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TITLE

Feedback on use of inspection reports of industrial establishments as teaching aids for process safety in the French chemical engineering curriculum.

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Abstract

Numerous teaching aids are available for process safety education. In this article, the contents of the public and mandatory inspection reports of industrial installations classified for environmental protection are used as teaching aids. The contribution of these documents has been experimented, in addition to the teaching of process safety, within the framework of a Master degree in chemical engineering from the University of Lorraine at the “National Higher School of Chemical Industries” (ENSIC) of Nancy (France). The recommended content of a “Regional Direction for the Environment, Planning and Housing” (DREAL) inspection report is first recalled. The protocol for the use of Seveso sheets, inspection reports and letters of notification by students is then described. The pedagogical interaction between the basic knowledge of process safety previously acquired and the elements extracted from the inspection reports is discussed and illustrated by a few examples.

Keywords

Process safety; Education; Teaching aid; Inspection report; Chemical engineering

Highlights

- A safety teaching aid for chemical engineering master students is exposed.
- Students search and examine public inspection reports of Seveso establishments.
- Examples of education activities are presented.
- Student feedback on the pedagogical experience was positive.

1 - Introduction

Meyer et al. (2019) indicated that the model for process safety education follows three main approaches:

- a university education with Bachelor, Master and PhD degrees,
- a professional education with internship, job training, continuous professional development and industry-based research,
- an inspection education with learning from internal company and/or external governmental authority inspections.

With regard to university education, the open literature reports three ways to include process safety into the chemical engineering curriculum. The question is whether the safety and hazards aspects should be:

- Included as part of all existing courses of chemical engineering (Amyotte, 2013; Benintendi, 2016; Dee et al., 2015; Hill, 2016; Leveneur et al., 2016; Pintar et al., 1998; Pintar, 1999; Shallcross, 2013, 2014).
- Taught as a separate full course on process safety (Benintendi, 2016; Dee et al., 2015; Gabas, 2010; Krause, 2016; Lemkowitz, 1992; Meyer, 2017; Perrin and Laurent, 2008; Pintar, 1999; Pitt, 2012; Schmidt, 2013).
- Integrated simultaneously in a separate process safety course and as a part into an existing course of chemical engineering (Benintendi, 2016; Dee et al., 2015; Lemkowitz, 1992; Mannan et al., 1999; Véchet et al., 2014). The final choice depends on the teaching philosophy of each university department.

The first way, including safety as a part of all existing courses of chemical engineering, presents an advantage as it can be coordinated with the rest of course material. However, the major drawback is the lack of focus on process safety. The second way promotes a separate

full course in safety. The course would be more consistent and could better aggregate other knowledges. The last way is a combination of both previous ways, which allows the integration of concepts of process safety within the basic subjects of chemical engineering (Benintendi, 2016).

In France, the present tendency is to promote a separate full course in process safety, including lectures, tutorials, laboratory work, mandatory and elective courses, projects... Perrin and Laurent (2008), Perrin et al. (2019) described the modalities of the process safety education in France for Bachelor and Master levels in the chemical engineering departments. The chemical engineering departments of the University Institutes of Technology organize the safety mandatory program at the undergraduate level. These institutes are located in 11 different cities throughout France. The Engineering Schools (called “Grandes Ecoles”) are responsible for the graduate program. These schools are located in 7 cities. There are also some other universities teaching chemical and process engineering as a part of their programs. As an example, the compulsory and elective master training programme for the chemical engineering department of ENSIC Nancy should be accredited by the French Commission of Engineer Titles (CTI) and by the Institution of Chemical Engineers (ICChemE) according to their respective recommendations and standards. Table 1 sums up the global distribution of mandatory and elective Master courses of process safety at ENSIC Nancy with the corresponding semesters, timetables and ECTS. The detailed corresponding courses are reported in Perrin and Laurent (2008).

Table 1 – Global distribution of the mandatory and elective courses of process safety - Master curriculum in the chemical engineering department ENSIC Nancy.

The main recommended teaching aids for process safety in the inventory of the literature are:

- Books (Crowl and Louvar, 2002, Kletz, 1993, 2001, 2009, Kletz and Amyotte, 2010, Laurent, 2011, Mannan, 2012, TNO The coloured books, Meyer and Reniers, 2016...).

- Reports and notes (CCPS AIChE, Collection of safety guidelines, INERIS Omega reports, HSL reports, SACHE online courses, Crawley, 2014...).
- Database (Aria, Facts, Mars...).
- Films and videos (CSB US Chemical Safety Board, INERIS, INRS...).
- Cases studies (Mannan, 2012, Shallcross, 2013, Loss Prevention Bulletin...).
- Automatic teaching devices (Cameo, Aloha, Phast, Hazid & Hazop softwares...)

The review of the literature shows that the inspection route is not used in initial university training and joint university - apprenticeship training for the teaching of process safety .

Since the adoption of the EU Seveso 3 Directive on July 4, 2012 and its implementation in the French legislation, a large number of technical documents must be made available to the public and to people living in the vicinity of industrial facilities. In France, in particular, the reports drawn up by the Inspectorate for Environmentally Classified Installations (ICPE) are normally available on the website of the database “Géorisques”, managed by the Geological and Mining Research Bureau (BRGM) of the Ministry of Ecological and Solidarity Transition (BRGM, 2019).

The proposed article is focused on public inspection reports as a teaching aid. The contribution of these documents has been experimented, as a complement to the teaching of process safety, within the framework of a Master degree of chemical engineering from the University of Lorraine at ENSIC Nancy. The typical content of a DREAL inspection report is first recalled. The protocol for the use of Seveso sheets by students, the prefectorial decree of authorization, the complementary modifying decree, the inspection report, the formal notice, the letter of notification and the summary of the report of hazard assessment is then described. The pedagogical interaction between the basic knowledge of process safety acquired beforehand and the elements extracted from the inspection reports is discussed and illustrated by a few examples.

2 – Reading assistance of inspection reports

Article 18 of the EU Seveso II Directive requires Member States to ensure that their competent authorities organize an inspection system or other control measures appropriate to the type of establishment concerned, such as upper tier Seveso establishments, for example. This inspection requirement is confirmed and reinforced in Article 20 of the EU Seveso III Directive. Some different guides are also specifically proposed to provide the minimum criteria for the required inspection (Papadakis and Porter, 1999 - OJEC, 2001).

In France, INERIS and DREAL have developed a guide to help inspecting the Safety Management System (SMS) in an installation classified as Seveso upper tier establishment (Plot et al., 2019). This guide proposes a global inspection approach in compliance with French and European regulations. This approach provides a method for designing an inspection framework that can be adapted to each industrial facility. This guide is therefore downloaded by students to facilitate their reading of the public inspection reports.

The main contents of the inspection framework are now summarized. The logic on which an inspection must be based is first built from the Hazard Assessment. As a reminder, Figure 1 shows a schematic illustration of the corresponding different steps.

Figure 1 – Schematic illustration of a hazard study.

The requirements of the hazard study are translated into prescribed critical tasks described in procedures and/or operating procedures. Then the proposed framework for reading must be used according to the three inspection angles indicated in Figure 2.

Figure 2 - Flowchart for reading the regulations distinguishing three inspection angles.

The inspection of the operational functions of risk management is at the heart of the approach. The inspection logic proposed in the guide focuses on questioning the proper performance of critical tasks in the field. The inspection must first be performed according to angle #1. Then the other proposed inspection angles (angles #2 and #3) make sense. In order to facilitate the appropriation by students of the ICPE's public inspection reports, these three aspects are recapitulated by various summaries of key questions and illustrated by simple practical examples.

2.1 – Angle #1: Process and operational management

The approach from angle #1 focuses on examining the content of the hazard study. The guide highlights the key issues present in the inspection report. They are essentially based on the identification and control of critical tasks. A summary of the following questions is proposed for the reader's appropriation:

- Consider the requirements that must be mastered in order to guarantee the acceptable level of risk over time validated in the hazard study. Are they identified and listed? Five types of requirements should be distinguished, concerning respectively:

- a. hazard potentials;
- b. assumptions related to the intensity of accidents selected;
- c. the frequencies of the initiating events and secondary;
- d. RMM;
- e. the monitoring of the parameters that have made it possible to justify the exclusion of accidental scenarios.

- Consider the critical tasks likely to take place in the control mastery of these requirements. Are they systematically identified and listed in a document or an information system (data base)?

- Is there any evidence of the implementation of these tasks?

The operator should be able to provide to create a table of correspondence between these requirements, tasks and this evidence. Any requirement formalised in the hazard study should correspond to one or more critical tasks and one or several proofs should correspond to every critical task (where possible).

The inspection may be carried out by a survey to verify the proper identification and implementation work of one or more critical tasks.

2.2 - Angle #2: Organization and training

The inspection of the organization and training must be able to question the capacity of the management support to:

- propose an organization to operators enabling them to implement critical tasks efficiently,
- offer a training directly related to the control of critical tasks,
- the key question to be asked to the industrialist can be formulated as follows: Does the organization and training give operators and managers the means to master critical tasks, including the case of subcontracted activities?

2.3 – Angle #3: Steering and piloting functions

The inspectorate must question the manufacturer on its ability to:

- identify planned modifications that may impact the requirements identified in the hazard study,
- carry out a risk analysis and, if necessary, before undertaking any modification, the revision of the hazard study (and apply for a derogation from the operating permit, if necessary), the review of the design and management of the critical tasks and the review of the support management and steering.

Summarizing, the application of this approach shows that the inspector plays a decisive role in the control of risks:

- From inspection to inspection, operators are becoming increasingly aware of their hazard assessment, especially the requirements that they must control on a day-to-day basis,
- The inspector helps operators to check their hazard assessment based on their operational constraints, to update it, to improve it,
- Inspectors are increasingly pragmatic in their approach to problems encountered in the operational field.

3 – Pedagogical protocol for implementation

A pedagogical experiment was initiated with a population of voluntary students from the University of Lorraine - ENSIC Nancy enrolled in the Master program in Chemical Engineering (semester 8). A first cohort (#1), named "initial training", comprises 127 students recruited at ENSIC Nancy after two intensive years specialized in maths and physics (CPGE) and a competitive examination at national level. A second cohort (#2), called "mixed university-apprenticeship training", is composed of 33 students recruited as company employees on the basis of their professional safety qualifications.

The pedagogical experience is proposed as a home-based exercise. First of all, the teacher assigns the numerical marker of a department, an administrative division of France (for example 69 for the Rhône), to each pair of students, in the class of chemical engineering, knowing that the services of the DREAL control authority work under the responsibility of the Prefect at the territorial level of the department.

Then, each pair of students looks for an example of an industrial establishment in the databases of documents accessible to the public. The use of the government's national "Géorisques" database is recommended (BRGM, 2019). Sometimes, it can be supplemented by the local departmental and regional databases of the DREALs, such as for example the site of the region Provence-Alpes-Côte d'Azur (PACA, 2020). The reference to the archived documents of the Site Monitoring Committee (CSS) meetings (formerly Site Monitoring

Committee CLI and Local Commission for Information and Monitoring CLIS) is also useful. In a report by the National Federation for the Protection of Nature and the Environment, Schaible and Arditi (2013) listed the various administrative and technical ICPE documents available to the public.

This consultation of public documents of the chronological life of the concerned establishment makes it possible to extract those of potential interest in terms of teaching aid for the process safety. For example, students are advised to give priority to the resources of the impact study, the hazard study, the regulatory framework, the prefect decrees, the inspection reports, the Seveso sheet, the deviation sheets from the authorized operation, the Internal Operation Plan (POI), the Special Response Plan (PPI), the Technological Risk Prevention Plan (PPRT) etc.

Each pair of students gathers themselves with a large variety of information contained in public documents. Then, they individually select representative facts and recommendations, according to their own level of knowledge acquired previously during the separate full course. Thus, the result depends on each group. However, the relevance of the proposed choices helps to assess their degree of assimilation of process safety concepts. The observations adopted by the students are recorded in a report of three pages maximum. Each pair presents a short oral presentation of their teaching aid and discusses it in front of the class. The effective pedagogical realization of this teaching aid experience by the voluntary students is awarded by the allocation of an ECTS credit bonus, at the discretion of the jury awarding the diploma.

4 - Practical examples of interactions

A few examples are briefly described to illustrate the proposed approach with the use of public inspection documents as a teaching aid to confront, validate and complement the knowledge and competency of process safety.

4.1 – Example ANTARGAZ, Bourogne (90)

A company has been authorized to operate an LPG relay depot, Seveso high upper tier, with a 400 m³ underground tank in an industrial zone in an urban area with a site supply capacity of around 16,000 t/year. The site was mainly supplied by private railway and, to a lesser extent, by road. The permanent presence on site of three tank wagons, each filled with 45 m³ of LPG and parked on the railway line, had been accepted and recorded.

During the subsequent implementation of a Technological Risk Prevention Plan (PPRT), it was envisaged to examine the operating conditions that would allow the site to be decommissioned to Seveso lower tier. Considering, on the one hand, the project of capacity reduction at the source and, on the other hand, the surrender of railway supply in favour of tank trucks with a capacity of 24 t by road, it was possible to meet the operating conditions of the site at the lower tier.

First of all, the pair of students highlighted the concept of "intrinsically safer process" implemented here with the principle of risk reduction at source. They also gave a detailed account of the specific requirements of the hazard study, which were a prerequisite for the decree approval of the Prefect classifying the depot as Seveso lower tier site.

During the oral presentation, an interesting question was asked. It was noted that the priority was given to the site safety, within the limits of the Internal Operation Plan and the Special Response Plan. On the other hand, in terms of territorial safety, particularly in the field of road transport, the impact of the noria of tank trucks carrying hazardous materials for the supply of the site would remain problematic.

4.2 – Example FINORGA NOVASEP, Chasse sur Rhône (38)

An organic fine chemicals company, operating several Seveso regimes A (authorization) and D (declaration) installations, submitted a dossier to the ICPE inspection concerning the

replacement of two refrigeration units operating with the refrigerant R22 by a single unit operating with 200 kg of ammonia.

After an interruption in the operation of the ammonia storage tank for more than 3 consecutive years, the initial authorisation of this installation thus ceased to have effect. Although the operator has made so-called non-substantial changes to its storage facilities, new, additional requirements have to be applied to them. For example, the engine hall of the ammonia refrigeration plant must be precisely located within the site boundaries according to the storage capacities limited to 50 kg of ammonia.

The pair of students first considered the concept of risk management assistance by retaining the principle of substitution of a substance. They noted the replacement of R 22 by ammonia. But they found that the application of this principle was not simple. In fact, in the present case, the observation of the potential destruction of the ozone layer by the non-flammable R 22 fluid led to the prohibition of its use. However, its substitution by ammonia can induce significant toxicity for the environment and an increase of the contribution to the greenhouse effect.

In addition, the complexity of the various technical considerations detailed in the hazard study for new ammonia refrigeration plants was commented on.

4.3 – Example CEA CADARACHE, Saint Paul lez Durance (13)

A Public Establishment of Industrial and Commercial character (EPIC) has submitted an application for authorization to operate outdoors the platform of a thermodynamic solar power plant in the form of a 55 kW prototype demonstrator designed to characterize all the technical aspects and the investment and operating costs of this process. This solar power plant, whose heat-transfer fluid is an organic oil, is the hot source of an Organic Ranking Cycle (ORC) machine, whose working thermodynamic fluid is ammonia. Thus, the unit makes it possible to

transform solar energy into electrical energy.

An initial operating campaign has shown the need to the deferred operation of the installation outside of sunny hours. This significant evolution of the initial design involves the addition of a heat storage unit (60 t at 300°C), bringing the new low tier Seveso unit (power plant and tank) to a floor area of 3600 m².

The pair of students considered that this teaching aid sheet allowed to simultaneously carry out an interesting synthesis of the knowledge acquired in chemical engineering (here, the thermodynamics of a compression-expansion cycle) and in process safety (hazard study). Three criteria of the working fluid performance were discussed: thermodynamic behaviour, safety (toxicity and flammability), environmental impact (global warming, ozone depletion, atmospheric lifetime). They also stressed that the platform operates without any carbon dioxide emissions, which is beneficial for the greenhouse effect, without any other atmospheric gaseous effluent and almost without liquid effluent (200 L/year of organic oil).

4.4 - Example LUBRIZOL, Rouen (76)

The feedback from this example is special. First, its genesis deserves an explanation. Initially the pair of students had a choice of 42 establishments with upper tier Seveso status in the national data bank. Motivated by the significant resonance, activated by social networks, of the comments and reactions following the health and environmental consequences of the major fire accident of 26 September 2019 in Rouen, the pair of students argued in favour of this choice.

Due to the constitution of the investigation file for the criminal investigation opened by the Public Health Unit of the Paris High Court, the teacher in charge asked the student duo to strictly limit themselves to verifiable factual data for this teaching aid sheet.

The studied plant which is classified as a Seveso upper tier plant, manufactures and sells chemical additives for lubricants, fuels and combustibles used in the automotive, marine,

aviation and industrial equipment industries. Four public documents of this plant are available in the national database. The Seveso public information sheet drawn up on 5 July 2017 mentions that the main hazard phenomena are fire, explosion and toxic dispersion. It is also noted that *"a fire could generate thermal effects on people and buildings"* and that the *"risk of accidents that could lead to a fire on the installations is relatively low (frequency can be assessed at most once every 10,000 years); this frequency is even lower for scenarios likely to generate effects off-site"*.

The minutes of the meeting of the Monitoring Committee of the "Rouen Ouest Seveso" site on 16 October 2019 mention the presence on site of 60 gas propane cylinders necessary for the operation of the forklift trucks. It also indicates that the site is adjoined over a length of 300 m by another company, specialising in warehousing, whose classification system has varied from a simple declaration (D) system to an authorisation (A) system and is currently subject to registration (E). The two companies share substantial storage and warehousing space in buildings and outdoors.

The student pair voluntarily supplemented their publicly available documentation by successively reviewing the risk assessment report prepared by FM Global Risk (Manach and Saenz, 2019) and the Ministerial inspection report (Chevet et al., 2020). The couple of students retained a limited number of interesting elements, extracted from documents accessible to the public, in their summary sheet on safety teaching aids:

- The knowledge of the stored products and their quantities is essential. The prerequisite for the storage of combustible chemicals involves the mandatory and rigorous examination of MSDS safety data sheets. Updating the inventory status is necessary for each entry and exit movement. The establishment of the respective product-product and product-material incompatibility matrices is recommended.
- The issue of possible underestimation of the fire hazard on the storage of non-flammable

fuels has been highlighted by the revision of their Classification, Labelling and Packaging regulation (CLP) according to flash point and boiling temperature. In this case, the major fire accident mainly concerned the storage of liquids with a flash point above 93°C, but also combustible liquids with a flash point between 60°C and 93°C.

- The review of the conditions necessary for the initiation of a fire involving non-flammable fuels made it possible to examine several potential scenarios, present or omitted, in the hazard study, which could have led to the hazard phenomenon.

- The thermal behaviour of intermediate plastic containers IBCs that can be stored in a stack was studied. In the presence of a proximity fire, the loss of containment due to the puncture and melting of their casings under the effect of thermal radiation could lead to the ignition of the fuel escaping from the IBCs. The flammable liquid would spread over the ground and create a large pool fire. Due to insufficient separation of the spaces and the lack of adequate containment and drainage systems, this pool fire would spread rapidly throughout the space, both indoors and outdoors.

- Finally, the complex question of the role of domino effects by fire escalation phenomenon between the storage facilities of neighbouring establishments was simply evoked.

4.5 - Example ARKEMA, Saint Avoird (57)

A company proposes to operate a new 250 m³ overhead storage tank for heavy flammable products on a pre-existing farm authorized for the storage of specialty products. These liquids are distillation residues from heavy acrylic ester production units. These first category flammable liquids are stored temporarily before disposal in an approved treatment centre. The tank is placed in a retention basin with a capacity of 728 m³. The tank is equipped with a vent sufficiently dimensioned to avoid pressurization of the capacity. The top of the tank is connected to a VOC collector. They are abated in a scrubbing column at 98% efficiency. A sprinkler crown is present to fight the fire. The respective minimum distances between the

other tanks in the park and between the edges of their retention basins have been set. A detailed set of various risk management measures (RMM), in particular the instrumentation of the tank sensors, is described in the hazard study.

The pair of students examined in particular the system for collecting VOCs at source and the network of pipes for these emissions in compliance with health and safety rules. In particular, the prevention of the risks of fire and explosion of the entire collection network was studied in a transitional regime.

The basic PID diagram of the tank - retention basin assembly was also sketched out from the detailed list of RMMs.

46 – Example AXENS, Salindres (30)

A company operating a plant of catalyst manufacturing has applied for an authorisation to set up a new catalyst impregnation line as an extension of the existing installations on the same geographical site. It will mainly produce hydrotreating, hydrogenation, sulphur recovery (Claus process) and mercury recuperation catalysts.

The line will comprise:

- a section for unloading raw materials and preparing impregnation solutions,
- an impregnation section,
- a drying/calcining section,
- a storage and packaging section, including buffer hopper and IBC big-bag packaging station,
- air effluent treatment devices (bag filters, washing column, treatment of nitrogen oxides by catalytic reduction, thermal oxidation for VOCs).

The thermal power of the drying, calcination and thermal oxidation equipment will be 6,290 kW. The workshop will also have an air-cooling tower. The workshop will also include a storage area for liquid raw materials. The area will also use a multi-product dumping area. The internal circulation routes of the area will be equipped with gutters connected to a sump.

The liquid effluents will then be directed to the treatment plant of the facility. The finished products will be stored on the edge of the workshop production line and on the other existing storage areas of the site. Existing storage areas that were initially at the site of the future workshop will be relocated to other existing storage areas.

The summary of the hazard study indicates that the main hazard potentials of this extension are related to the presence of:

- flammable liquids with fire and explosion risks,
- combustible powdery solid products that could generate an explosion if suspended, and under special containment conditions,
- toxic gaseous products (ammonia, sulphur dioxide, etc.) or products with explosion risks (natural gas, hydrogen, etc.),
- certain oxidized metal dusts used may exhibit some toxicity, if entrained in fire fumes,

Finally, the liquid products used mainly present risks of water and soil pollution (acids, bases, metal solutions, etc.).

The pair of students had the opportunity to simultaneously consult the environmental authorization order issued by the Prefect for the operation of the new unit, the corresponding ICPE inspection report and a large part of the Hazard Study, whereas most often only the non-technical summary of the latter is available to the public.

Due to the amount of information available, the teacher in charge had to moderate the content of the Safety Teaching Assistance Report.

Classically, the pair of students selected :

- the assessment of the risk control approach carried out through the RMM regulatory matrix grid, which includes three types of risk zones,
- the evaluation of ATEX zones for flammable products and dusts.

More specifically, in addition to their basic knowledge of process safety, they were interested

in:

- the prevention of noise, vibrations and light emissions in a regulated urbanized area,
- the often little addressed or neglected inventory of human aggressions generated by the environment of the site and neighbouring industries, by falling aircraft, by accidents of traffic external to the site,
- the list of naturally occurring hazards such as winds, earthquakes, lightning, floods, ground movement, vegetation fires, etc.
- the risk of legionella proliferation in cooling circuits and air-cooling towers and the risk of air pollution by sending legionella into the water vapour, following a potential contamination of a tower.

5 – Conclusion

An assessment of this first pedagogical experience of using official public documents published by the DREALs as an aid to teaching process safety has been carried out.

Safety is an interdisciplinary subject. In practice, chemical and process engineers have to consider complex situations involving different disciplines. At ENSIC Nancy, the horizontal integration of knowledge and expertise is promoted by the systemic model of hazard. The full course dedicated to teach process safety is carried out using lectures, tutorials and a combination of teaching tools. Among these, the innovative experience of analyzing public inspection reports of Seveso establishments has proved to be an interesting teaching aid. The two expected outcomes of this pedagogical approach are respectively:

- The main outcome consists of revisiting the concepts of process safety in the industrial reality of the inspection reports, such as for example fire, explosion, dispersion...
- The appropriation of the second outcome is more difficult for students. It is proposed to identify and research the interaction links between the concepts of process safety and basic

knowledges in chemical engineering. For example, show that the study of thermal runaway involves the knowledge of reaction kinetics, thermodynamics and heat transfer. In the same way, verifying that the implementation of Risk Management Methods implies, among other things, some solutions of process design such as the practical realization of intrinsic safety principles, of the design of barriers...

An anonymous satisfaction questionnaire was proposed to the two cohorts of voluntary students, at the end of the pedagogical sequence, including four levels of appreciation to avoid the possible bias of the choice of the median level of a grid with an odd number of ratings. The 4-scale in which 1 point is assigned to the response “Acceptable” and 4 points is assigned to “Very good” was used. The submitted question was: “I found that the public inspection reports were useful as teaching aids in illustrating some process safety principles”. The responses and the average scores of the two cohorts of students for the question are presented in Table 2.

Table 2 – Frequency responses (%) and average score (point) of the two cohorts of students.

The clear majority of students either agreed or strongly agreed with the question. The two graduating classes are satisfied with the teaching experience. This result is not surprising, as the students participated voluntarily in the proposed exercise. However, on the one hand, the satisfaction index of the cohort #2 of apprenticeship students is higher than that of the cohort #1 of initial training students because of their previous industrial experience. On the other hand, this cohort #2 had been offered, during their previous sandwich course, a simulation exercise asking them to register their host industrial establishment in the plethora of French regulations on ICPE.

Both classes emphasized the fruitfulness of the discussions that took place in front of the class after the short oral presentations of the studied examples.

It should be noted that the reading and analysis of the public inspection documents by the

students were mainly carried out according to the inspection angle #1 (Figure 2) by favouring the operational management of identification and evaluation of risk control.

Following a Seveso inspection, public inspection reports and in particular notification letters are prepared by the DREAL and officially issued by the departmental prefect. They are read in order to give an account of the priority given to the corrective approach before a repressive approach. In practice, the corrective approach consists of negotiating agreements between the ICPE inspector and the company with respect to the actions to be taken and how to comply with these agreements. In this way, the students can integrate that the control of ICPEs is based on a negotiation between the inspector and the operator. This negotiation attempts to reconcile conflicting interests, including the maintenance of economic development, in a discussion between the controller and the controlled entity. The compromise leads to finding negotiated solutions for compliance with the requirements applicable to an installation, prior to possible prosecution.

The difficulties of this first experience should not be evaded. The students often found that the national public database "Georisques" lacked updating and/or was sometimes poorly documented.

They also noted the lack of access to certain documents due to the application of the Government Instruction of 6 November 2017 on the availability and conditions of access to potentially sensitive information that could facilitate the commission of malicious acts in facilities classified for protection (security).

Similarly, the consultation of public reports from Site Monitoring Committee (CSS) meetings is often disappointing. Normally, CSSs should be major sources of information on ICPEs and should participate in the development of a local and industrial culture of safety. The two authors, members of several CSSs as qualified persons, have experienced the quiet,

formalistic, chamber-like functioning of these bodies in a rather bureaucratic climate. It results in very administrative written reports, where the technical annexes mentioned and listed are not attached to the public consultation.

In terms of learning from company inspectorate, in each major international industrial group, the organization chart shows an “Hygiene– Safety and Environment” (HSE) department, within which there is an "Inspectorate" entity, whose inspectors are accredited internally. However, the inspection reports that are produced for the management are not available to the public.

Nevertheless, the overall assessment of this educational experience has enabled a critical reading of the public ICPE inspection documents and reports. This intellectual path led the students to evaluate the quality of their contents and to formulate a well-founded opinion, in order to allow, in terms of process safety, a useful interaction of their basic knowledge with these potential help sheets for teaching process safety.

It is also possible to express the hope that this synthesis will lead some students to devote themselves to the ICPE inspection professions by applying in France for the annual recruitment competition and/or by participating in Europe in the implementation and standardisation of inspection practices during mutual joint visits.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily represent those of others.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Glossary

ATEX Explosive Atex area

BRGM Bureau des Recherches Géologiques et Minières (Geological and Mining Research Bureau)

CEA Commissariat à l'Energie Atomique et aux Energies Alternatives (Atomic Energy and Alternative Energies Agency)

CLIC Comité Local d'Information et de Concertation (Local Information and Consultation Committee)

CLIS Commission Locale d'Information et de Surveillance (Local Information and Monitoring Commission)

CLP Classification, Labelling and Packaging

CPGE Classes Préparatoires aux Grandes Ecoles (Preparatory Classes for entrance to High School)

CSS Commission de Suivi de Site (Site Monitoring Commission)

CTI Commission des Titres d'Ingénieur (French Commission of Engineer Titles)

DREAL Direction Régionale de l'Environnement, de l'Aménagement et du Logement (Regional Direction for the Environment, Planning and Housing)

ECTS European Credit Transfer System

ENSIC Ecole Nationale Supérieure des Industries Chimiques (National Higher School of Chemical Industries)

EPIC Etablissement Public à caractère Industriel et Commercial (Public Establishment of Industrial and Commercial character)

HSE Health Safety and Environment

IBC Intermediate Bulk Container

IChemE Institution of Chemical Engineers

ICPE Installation Classée pour la Protection de l'Environnement (Installation Classified for the Protection of the Environment)

INERIS Institut National de l'Environnement industriel et des Risques

LPG Liquefied Petroleum Gas

MSDS Material Safety Data Sheet

ORC Organic Ranking Cycle

PACA Provence Alpes Côte d'Azur

PID Piping and Instrumentation Diagram

POI Plan d'Opération Interne (Internal Operation Plan)

PPI Plan Particulier d'Intervention (Special Response Plan)

PRRT Plan de Prévention des Risque Technologiques (Technological Risk Prevention Plan)

RMM Risk Management Measures

VOC Volatile Organic Compounds

References

- Amyotte P. R., 2013, Process safety educational determinants, *Process Safety Progress*, 32 (2),126-130.
- Benintendi R., 2016, The bridge link between university and industry: a key factor for achieving high performance in process safety, *Education for Chemical Engineers*, 15, 23-32.
- BRGM, 2019, Base de données Géorisques, Ministère de la Transition Ecologique et Solidaire, <http://www.georisques.gouv.fr>
- CCPS AIChE, Collection of Safety guidelines, <https://www.aiche.org/ccps/ressources/publications>.
- Chevet P. F., Homobono N., Michelet P. and Schmitt A., 2020, L'incendie "Lubrizol/ NL Logistique du 26 septembre 2019 à Rouen (F) – Eléments d'analyse et propositions de suites à donner, Rapport n° 013014-01, Ministère de la Transition Ecologique et Solidaire (CGEDD), Ministère de l'Economie, de l'Industrie, de l' Energie et des technologies (CGE). <http://www.cgedd.developpement-durable.gouv.fr/l-incendie-lubrizol-nl-logistique-du-26-septembre-a2910.html>
- Crawley, F. K., 2014, Notes on safety and loss prevention-safety engineering, University of Strathclyde, Department of Chemical and Process Engineering.
- Crowl D. A. and Louvar J., 2002, *Chemical Process Safety: Fundamentals with applications*, Third ed. Prentice Hal, Boston, USA.
- CSB videos, <https://www.csb.gov/video>
- Dee S. J., Cox B. L., Ogle R. A., 2015, Process safety in the classroom: the current state of chemical engineering programs at US universities, *Process Safety Progress*, 34 (4), 316-319.
- Gabas N., 2010, Teaching safety in a French engineering school: experience of ENSIACET, In: *European workshop on teaching safety in chemical engineering*, Manchester, UK.
- Hill Jr R. H., 2016, Undergraduate need a safety education, *Journal of Chemical Education*, 93, 1495-1498.
- Kletz T.A., 1993, *Lessons from disaster*, IChemE, Rugby, UK.
- Kletz T. A., 2001, *Learning from accidents*, Third ed. Gulf Professional Publishing, Oxford, UK.
- Kletz T. A., 2009, *What Went Wrong?* Fifth Ed. Butterworth-Heinemann, Berlin, Germany.
- Kletz T. A. and Amyotte P., 2010, *Process Plants: a Handbook for inherent safer design*, second Ed. CRC Press, Boca raton, USA.

- Krause U., 2016, Process safety in engineering education – pro's and con's of different approaches, *Chemical Engineering Transactions*, 48, 871-876.
- Laurent A., 2011, Safety of chemical processes – Basic Knowledges and risk assessment, second Ed. Tec & Doc Lavoisier, Paris, France, in French.
- Lemkowitz S. M., 1992, A unique program for integrating health, safety, environment and social aspects into undergraduate chemical engineering education, *Plant Operations Progress*, 11 (3), 140-150.
- Leveneur S., Vernieres-Hassimi L. and Salmi T., 2016, Mass & energy balances coupling in chemical reactors for better understanding of thermal safety, education for Chemical Engineers, 16, 17-28.
- Manach P. and Saenz C., 2019, FM Global risk report, All in One Regular Risk Evaluation, index FRB 028.00-01. The Lubrizol Corporation <https://www.urps-infirmiers-normandie.fr>
- Mannan S., Akgerman A., Anthony R. G., Dary R., Eubank P. T. and Hall K. R., 1999, Integrating process safety into ChE education and research, *Chemical Engineering Education*, Summer, 198-209.
- Mannan S., 2012, *Lees' Loss Prevention in the process Industries*, Fourth Ed. Elsevier Butterworth-Heinemann, Oxford, UK.
- Meyer T. and Reniers G., 2016, *Engineering Risk Management*, Second Ed. De Gruyter, Berlin, Germany.
- Meyer T., 2017, Towards the implementation of safety education program in a teaching and research institution, *Education for Chemical Engineers*, 18, 2-10.
- Meyer T., Reniers G. and Cozzani V., 2019, *Risk management and education*, Ed. De Gruyter, Berlin, Germany.
- OJEC, 2001, 331/EC Recommendation of the European Parliament and of the Council of 4 April 2001 providing for minimum criteria for the environmental inspections in the Member States, OJEC n° L 118, 27 April 2001.
- PACA, 2020, DREAL, Les inspections en PACA (Provence – Alpes – Côte d'Azur), http://www.installationsclassees-paca.fr/paca_inspection/depart.php.
- Papadakis G. A. and Porter S., 1999, Guidance on inspections as required by article 18 of the Council Directive 96/82/ EC (Seveso 2), EUR 18692 EN, Institute for Systems Informatics and Safety.
- Perrin L. and Laurent A., 2008, Current situation and future implementation of safety curricula for chemical engineering education in France, *Education for Chemical Engineers*, 3(2), e84-e91.
- Perrin L., Gabas N., Corriou J. P. and Laurent A., 2018, Promoting safety teaching: An essential requirement for the chemical engineering education in the French universities, *Journal of Loss Prevention in the Process Industries*, 54, 190-195.

Pintar A. J., King J. A. and Crowl D. A., 1998, Incorporating process safety into the chemical engineering curriculum, In: Conference Proceedings, Process Plant Safety Symposium, Houston, USA (October 1998).

Pintar A. J., 1999, Teaching chemical process safety: a separate course versus integration into existing courses, In: Conference Proceedings, ASEE Annual Meeting, Charlotte (June 1998).

Pitt M. J., 2012, Teaching safety in chemical engineering: what, how and who? Chemical Engineering & Technology, 35 (8), 1341-1345.

Plot E., Moulin L., Fabre D., Kribi S. and Pannefieu D., 2019, Guideline for the inspection of the SMS in a Seveso upper tier establishment, INERIS, Report DRA-17-164428-03163B, Verneuil – en - Halatte (France).

SACHE, Safety and chemical engineering education

<https://www.aiche.org/ccps/community/technological-communities/safety-and-chemical-engineering-education-sache>

Schaible C. and Arditì M., 2013, A la recherche des informations sur les sites – DREAL – Base nationale ICPE – Base CEDRIC, Recommandations simples pour plus de transparence, Réseau Risques et Impacts industriels, Fédération Nationale de Protection de la Nature et de l'Environnement, Paris (France).

Schmidt J., 2013, Process and plant safety – research and education strategy to keep long term competences, Chemical Engineering Transactions, 31, 421-426.

Shallcross D. C., 2013, Safety education through case study presentations, Education for Chemical Engineers, 8, e12-e30.

Shallcross D. C., 2014, Safety shares in the chemical engineering class room, Education for Chemical Engineers, 9, e94-e105.

Vechot L., Casson V. and Olewsji T., 2014, Training future engineers to be committed to safety, QScience proceedings 2014, World Congress Engineering Education, 28, 1-8.

FIGURES

Figure 1 – Schematic illustration of a hazard study.

Figure 2 – Flowchart of the operating reading the regulations distinguishing three inspection angles of the framework.

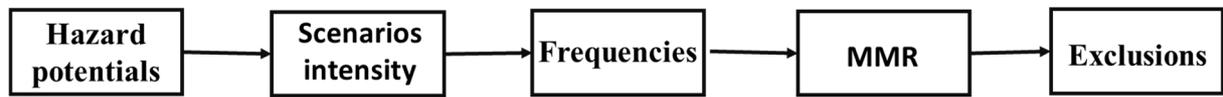


Figure 1 – Schematic illustration of a hazard study.

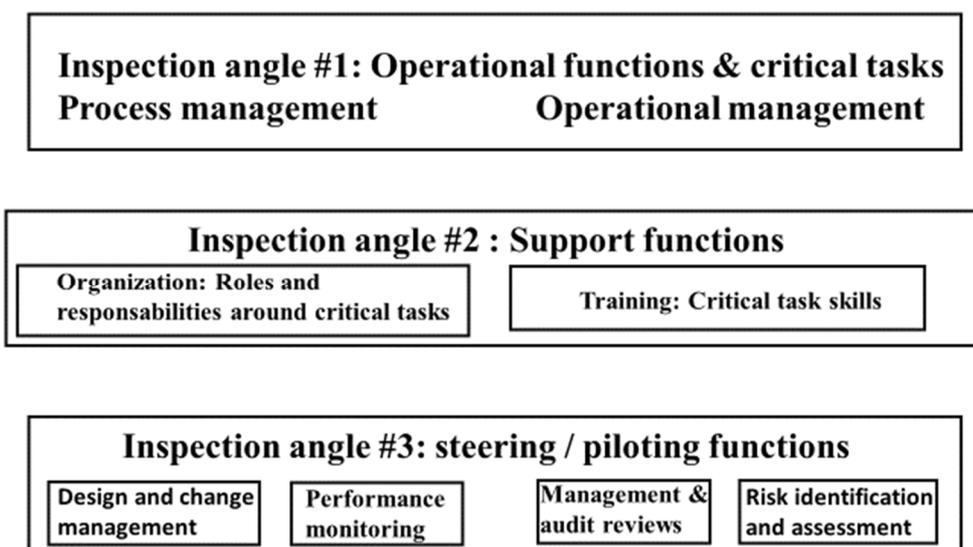


Figure 2 - Flowchart for reading the regulations distinguishing three inspection angles.

TABLES

Table 1 – Global distribution of the mandatory and elective courses of process safety - Master curriculum in the chemical engineering department ENSIC Nancy.

Table 2 – Frequency responses (%) and average score (point) of the two cohorts of students.

Table 1 – Global distribution of the mandatory and elective courses of process safety - Master curriculum in the chemical engineering department ENSIC Nancy.

| Semester | Mandatory course | | | Elective course | | |
|----------|---------------------------------------|------------|------|-----------------|------------|------|
| | Type | Volume (h) | ECTS | Type | Volume (h) | ECTS |
| 5 | Lectures I | 6 | 0.5 | | | |
| 6 | Lectures II | 6 | 0.5 | Lecture I | 12 | 1 |
| 7 | Lectures III | 18 | 1.5 | | | |
| | Tutorials | 6 | | | | |
| 8 | Lecture | 24 | 4 | Lecture II | 16 | 3 |
| | | | | Tutorials | 12 | |
| 9 | Research & development project | | 10 | | | |
| 10 | Industrial training course (6 months) | | 10 | | | |

Table 2 – Frequency responses (%) and average score (point) of the cohorts of students.

| Population | Answers | Acceptable % | Quite well % | Good % | Very good % | Average (points) |
|------------|---------|-----------------|-----------------|-----------|----------------|---------------------|
| Cohort #1 | 96/127 | 2.5 | 18.6 | 33.2 | 45.7 | 2.9 |
| Cohort #2 | 33/33 | 1 | 7.3 | 33 | 58.7 | 3.3 |