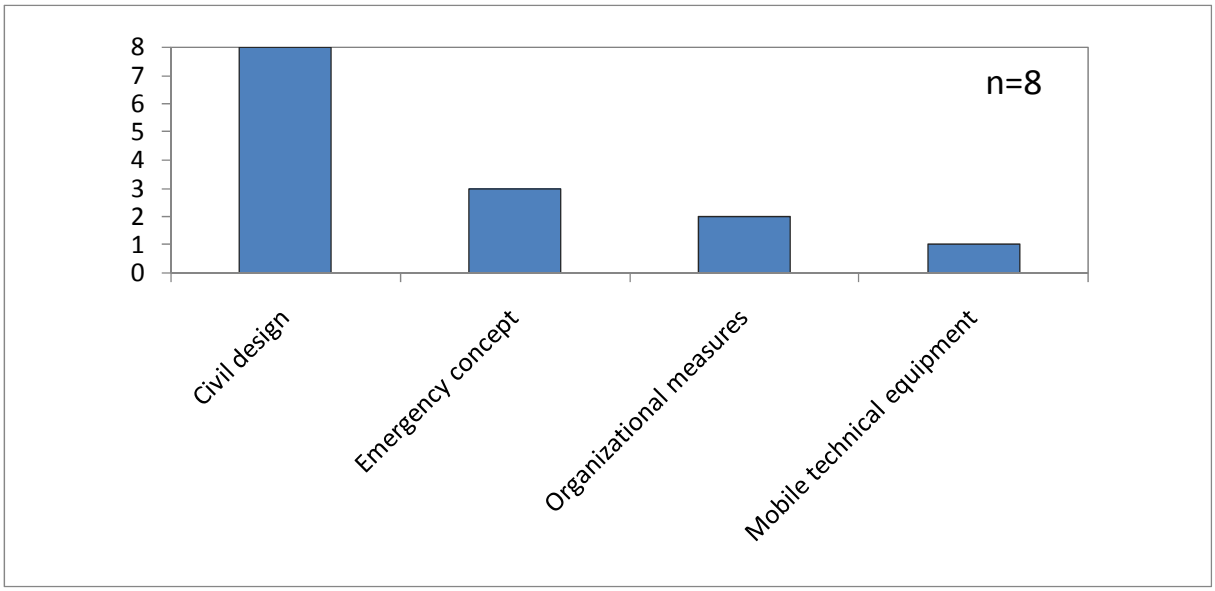

Figure 6: Protective measures which protected the sites completely against the effects of the mentioned natural hazard event

All of the 8 affected establishments without any damages on the site mentioned the importance of civil design measures such as oil or water barriers, catch basins, flood dams, pressure doors, check valves and ground sealing for the protection against natural hazards. In three cases, an emergency concept proved essential to alert the crisis management group and the fire brigade of the company. Twice, organizational measures such as the maintenance and regular control of the protective measures or the training of the employees were named and one establishment referred to mobile technical equipment, i.e. mobile water barriers.

Question 4: Were dangerous substances, preparations or hazardous wastes released in your establishment due to the natural hazard event?

In 26 of the 32 establishments with damages, no chemicals were released on the site due to the mentioned natural hazard event. In 6 cases - or about 0.3% of all the ERKAS establishments - a release took place (see Figure 7).

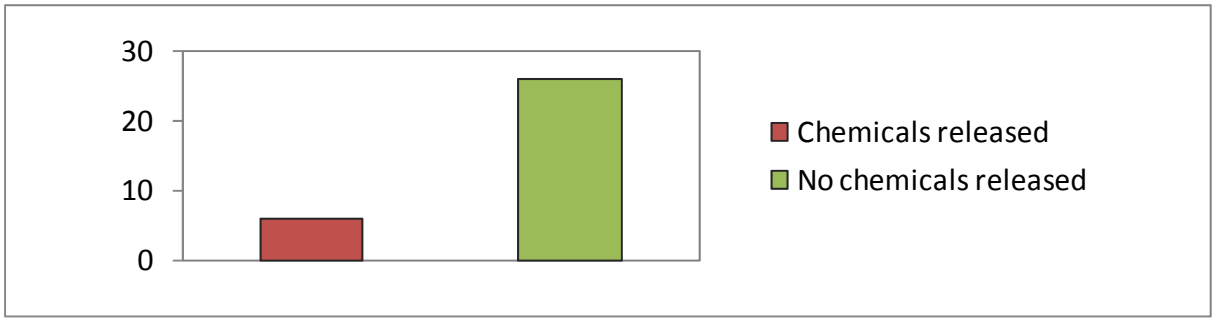

Figure 7: Establishments with and without release of chemicals

Question 8: What protective measures prevented a release of chemicals?

24 of the 26 establishments with damages, but without releases of chemicals on the premises provided information about the protective measures in use. Again, this was an open question. An overview of the replies is shown in Figure 8. In 15 cases, the storage location seemed to be of particular importance: Dangerous substances or preparations were not stored in inundated basement rooms or other critical locations affected by the flood, but in elevated sites or in upper floors. In contrast to question 10, where all 8 establishments relied on civil design to completely protect the premises against the effects of the mentioned natural hazard event, only one third of the establishments indicated that civil design was crucial to prevent the release of chemicals at this point. The reason for this difference could be that civil design had failed in some cases and water could penetrate the premises, so to prevent of a release of chemicals these establishments mainly had to rely on other types of protective measures.

In 7 cases, the importance of flawless, closed containers and the storage of small quantities of chemicals only were pointed out. 4 companies used mobile technical equipment such as sand bags and mobile water barriers or pumping contaminated water and mud out of the inundated rooms to prevent a release of chemicals on the site. Three times, the emergency concept was named, which included shutting down the facilities when a critical value of the water was reached or alerting the crisis management group and the fire brigade of the company among other things. One establishment mentioned the professional handling of chemical substances, which is rather an organizational measure.

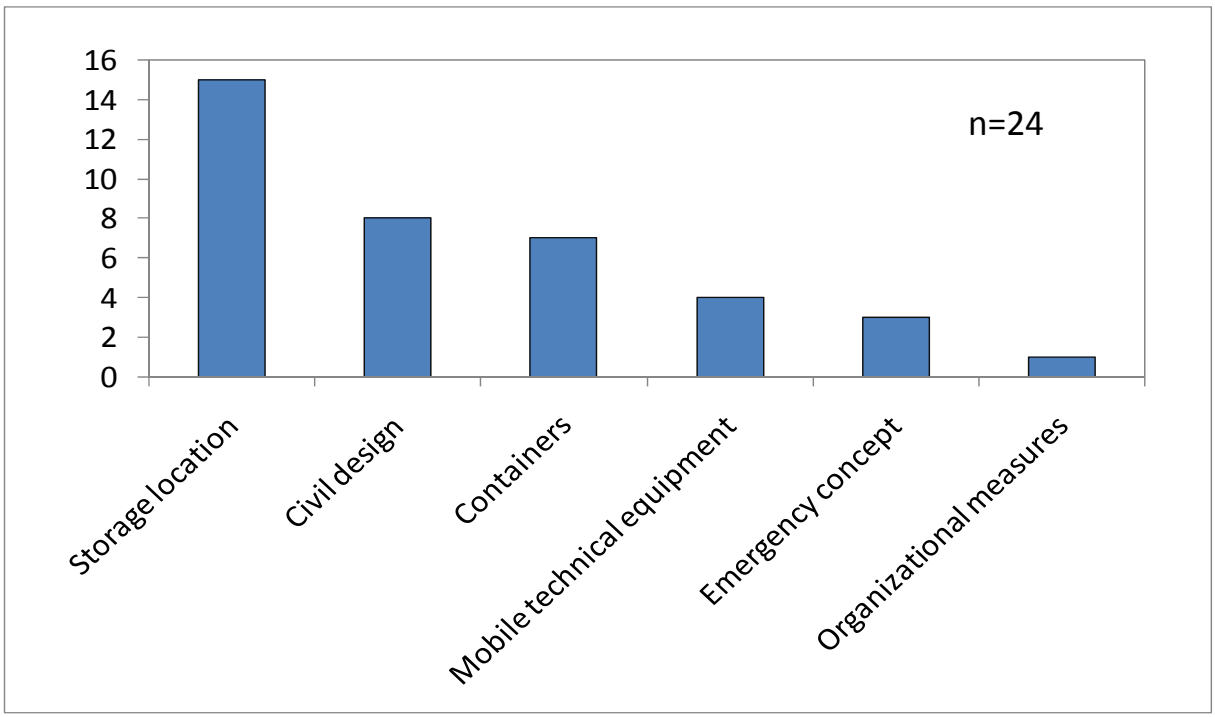

Figure 8: Protective measures which prevented a release of chemicals

Question 5: Why were chemicals released and to what extent (substances and quantities)?

In all of the 6 present cases, chemicals were released because water had entered the establishment and inundated the chemicals storage or parts of it. Three establishments explicitly mentioned that the chemicals storages in the basement rooms were put under water. The water level in the flooded rooms varied between 60 cm and several meters. The released substances and quantities also varied widely and were partly not known. 4 establishments gave more detailed information:

- In establishment A, almost no chemicals were released due to flawless containers, but problems were caused by deposited mud. Totally, 38‘170 m³ of mud and water, 45‘804 m³ of water and 22‘902 m³ of storage goods and production materials had to be disposed of.
- In establishment B, approximately one ton of chemicals was released and 20 tons of production materials had to be disposed of.
- In establishment C, raw materials, semi-finished and finished products were rendered unusable by the water ingress and had to be taken away and be disposed of partly as hazardous waste.
- In establishment D, significant amounts of chemicals (20 to 150 kg) and 15 m³ of waste oil at the most were released.

Question 6: Could the release be contained within the site boundaries?

Only in 2 of the 6 cases with releases, chemical substances, preparations or hazardous wastes were released beyond the premises. This corresponds to about 0.1% of all the ERKAS establishments.

Question 7: What protective measures prevented a release of chemicals beyond the site boundaries?

In the 4 establishments with a release of chemicals on the premises, the following measures could limit the release to the company grounds: In 2 cases, the basement served as a catch basin for contaminated water, once the short duration of the event and structural measures (protective trough) were mentioned and once luck played a certain role when solid and pulverized substances still in their packaging were soaked, but were not leaking.

Question 9: What substances and quantities were released beyond the site boundaries and what were the consequences (health hazards, property or environmental damages, environmental clean-up costs, etc.)?

This being the central question of the present study, the following answers were received:

- In one of the two cases with releases beyond the site boundaries, the substances and quantities were not known anymore. But according to the person in charge, "the amounts were small in proportion to the other substances that were coming down the river".
- In the second establishment, between 20 to 150 kg of chromium VI salts were released from the installation in dissolved form in the mud. All the wastes that had been sampled could be disposed of according to valid law. No immediate danger for both people and the environment existed and there was no damage. Beyond the site boundaries, no remediation costs incurred. Moreover, approximately 10 m^3 of waste oil were released, which were collected with an oil barrier of the fire brigades.

Question 12: If you are interested in the results of this study, please leave your e-mail address below.

The establishments showed great interest in the survey; 40 of 68 persons in charge (60%) wished to receive the results of the study.

5 Conclusions

As pointed out in chapterProblem Statement 2, the main objective of this study was to find out what role natural hazard events have played in causing major accidents in establishments with a high chemical exposure in Switzerland so far.
Regarding this question past experience has shown that:

1) Natural hazards have played a marginal role in causing major accidents in establishments with a high chemical hazard potential since 1991.
   Only in two cases, dangerous substances, preparations and hazardous wastes were released beyond the site boundaries as consequence of natural hazard events within the last 20 years. In contrast, more than 50 accidents occurred between 2005 and 2009.
2) Still, 40 of the 2189 ERKAS establishments, i.e. 2%, were affected by natural hazard events within the last 20 years. In at least six cases, dangerous substances were

released within the site boundaries, in two of which even beyond. Although the risk seems to be small, it exists and has to be tackled.

3) Hazards related to water are statistically decisive. All establishments affected by natural hazards were exclusively damaged by flood events. Possible explanations for this fact could be that inundations often cover a much larger area than other natural hazard types and that establishments with a chemical hazard potential are often located on the waterside for historical reasons (Hartmann, Jordi 2007).
4) The possibility for timely action is given. Only in 6 of the total 40 affected establishments, dangerous substances were released.
5) Nevertheless, a considerable potential for better protective measures exists. Only 8 of the 40 effectively affected establishments protected their site successfully against all the effects of the natural hazard event. Advice on effective natural hazard prevention measures can for example be found in the manual “Lessons Learned from Natural Disasters” of the Center for Chemical Process Safety (CCPS 2006).
6) The owners of the companies seem to be interested in and aware of the topic. If the competent authorities provide them with sufficient information, the establishments get active themselves in their own interest. As also Leuschner (2008) states, the implementation of protective measures mainly serves to prevent failures and loss of production in the case of a natural hazard event and not to meet the legal requirements. The main focus lies on the maintenance of the competitiveness and jobs even after crisis situations.

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