Risk assessment of chlorine dioxide storage facilities

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Abstract

Chlorine dioxide (ClO_2) is universally used as a bleaching agent in the manufacturing of pulp for paper production. ClO_2 is very reactive and hazardous, and one of the largest risks associated with production of ClO_2 is the storage facilities. The intent with this master thesis was to develop a method for risk assessment of the ClO_2 storage facilities at pulp mills.

From methodical scientific work comprising literature searches and interviewing professionals has resulted in a thorough identification of the risks associated with ClO_2 storage facilities.
The gas release in case of several different scenarios has been simulated using the software ALOHA. These calculations are associated with uncertainties and assumptions. Consequently, the extent of the gas release as well as the concentration gradients is exaggerated. Never the less, the simulation work allows distinguishing between various scenarios.

Based on the identification of risks and the simulations of various scenarios, an "ideal" ClO_2 storage facility can be defined. A method for comparing a real storage to this ideal facility has been developed. The result is very promising; the method allows the user to efficiently identify the gap between an actual storage facility and the "ideal" storage. The method also indicates, through an easy to comprehend colour coding, in which areas improvement is most imperative.

Whilst improvement of the simulations of gas release and adoption of the method to reflect also internationally conceivable risks would even further extend the result from this master thesis, the overall result is still very satisfactory and indicates an efficient route for safe ClO_2 storage facilities.

Introduction

Chlorine dioxide (ClO_2) is universally used as a bleaching agent in the manufacturing of pulp for paper production. ClO_2 is very reactive with properties enabling cost efficient and environmentally friendly processes. However, the reactive properties and the fact that the chemical is hazardous make it necessary to take cautions, employ strict management and design of the systems used for manufacturing and storage.

The acute health effects from exposure to ClO_2 are damages to the eyes and the respiratory tracts that in the worst case can lead to death. There are no consistent conclusion of effects due to long-term exposure, but the is reason to believe that there are damages as well and therefore appropriate to be careful.

The fact that ClO_2 has hazardous and dangerous properties is well known by the pulp mills, and because of this, the overall safety at the pulp mills is generally good. Nevertheless, there is an increasing concern and focus on the area of safety, driven from internal, external and commercial aspects. As the pulp mills continuously strive to improve the overall safety and knowledge around ClO_2, it has been noticed that one of the largest risks associated with production of ClO_2 is in the storage facilities.

The overall goal for this master thesis is to create and develop a method for risk assessment of ClO_2 storage facilities at Swedish pulp mills. Fundamental is the requirement for the method to be useful and suitable for workers at the pulp mill, that has no knowledge about risk assessment. To reach this requirement the method should be:

- easy to use
- fast to use
- present results that are easy to comprehend

To reach these goals, it was early decided that the method should be a checklist consisting of yes or no questions. To create this checklist, the following working process was used:

- Risk identification
- Risk selection
- Parameter identification
- Defining an “ideal” pulp mill
- Creating the method

Risk identification

Essential for the development of the new method for risk assessment was a consistent and broad understanding of the possible risks arising from the ClO_2 storage facility and the surroundings of this. To gain this understanding, several sources were used for identifying as many of the risks as possible. The first source is the contexture of a representative ClO_2 storage facility, based on study visits at Swedish pulp mills, and the following risk analysis of this. This risk analysis was complemented with a consequence analysis. Other sources of information consist of precedent risk assessments and risk analyses, incident reports and accident reports as well as articles from media.

A wide range of risk was identified through the risk analysis of the representative storage facility. Five scenarios were identified; tank collapse, tank leakage, pipe rupture, pipe leakage and spill. Several causes for these scenarios were identified, including for example corrosion, collision and falling objects.

The consequences were roughly evaluated by consequence calculations in ALOHA, a software developed by EPA. Due to the need of assumptions and simplifications in these calculations, the results in aspects of calculated plume lengths and concentrations at various distances are of little value other than comparing scenarios in order of magnitude.

In summary, the risk analyses lead to an estimation of the consequences of the different scenarios and an estimation of the probability for causes that may lead to these scenarios.

Risk selection

The next step was the risk selection. In this step, all the risks identified in the risk analysis of the representative ClO_2 storage facility were compared to the risks identified in other literature, for example precedent risk assessments and media. This comparison was made to point out the most prominent risks affecting a ClO_2 storage facility, so that these could be given extra focus in the developed method. To be considered an extra serious risk either the probability or consequence had to be high or both had to be medium high.

Parameter identification

Looking at the selected risks and their causes, one could find several different parameters affecting the probability and consequences of these. These parameters can both increase and decrease the probabilities and the consequences. By knowing and understanding the effects from these parameters, one could better understand the measures that need to be taken to ensure safety at the ClO_2 storage facility.

The focus of the parameter identification was on analyzing the parameters of the selected risks and the selected causes.

"Ideal" storage facility

After identifying what parameters affect the consequence and probability, an "ideal" storage facility was defined.
This consisted of features that could enhance the safety and minimize the risks affecting the ClO_2 storage facility.
This "ideal" played would henceforth play an important role in the method for risk assessment of ClO_2 storage facilities. The "ideal" act as a measuring rod with which the storage facility being assessed are compared with.

The "ideal" storage facility were based on the parameter identification as well as literature and reasoning.

The method

The finished method is a checklist consisting of 84 questions with the alternatives yes and no. Systematically, one will have to answer the different questions in the method. While the general checklist is referred to as a qualitative method for risk assessment, this method will somewhat differ from this. The method has features of semi-quantitative elements. In fact, the method could be seen as a mixture between a qualitative and a semi-quantitative method.

The semi-quantitative elements are included into the method through the points linked with each question. When starting to answer the questions, one will have a sum of points corresponding to the sum of the "ideal" ClO_2 storage facility. Depending on the answer to the questions, one might have to deduct points from this sum because of defects in safety and differences from this "ideal". The deduction of points for each question is based on subjective thoughts, which are based on the risk selection and the preparatory work of this. The number of points deducted is an integer from 1 to 5.

When all the questions are answered, the remaining points are counted. The sum is then compared with fixed scales. Thereby, one can see how close to the "ideal" ClO_2 storage facility the ClO_2 storage facility is, concerning the safety. The scale has three levels:

- the safety is good
- the safety is sufficient
- the safety is insufficient

To make the result even clearer, the different levels have been given a classic "stop light" color scheme; green, yellow and red.

To make the method more specific, a number of "keys" were defined. These "keys" are questions linked to certain areas of concern. The "keys" defined in the report are; overall safety, organizational safety, physical safety, maintenance and preparedness. By defining these keys, and make scales for each key, the user of the method can get more detailed information of which area that should get extra attention.

Strengths and weaknesses

The developed method has both strengths and weaknesses. A weakness is that it is not valid outside Sweden. Moreover, it does not give any examples of risk reducing actions. However, this was never the intention with the method. Last, most of the questions in the method is asked the same way, where "yes" is a "positive" answer that do not result in a deduction of points. This might lead to that persons conducting the method unconscious or conscious, notice the pattern and falsely answers questions in order to reach higher results in aspects of points.

The major strength is that the method reached its goal to be easy and fast to use and that the results are easy to comprehend. The method also rests on a stable foundation of literature, even if it in some parts relies on subjective reasoning. The method is also transparent, meaning that the subjective thoughts are motivated in the text.

Future work

Even though the method in its current form are ready to be used and with great efficiency and success, there are possibilities of enhancement and improvements. Some examples of possible future work that might be done on this method are:

- adaption for international conditions
- further tune the point deduction
- further tune the scales
- add/remove questions as well as "keys"

Last, the authors see potential in transforming and using this concept of the method on to other facilities and other chemicals in the future.