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Chemical Incidents at School: Could Data from Poison Information Centre fill Current Knowledge Gaps?

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Abstract

Children may be exposed to hazardous chemicals at school and according to the Swedish work environment legislation school environment constitutes a part of the work environment legal domain. Nevertheless, data on prevalence and severity of chemical incidents at school are incomplete in official statistics at the work environment authority. In this work we investigate what information on chemical incidents at school can be retrieved through call records of the Swedish Poisons Information Centre. Data from 648 incoming calls concerning children in school environment were extracted and analysed. The most common sites of chemical incidents were in unspecified school area (43 %) followed by laboratory work (38 %) involving boys (54%) and girls (40%). Most incidents were considered to pose minor (38%), moderate risk (52%) or major risk (8%) related to eye exposures of corrosive acids or alkali. Additionally, we completed ten semi-structured interviews with chemistry teachers regarding chemical safety and risk management. Several examples of deficiencies among schools were described and the interviewed teachers perceive chemical misuse and mishandling and large class size as the main cause of incidents besides lack of knowledge and experience among teachers. Required time and resources for safety are not given to the teachers. Data from PIC may serve as a source of information about accidental exposures to chemicals at schools and may serve as a complement to the official statistics. Also, there is a need for organisational support for the teachers, as restrictions in time and resources were major barriers to risk management.

Popular science summary

Do incidents with chemicals occur at schools you may think; how often and with what kind of substances in that case? Schools contain several hazardous chemicals for several purposes which children come in contact with. In Sweden, school work environment falls under the Swedish work environment legislation. Although schools' incidents should be reported to Swedish Work Environment Authority, they are not included in the reporting towards the official statistics. In the present work we investigate what information on chemical incidents at school can be retrieved through the call records of the Swedish Poisons Information Centre (PIC). During 2010-2014, PIC has received 648 calls regarding occupational incidents considering students in school environment. The records showed that several incidents occurred in unspecified school area followed by laboratory work. Most incidents were considered to pose minor, moderate risk. Major risk cases often concerned eyes exposures of corrosive acids or alkali. Additionally, the study was deepened in terms of laboratory work by interviewing chemistry teachers regarding chemical safety and management. The interviews showed deficiencies among schools concerning documentation of risk assessments and the culture of laboratory safety. Teachers perceive chemical misuse and mishandling, and large class size as well as lack of knowledge and experience among teachers as important causes of incidents. The teachers are taking chemical substitution and group dynamic into consideration for risk minimization and safer laboratory exercises. However, teachers need more organisational support, as restrictions in time and resources were major barriers to risk management.

List of abbreviations

AFS:	Statute book (Arbetsmiljöverkets författningssamling, Swedish abbreviation)
ICE:	International Chemical Environment
ISA:	Informationssystem för Arbetsskador, Swedish abbreviation
KRC:	National Resource Center for Chemistry Teachers (KRC in Swedish)
PIC:	Swedish Poisons Information Centre
SDS:	Safety data sheets
SWEA:	Swedish Environment Authority

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1. Introduction

Today school is our largest work-place with both staff and students and those have the right to a good working environment. At schools hazardous chemicals are used for both maintenance and teaching. Laboratory work designed to provide experience and knowledge concerning the properties, structures and reactions of chemicals which may involve hazardous moments. Chemistry experiments cannot always be risk-free and incidents/accidents occur daily, but the risks should be minimized by training and education in chemical safety and management [1].

Hellman et al.,1986 [2] looked at accident survey to investigate laboratory related accidents in Colorado institutions of higher education. Between 1966 and 1984, 574 accidents had been reported and 502 accidents occurred within chemistry buildings. More specifically, 81% out of 502 accidents occurred in teaching laboratories, 13% in research laboratories, 2% in manufacture rooms and remaining 4% occurred in other areas [2]. In October 2000 a survey was created among public schools in Texas in order to discover types of accidents among the schools. Among the responders, 36% reported 460 minor laboratory accidents during the last two years and 13% reported 85 major accidents which required health-care care over the last five years. In the survey from Texas, it was shown that the most common types of accidents were broken glass, heat burns and foreign material in the eyes, mostly considered as minor accidents [3, 4].

In addition to inadequate training many factors that contribute to laboratory accidents, includes lack of adequate safety equipment and overcrowded class rooms [4]. Studies have showed that teachers with advanced degrees and with many years of experience have fewer accidents compared to teachers with low teaching experience [5].

1.1 Swedish Work Environment Authority

The Swedish Work Environment Authority (SWEA) is a national authority responsible for work environment and that includes occupational health and safety including school environment. SWEA provide provisions clarifying the Swedish Work Environment Act (Swedish Parliament 1977), and they check that the provisions as well as the Work Environment Act are followed. They also do inspections on different workplaces including schools where they look at the work environment and check that laws and regulations are followed [1].

SWEA's requires a systematic written risk assessment of work and school duties including assessment of ill-health and accident in connection with lessons in e.g, craft, sport and health, home economics and laboratory work in chemistry and biology. According to SWEA's provision (Chemical Hazards in the Working Environment) the measures and safety equipment provided, chemical handling and storage must be appropriate to the hazards posed by the chemicals. The minors shall be introduced and informed about the obligations and the risks. Employers and principals have to make sure that the minors understand the given information and the meaning of it. School duties shall be performed under supervision of a teacher or a person with appropriate knowledge regarding risks and safety. It is forbidden for children under 18 years old to use chemicals that are respiratory sensitizer, carcinogenic, mutagenic and reprotoxic, that fulfil criteria under Article 36 of EU regulation (EC) 1272/2008 on CLP of substances and mixtures. This ban applies also to substances that are explosive, oxidizing or with flammable properties. However, such chemical agents may be used if the task is located in a school building arranged especially for teaching and is under the supervision of a teacher [6-9].

Employers are obligated to report accidents leading to injuries to the social insurance system, which in turn forwards these reports to SWEA. Reported accidents involving at least one lost day are enter into the ISA (Informationssystem för Arbetsskador, Swedish abbreviation) database, and make up the basis for Swedish official statistics. As school children do not report lost days to the social insurance system, they are not covered by ISA. However, the Swedish Work Environment Act also requires employers to report severe accidents and severe near-accidents directly to the SWEA (Swedish Parliament 1977). SWEA does not define severe accident; however, injuries to internal organs, burns covering >5% of the body surface, or accidents were several persons were injured are given as examples. Severe near-accidents are defined as near misses that could have caused severe injuries (anmalaenarbetsskada.se; 2017-04-24). These records are not publicly available. However, a survey of these records for 2012 to 2014 identified 37 cases of chemical exposures at school (Linda Schenk, personal communication)

Analysis of registered information of accidents makes up part of the authorities' work to identify areas of interest and inspection areas as well as information efforts [10]. There is an under-reporting issue with occupational injury and disease statistics making it incomplete. There may be many reasons of under-reporting of accidents, for instance the unclear definition of an accident. For instance, the degree of under-reporting has been found to be larger for less severe injuries [11]. Hence, SWEAs data on near-accidents is likely more affected by under-reporting than the accident data in ISA. Every second year, SWEA performs a survey among the population of working age where they investigate self-reported occupational injuries, including extent and cause of absence from work in order to target the under-reporting issue for occupational disease and injury [12]. However, such survey is not performed for students although they are considered as workers. Hence, as neither ISA nor occupational injury surveys cover schoolchildren there are no official statistics available on injuries incurred during school hours. Consequently, the currently available data seem insufficient as a basis for SWEAs management of chemical risks at schools.

1.1.1 School inspections

In 2005, SWEA had a project for safer laboratory work at schools. They audited 500 science facilities looking at preparation room and a review of the regulations applicable to laboratory work with chemicals, around Sweden at both elementary and secondary schools. Only 16 out of 500 schools covered the requirements for safety set by SWEA [13]. Although there were generally chemistry teachers with suitable competence within the area of teaching chemistry and knowledge regarding risks and safety some flaws were found respect to several management issues. Risk assessments were not properly documented, chemicals were found to be stored improperly, safety data sheets and instructions on safe handling of chemicals were missing. The class rooms as locals were found not to be functional, the size and space of science settings were inadequate. Several schools were performing laboratory work with large number of students (24-26 and in worse cases 30 students). Furthermore, a clear procedure for first aid could not be found, neither an access to a phone for emergency calls. Schools with occupational deficiencies were followed up where SWEA demanded to rectify certain occupational deficiencies within certain time period. A report on the inspections could not be found by the authority because it is not registered and by this reason not obtained despite repeated contact with the authority. A press release and a few inspections reports from individual schools were the only information received from the authority [13]. During 2013-2016, school inspections were carried out again auditing the work environment at 30% of the 6 000 elementary- and secondary schools around Sweden focusing on systematic work environment and not laboratory specific and noted some deficiencies regarding documentation of risk assessment but whether those were laboratory specific or not were not clarified in their report [14].

1.2 Swedish Poisons Information Centre (PIC)

Swedish Poisons Information Centre (PIC) is a service answering questions in case of acute poisoning. It was established in 1960 and is located at Karolinska University Hospital area. Since November 2009 PIC is a part of Swedish Medical Product Agency. Moreover, PIC is the Swedish National ICE (International Chemical Environment) Centre. There is only one PIC unit in Sweden serving the whole country. The PIC service is open twenty-four hours a day, seven days a week manned with educated pharmacists and physicians and connected to the national emergency number 112. The service is open to medical professionals as well as the general public. The service gives information on risks, symptoms and treatments and informs about the availability of antidotes in case of acute poisoning with different poisoning agents. PIC has their own database where all received calls are recorded [15]. During 2014 PIC received many calls concerning human poisonings/incidents (n= 76 811), 39 % of the calls were related to children <10 years and 8% concerned 10-19 years old. Most of the calls concerning humans came from the general public, followed by health-care personnel. The chemicals/chemical products most frequently involved in poisoning incidents among children<10 years included pharmaceuticals, cleaning products, disinfectants, pesticides, paint, household products. The poisoning incidents among adolescents 10-19 years included pharmaceuticals, cleaning products, fuel, gases and disinfectants [16]. The PIC annually reports a summary of their telephone consultations, but does not specifically report occupational exposures nor exposures related to school environment.

However, PICs receive numerous of calls regarding workplace exposures on a regular basis [17]. The PIC database is a potential source of information for exposures occurring at workplaces and can be used to increase the awareness of incidents and ability to identify relevant risk management measures. PIC gives the possibility to investigate exposure agents and specific products such as pesticides [18-19] or vulnerable groups such as workers in small enterprises [20] or adolescent workers [21-22]. The Swedish PIC database was recently investigated as a source to inform accident awareness at Swedish workplaces. In this work 9509 telephone sessions performed by PIC during 2010-2014 were identified concerning 8240 occupational incidents. The PIC data were found useful especially for identifying the nature of chemical hazards involved in occupational incidents and accidents. Also, the information on less severe incidents, not covered by any official statistics, was found valuable [23]. No example of PIC data used for investigation of chemical hazards at schools has been identified in the literature.

1.3 Aims

In the present work we investigate how the data of the Swedish PIC may be used as a means for surveillance and provided knowledge of incidents with chemicals at schools, as this source of information has not been used for this purpose previously. In addition, we illustrate incidents and the risks among Swedish schools more specifically in connection with laboratory work by interviewing chemistry teachers regarding chemical safety and management.

PIC records for the years 2010 to 2014 are studied with the objective to investigate how PIC data can inform us about accidental chemical exposures at school. Questions addressed are: Who calls (students, teachers, doctors…) the PIC in connection to incidents at school? Are there any differences with respect to age and gender among students? Which kind of chemical hazards are implicated? What are the exposure routes? How severe are these exposures? We also intend to describe teachers' views of safety, health and laboratory work environment. Based on the results we will propose recommendations for improved chemicals management at schools and identify future research needs.

2. Materials and Methods

2.1 Analysis of information in the PIC database

The records of Swedish PIC were from January 2010 to December 2014, containing approximately 400 000 calls regarding occupational incidents. These data are reported by general public, work-places, day-care, police, hospital, and primary care. Here, we searched all call records concerning children 7-19 years old (roughly n=752) using Excel's filter function and the keywords: "school*";" secondary*"," pupil"," teacher"," vocational training", "lesson", and "lab*". The incidents thus identified were subsequently examined individually to ascertain that they were school-related, leaving 648 after manual removal of duplicates and not school-related calls. The resulting database is outlined in Table 2.

The poisoning agents were categorized into different substance groups according to different chemical groups (alkali, acids, alcohols etc.). Information about the incident site was collected from the free-text fields but also from the category of poisoning agents which was logged as experiment, chemistry, chemistry-lesson, laboratory, and other types of teaching or/and activities. Based on this information the type of teaching situation was determined: Arts & craft, Home economics; Laboratory and Vocational. When not possible to determine teaching subject "School" was used.

In the PIC database there is a category named advice where personnel from PIC give advice on whether seek health- care or not. Three types of advice were observed in the current database, none/simple action; incident site, medical health care, health care advised treating the patient. In the current database advice were not given to all caller. For the interpretation of the remaining call records, information regarding the incident was collected from the free-text fields and from risk judgement category and missing advice codes complemented. Basically for incidents judged as minor risk was the advice none/simple action; incident site, and for major risk; to seek health-care. Moderate risk could receive either of these two advices. Those already in health care were coded as receiving treatment advice; health care.

The database was screened and checked for typos but also other types of errors before going further. Further, various types of tables were gained by using Excel (Version 2010).

2.2 *Interviews*

The findings from the analysis of the PIC database guided the design of the interview study. For instance, many incidents occurred during laboratory work through different routes of exposure involving different types of chemicals. Hence, we wanted to further study the infrastructure of laboratories as well as chemical safety and management at different schools in order to get an overview of schools and causes of incidents. Therefore, the interviews focused on chemistry teachers in elementary and secondary schools teaching students from 7-19 years old.

The participants were selected trough convenience sampling. Ten teachers from Stockholm or Västerås were interviewed; four worked at elementary schools and six at secondary schools. Both female (n=6) and male teachers (n=4) participated and they were in the age of 37-60 years old.
Interviews were semi-structured following an interview guide drawing on several issues regarding chemical safety in laboratory teaching, specifically:

- Teachers' knowledge and experience
- Awareness and previous experience of incidents or accidents.
- Awareness and fulfilment of risk assessment requirements
- Sources of information and knowledge of chemicals risks and safety measures Informant's approach to chemical risk- and safety management
- The culture of laboratory safety at school

The shortest interview was 20 min and the longest 49 min.

An additional set of two interviews were performed with staff from the National Resource Center for Chemistry Teachers (KRC in Swedish). This is a Centre supporting activities of chemistry teachers in Sweden for both elementary- and secondary schools, promoting and stimulating the interest and up-date the teaching of chemistry in Swedish schools. This Centre holds courses and education regarding chemical safety at schools around Sweden. The interviews covered the following topics:

- KRC views on chemical safety in the laboratory classroom
- The structure and outline of the chemical safety course
- Reported reasons for the teachers to take the course
- Reported concerns among teachers regarding risk- and safety management
- Teachers' awareness of available information sources on chemicals safety and risk management

All interviews were audio recorded and transcribed. The transcripts were analysed by repeated close readings and coded according to the structure of the interview guide. To improve reliability of results the analysis was discussed with a second researcher that had read and coded transcripts independently.

2.3 Ethical permits

Ethical permit was applied for the analysis of the PIC call records and approved (ref: 2015/1-31/5) by the regional ethical board in Stockholm, Sweden. Interviews did not collect sensitive personal data according to Data Protection Act 13 §, hence not requiring ethical vetting.

The teachers were informed about the purpose of the study and data collection and they were allowed to ask questions before the interview started. Informed consent and permission to record the interviews was collected from the teachers before the interviews.

2.4 Statistical analysis

Statistical analysis has been performed on PIC call records for an association using R, Version 2016 in form of Pearson's Chi-square test with cross tabulations where only the overall proportion of boys and girls were compared to different variables. The interviews were not statistically analysed, due to the limited participated size, not giving enough power.

Table 1:Description of PIC database extracted for the purpose of the present study including different variables and categories.

Variable	Categories
Date and year	-
Identity of the caller	• Preschool, school • Primary care, doctor& other • Hospital, doctor& other • Police, fire department • General public[b]
Route of exposure	• Eye • Skin • Inhalation • Ingestion • Several • Other (nasal and injection)
Age group	• Juvenile <10- 14 years • Adolescent 15-19 years • Unknown
Gender of exposed	• Girl • Boy • Unknown
Poisoning agent[a]	• Acids • Alkali • Hydrocarbons
Caller's question	• Free text field
PIC response	• Free text field
Advice	• None/simple action; incident site (mild symptoms to manage on site) • Health care advised (patients in health-care received treatment advice) • Seek health-care (severe symptoms which require health-care)
Risk judgement (based on exposure and symptom description)	• Major risk (were given the recommendation to seek health-care due to symptom severity) • Moderate risk (health care may be recommended and those already in health care receive treatment advice) • Minor risk (No to mild symptoms, none/ simple action on site given) • Not possible to determine (due to limited information about symptoms and exposure)

[a]Does not include all possible categories.
[b]Includes both exposed individuals that call PIC themselves, or calls made responsible adults (school teachers and nurse) or family member.

3. Results

3.1 Analysis of PIC database

Of the 752 call records from 2010-2014, 648 cases were included in the final database. The number of chemical incidents per year were rather stable during the examined period with an average of 130/yr. Calls were received from three main categories - school personnel (n=253), the general public (n=212, half of came from parents and remaining from school staff) and primary care (n=148) (Table 2). A clear association between genders and risk judgement was shown and which was statistically significant ($X^2_{(2)} = 11.73$, p=0.0028). Incidents judged as moderate-to-major risk were equally common between boys and girls. However, boys are over represented in less severe incidents ($X^2_{(1)} = 5.58$, p=0.018) resulting in a higher prevalence in total. We observed a slight shift from major risk incidents towards less severe risk incidents during the examined period of time. The numbers posing moderate-to-major risk decreased from 71 in 2010 to 53 in 2014.

The numbers of incidents identified in the PIC data were distributed to a similar extent among the two age groups representing elementary school (<10-14 years) and secondary school (15-19 years) (Table 2). Adolescents 15-19 years were involved in more incidents occurring during vocational training compared to the younger children ($X^2_{(1)} = 12.56$, p<0.001). Meanwhile, <10-14 years' olds were involved in incidents occurring during home economics($X^2_{(1)} = 47.03$, p<0.001) and school in general ($X^2_{(1)} = 11$, p<0.001) and fewer during laboratory work. Very few incidents were related to children younger than 10 years.

The most common sites of chemical incidents were in unspecified school area 43% (n=277) followed by laboratory work 38% (n=248) (Fig.1.), with given advice. More girls were involved in the incidents occurring during laboratory work ($X^2_{(1)} = 10.60$, p=0.001) compared to boys. Furthermore, Boys had a higher prevalence of incidents during vocational training and in incidents at unspecified school areas compared to girls ($X^2_{(1)} = 11.96$, p<0.001), explaining some differences between how boys and girls experience potential chemical incidents in different types of lessons.

The routes of exposure between the age-groups were statistically significant (Fig.2.). The most common routes of exposure for both age-groups were eyes. More specifically, the common routes of exposure among adolescents were inhalation($X^2_{(1)} = 9.33$, p=0.0023) followed by skin ($X^2_{(1)} = 7.54$, p=0.006) while ingestion for the juveniles($X^2_{(1)} = 25$, p<0.001).

Table 2. Overview of incidents concerning children and young adults, retrieved from PIC during 2010–2014. The incidents are presented for girls, boys and unknown patients individually and in total.

	Number			
	Boys	**Girls**	**Unknown**	**Total**
All cases	**353**	**256**	**39**	**648**
Cases per year				
2010	69	45	10	124
2011	69	57	5	131
2012	71	49	8	128
2013	70	63	7	140
2014	74	42	9	125
Age-group[a]				
Juvenile <10-14years	175	123	22	320
Adolescent 15-19 years	175	129	16	320
Caller				
Preschool, school	140	96	17	253
General public	121	85	6	212
Primary care, doctor& other	74	63	11	148
Hospital, doctor& other	17	12	4	33
Police, fire department	1	-	1	2
Risk judgment[b]				
Major risk	22	26	3	51
Moderate risk	168	150	16	334
Minor risk	151	79	19	249
Not possible to determine	12	1	1	14
Advice				
Treatment advice; health care	76	58	14	148
Seek medical care	70	66	6	142
None/simple action; accident site	185	125	19	329
Others[c]	22	7	-	29

[a] The age has not been recorded on eight cases
[b] The criteria of risk judgement are described in Table 1.
[c] Includes cases with unknown poisoning agents, interrupted calls, and calls with insufficient information

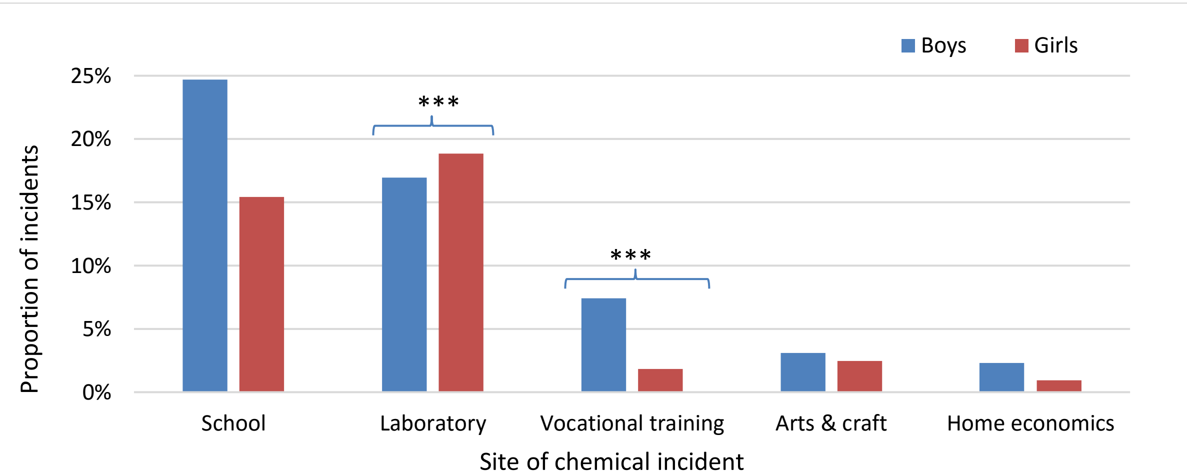

Fig. 1. Proportion of incidents and site of chemical incident including types of lessons and undetermined teaching "School" for boys and girls. Boys had higher prevalence of incidents in vocational training (p<0.001) and girls in laboratory (p=0.001).

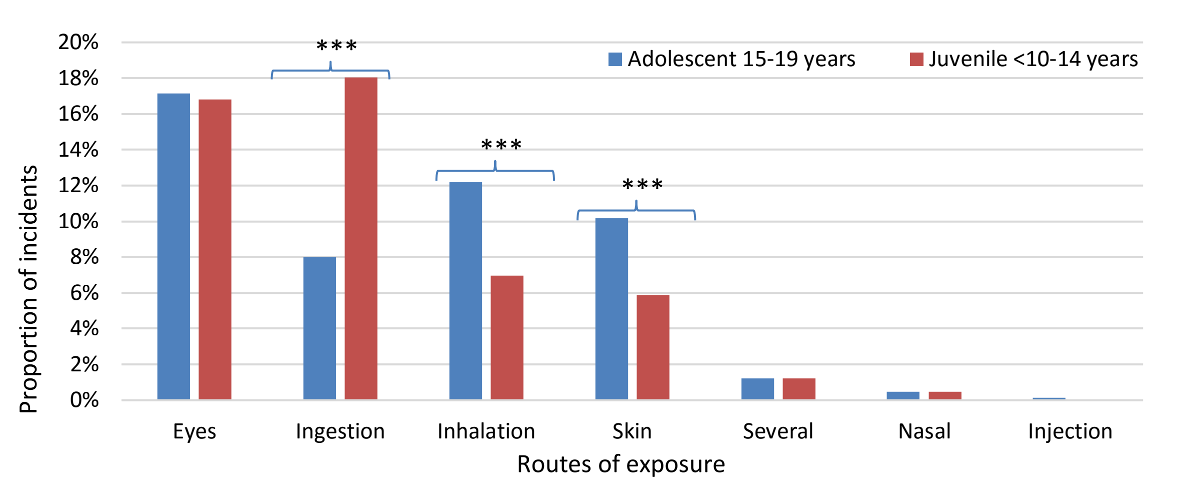

Fig. 2. Proportion of incidents per age-group and routes of exposure for adolescents (15-19 years) and juveniles (<10-14 years). The most common routes of exposure for adolescents were inhalation (p=0.0023) followed by skin (p=0.006), while ingestion for juveniles (p<0.001).

Table 3: Overview of exposure agents, categorized into different groups beside the routes of exposure with total number of cases obtained from PIC database analysis.

	Routes of exposure:						
Exposure agents	**Eyes 224**	**Ingestion 169**	**Inhalation 125**	**Skin 107**	**Several 16**	**Nasal 6**	**Total 648**
Chemicals/chemical products	63	50	21	24	1	2	161
Alkali	48	17	7	17	6	-	95
Hydrocarbons	24	17	12	9	-	1	63
Household products	18	29	3	12	1	-	63
Acids	17	3	13	27	3	-	63
Fumes, gases & vapors	5	-	50	1	1	1	58
Alcohols & glycols	27	19	4	5	-	-	55
Metals & metal compounds	11	24	2	11	2	2	52
Fire extinguisher	5	2	7	-	1	-	15
Unknown chemical	3	4	1	1	1	-	10
Pesticides	1	2	4	-	-	-	7
Pharmaceuticals	2	2	1	-	-	-	6[a]

[a]One case with injection as route of exposure was included

An overview of recorded exposure agents among the PIC records is described in Table 3 and more in detail in Appendix 1.

A statistically significant association ($X^2_{(22)} = 84.05$, p<0.001) between types of chemicals and risk judgement (major-, moderate-, and minor risk) were observed. Chemicals/chemical products such as cosmetics, tensides, etc. were the most common involved agents ($X^2_{(2)} = 12.94$, p=0.001) followed by different forms of alkali ($X^2_{(2)} = 23.01$, p<0.001). Other types of common exposure agents were hydrocarbons ($X^2_{(2)} = 8.85$, p=0.01), and acids ($X^2_{(2)} = 25.73$, p<0.001) in its various forms.

No confirmed severe cases could be identified in the database. However, several of the incidents were determined to pose a major risk (n=51). Approximately sixty percent of these major-risk incident involved corrosive chemicals and 16% were related to household products. Considering types of lessons (site of exposure), 57% of the more severe incidents occurred during laboratory work involving corrosive acids and alkali.

Cases with moderate risk (n=334) were dominated by corrosive and irritant substances. Exposure to irritant substances, tensides, cosmetics, hydrocarbons and many household products were generally considered to pose no or minor health risk.

3.1 Analysis of interviews

In the current study we have interviewed ten chemistry teachers at both elementary- and secondary schools and additional set of two interviews with staff from the National Resource Center for chemistry teachers.

3.1.1 National Resource Center for chemistry teachers (KRC)

KRC is a national resource center in Sweden where they hold courses in chemical safety for chemistry teachers once a year at Stockholm University. They also answer questions, give advice and develop new experiments.

Many chemistry teachers apply for the course because they have heard of it and feel the need for the course in safety or at the principal's request take the course at KRC but usually the chemistry teachers take it on own initiative. According to KRC teachers the teachers are aware of the available information and legislation that has to be followed but they do not have enough of time and resources for such work. Reportedly, the main concern among chemistry teachers when coming to KRC is risk assessment and documentation of those. The teachers have many demands on themselves and besides aiming and trying to fulfil the requirements; a major obstacle identified by KRC teachers was the lack of clear routines for documentation of risk assessments.

KRC teachers emphasized the importance of chemical knowledge. According to them the property of chemicals has to be discussed with students and they have to be aware of the properties before the chemical risk. Chemical- or other types of incidents/accidents have to be communicated and discussed with the students in order to pay attention and clarify errors during laboratory exercises or from their everyday life. The KRC teachers pointed out opportunities to learn from previous mistakes and from accidents/incidents, as opposed to only viewing accidents as something bad.

3.1.2 Teachers' background and risk management strategy

The participating teachers were found to be generally interested in chemical risk and safety management and this was probably a factor in their agreement to participate in the present study. The majority (n=8) of the teachers had a background as chemistry related professionals and had obtained their teachers' qualifications after a change in careers. Beside their previous professional experience these teachers had 4-17 years of working experience as chemistry teacher. The teachers generally consider it easy to determine chemical hazards and risks.

The most common risk mitigation strategy was to exclude hazardous chemicals from laboratory teaching activities and replace chemicals with less hazardous alternatives. Even though the teachers report this substitution mainly for minimization of the risks, some of them also stated that use of household chemical serves to enhance the understanding of chemistry in another perspective and put it into the context of everyday life.

3.1.3 Awareness and previous experience of incidents or accidents

When asked about incidents in the school chemistry lab in general, the teachers answered that the main cause of accidents/incidents is lack of knowledge and experience among the teachers. The teachers claimed that teachers in general are not aware of chemical risks and safety and may not be able to handle failures or chemical misuse. It was also pointed out that it is rather common with uncertified chemistry teachers among elementary schools but not among secondary schools. Teachers found that uncertified teachers do not have sufficient knowledge regarding chemistry and chemical safety. Another issue seems to be inadequate training among chemistry teachers resulting in fewer laboratory exercises. The teachers reported their own experience of experiment failures also considered as cause of incidents. They claimed that new chemistry teachers may be more involved in incidents when performing new experiments because those are inexperienced. The teachers reported previous experiences regarding types of incidents and the majority of them reported similar types of incidents. The main reasons for incidents were "sloppy students". Teachers found students to commonly forget safety instructions. For example, students get heat burns after touching hot test tube or cut themselves with scalpels.

The majority stated that they never had called PIC because of the job even though the majority of them had been involved in chemical incidents. Rather, they explained to have been able to manage the failures and incidents in the past thanks to their experience and knowledge regarding chemical safety and management.

3.1.4 Awareness and fulfilment of risk assessments requirements

The teachers stated that they do perform risk assessments before laboratory work referring to that every chemistry teacher is responsible for their own experiments and risk assessments. They claimed that the risk assessments are done properly but the majority of the teachers stated that they do not always use written risk assessments. The teachers interviewed in this study had different interpretation and opinions on written risk assessments. Some of them mentioned that written assessments will be when it is written on the board while others declared that it becomes written when present in the instructions received by the students. Teachers were aware of the requirements and that risk assessments should be done, which depends on the group dynamic and adapted to students' physical and psychological maturity according to SWEA's provisions. This differs between groups of students, and adjustment of it requires many hours which the teachers claim not to have. However, they clarified that they have risk assessments for some laboratory exercises but not for all.

The Act regarding documentation of risk assessment in writing is new according to an informant from KRC, and the KRC teachers find teachers to be aware of the requirements but do not have clear routines for it. "KRC teachers report that the rules and legislation considering a risk assessment have become stricter and the legislation has become clearer and the responsibility clarified. KRC teachers saw this as a positive development, although it is problematic to allocate suitable working time for the task.

3.1.5 Sources of information and knowledge on chemical risks and safety measures

The majority (n=7) stated that they have been specifically educated on chemical safety except from what they had been taught during their own education and they had taken the chemical safety course at KRC. All of the teachers claimed they have enough of knowledge and experience on chemical safety in order to prevent illness and incidents. Upon being asked who to call in case of an accident, most responded they would call national emergency number 112 to be forwarded to the proper phone service (such as PIC). Few (n=2) stated that they would call PIC directly in case of an incident. Moreover, a number of teachers (n=3) claimed that they would not call anyone, because in many cases may the school nurse has sufficient competence to take care of student injuries when required.

The teachers claim to be aware of and have access to safety data sheets for the chemicals they are using. However, they also stated that their safety data sheets are not regularly updated, safety data sheets as old as from 2002 were observed during school visits.

3.1.6 Organizational and infrastructural conditions

All teachers specified that safety equipment, including safety shower, eyewash and fume hood, are working well and that the function of those are inspected on a regular basis. The chemicals are generally stored properly, in ventilated and locked cabinets that only teachers can access. However, the teachers also told that there is not enough time to keep track of the chemicals in the chemical storeroom. Lack of time was given as the main reason for problems with correct labelling and adequate chemical registers. Hence, the organization does not sufficiently support safety in science education.

The students are generally provided with protective clothing including lab coat, goggles and sometimes gloves. Some teachers (n=3) explain that they prefer to work without gloves in relation to allergy reactions and that gloves sometimes give rise to a false sense of safety. Moreover, they argue that gloves make it more difficult to assess whether students have been exposed to chemicals through the skin when working with acids and bases. The teachers also avoid gloves when working with fire or hot objects. The students are aware of risks and in many cases they know how to act in case of incidents; how to alarm and call for help. All school laboratory facilities visited had an emergency first aid kit at a suitable place and there is fire-extinguisher in the classroom. However, only half (n=5) of the teachers reported to have a landline phone in the science facility for emergency calls. In many cases the lack of a landline was justified with all the students having their own mobile phones.

A major reason for incidents according to the teachers is too large classes resulting in poor overview of the students. For this reason, some teachers (n=4) reported to opt out on performing certain experiments and/or choose to do less laboratory work because they do not feel safe with the number of students and the group dynamic. The majority of teachers reported that groups of no more than 15-16 students allow for safe laboratory work. A number of teachers also specifically wished for a legislation limiting the number of students allowed in the laboratory classroom at one time.

3.1.7 The culture of laboratory safety at school

Instructions and information regarding risks and safety are reportedly given to the students through various means. Teachers state that the information transfer is contextualized through writing on the white-board, through laboratory instructions on paper, or by oral instructions. All of the teachers reported that the students are tested on their knowledge of laboratory safety and classroom rules before starting laboratory work to make sure that they have understood.

They noted that they have a written student safety and risk policy explained to the students and signed by them when they begin with laboratory work for the first time. In this way, the teachers acknowledge their understanding of the given information regarding safety and risks. The teachers stated that students receive information about pictogram and warning labels. There are currently two types of warnings labels that consumers have to be aware of, CLP- regulation is applied in parallel with the old legislation until 1 June 2017. Few of the teachers stated that they go through both of the warning labels. The majority of them do not go through the new labels because the majority of their chemicals are labelled with the old labelling symbols and those are present in the textbooks.

While students are given the protective equipment required for each laboratory, teachers report the equipment is not always properly worn. Lab coats are always used by the students and gloves when teachers think it is appropriate. The students are described as "casual" with wearing goggles, and they do not follow the instructions regarding the eyewear and therefore have to be reminded. One teacher stated that students often remove the goggles when cleaning the used equipment containing chemicals, which may result in harmful splashes to the eyes.

However, there are incidents occurring also during laboratory work and according to the teachers the main reason for that are the carless and badly behaved students. The students from time to time try "new experiments" by adding other chemicals or larger amounts than instructed. Consequently, teachers emphasized that it is very important to adapt the types of experiments considering the particular group currently being taught. The students behave differently within and not only between age groups according to the teachers.

4. Discussion

From the call records, 648 cases could be extracted concerning children and young adults in a school environment. The most common incidents were those occurring in unspecified school area followed by laboratory work. Overall, the numbers of incidents that are judged as minor risk have increased over the years, while incidents of moderate risk have decreased. The numbers of incidents were differently distributed between the genders and between the two age groups. However, the routes of exposure between the age- groups differed, where the most common routes of exposure among adolescents were inhalation and skin while ingestion for juveniles Fig. 2). In general boys were more involved in the incidents than girls. The inquiries considering adults' occupational incidents have increased during same time period shown by

Schenk et al.,2017 (manuscript) and they could also observe that males were more involved in the incidents compared to females consistent with what was shown in this study.

The numbers identified through the PIC database would correspond to an average chemical-incident-at-school incidence of 0.0087 % per year. More specifically, it corresponds to 0.009% for boys and 0.007% for girls on average per year in Sweden (population data from SCB)[24].

Studies have showed that teachers with advanced degrees and with many years of experience are involved in fewer accidents compared to inexperienced teachers and those with insufficient knowledge [10]. These statements could be confirmed by the teachers but there is no statistical data establishing those statements yet. The teachers had many years of experience regarding chemical safety and management as well as advanced degrees and therefore they had not been involved in many incidents. There may be uncertificated teachers among elementary schools but not secondary schools according to the teachers. Those have less academic background and are usually inadequately prepared. The main reason is teachers' termination and many times schools are forced to replace those with new teachers that are unqualified and inexperienced according to the teachers giving bad quality of science teaching. Previous studies as well as interviewed teachers pointed out that certificated chemistry teachers are not the main solution to the problem because certificated teachers alone are not enough in order to ensure sufficient level of safety in science classrooms, experience and given time are equally important [5]. The time and resources for safety education have to be given to the chemistry teachers. Moreover, chemistry teachers have to collaborate and support each other so that experienced teachers support less experience teachers at schools.

A major organizational constraint is lack of time. In general, the teachers do not have the opportunities and time for preparation of their science exercises due to other work such as new teacher assignment, planning of duties and scheduling of classes and others included in their daily work. The teachers are asked to do more and they have higher demands on their time and sufficient time is not given for safer science teaching. Teachers need more time in order to reinforce their knowledge and teaching practices and thus improve the quality of science teaching. Lack of time is also a cause for the lack of written risk assessments and bad laboratory safety culture explaining bad risk management among schools as observed in PIC call records. The schools do not always have documented risk assessments due to time restrictions even though they are aware of the requirements set by SWEA. This has also been shown by SWEA at school inspections over the years. The interviewed teachers confirmed that teachers do not have sufficient time and routines for writing risk assessments. The teachers agreed on the importance of risk communication with the students, and the importance of knowledge regarding chemical properties in connection with their everyday life. The teachers are aiming for safer work environment for the students by informing them about risks and safety, and they are taking chemical substitution and group dynamic into consideration but still expressed that organizational obstacles hampered their work with chemical safety

West, Westerlund et al., 2001[4] has identified a number of factors contributing to incidents in the chemistry lab such as, inadequate chemical management, safety training, overcrowded class rooms and inappropriate class size [4]. The class size has changed over the years in Sweden and in many schools around Sweden, several students are performing laboratory work at the same time; it may be between 24-26 students and 30 students in worse cases [1,13]. The frequencies of incidents increase with increased number of students in one science class at one time [4]. This issue was also raised by the teachers in the present study, making them feel unsafe when performing laboratory work because it is too crowded. Teachers even specifically requested legislation limiting the number of students allowed in the laboratory class room at one time.

Lack of adequate safety equipment was another factor identified by West, Westerlund et al., 2001[4]. Today in Sweden, students are provided with protective equipment including goggles, lab coat and gloves. The main problem is many time not the availability of protective equipment but faulty or inadequate use of those [4]. The students have to be reminded of protective eyewear and they do not constantly follow the instructions according to the interviewed teachers. The analysis of the PIC data revealed a large number of eye exposures, both during laboratory and vocational training, indicating that safety glasses are not always properly used.

Our PIC data analysis clearly shows that incidents are occurring at school and especially during laboratory work. Many are likely a result of misuse and mishandling of chemicals as well as faulty use of protective equipment. The number- and site of incidents were differently distributed between genders and age groups. This may be explained by differences in choice of educational orientation but also by behavioural factors. While behavioural factors are not investigated in the present work, we see that the nature of hazards differs depending on type of education. The exposures to acids occurred mainly during laboratory work and alkali during vocational training. Exposure to acids and alkali were generally considered to pose a moderate or major risk and in need of health-care by PIC experts.

All of the incidents and deficiencies among Swedish schools could not be covered by the interviews and therefore not consistent with what we have seen with PIC data analysis. Our sources for data collection can be seen as complement to each other, as each of them provided us with different types of information. The main routes of exposure seen by PIC were eyes followed by skin, and when we asked the teachers about eyewear and gloves they claimed that students not always use those consistently and they have to be reminded. The same with types of chemicals, where we have seen that acids and alkali are the most common poisoning agent in our database but according to the teachers they generally choose to not use hazardous chemicals. They rather use household products with the same chemical property as the traditional one. These discrepancies may be due to the low number of teachers in this case and/or that our recruitment procedure resulted in particularly informed and interested teachers, making them a kind of golden standard compared to teachers not agreeing to participate in this study.

SWEA has done several school inspections over the years, during 2005 where they had a project aiming for safer laboratory work at schools and observed inadequacy among schools regarding laboratory safety. Later, during 2013-2016 performed other school inspections focusing on systematic work environment management and not specifically laboratory safety and noted some deficiencies regarding documentation of risk assessment but whether those were laboratory specific or not were not clarified in their report. SWEA has to increase the communication with schools and get deeper understanding of the shortcomings. Those reasons have to be taken seriously because it is affecting the students and might increase the risk of incidents if not resolved. Safe work environment is the responsibility of schools, whose managers need to give time and resources to the teachers in order to create a better occupational health and safety in laboratories.

We have been able to identify 648 incidents among schools, incidents that SWEA may not be aware of, as reporting according to the work Environment Act seemingly only covers 37 incidents (Linda Schenk, personal communication). PIC is very helpful in the sense of supporting first responders including public, work-places and health care personnel for agent(s) determination, but also for preventing and giving treatment advice. In addition, PIC gives the possibility of location findings facilitating where the exposure(s) took place making it easier for determination of occupational exposures- and settings. PIC annually publishes a report on number telephone inquiries during one year, age distribution of exposed and types of chemicals involved. They do not report occupational exposures in their report, consequently also no incidents happening at school. We would encourage the PIC to report also the data concerning occupational and school related exposures; because this kind of data is incomplete in the official statistics and such data would be useful for SWEA.

Hence, collaboration between SWEA and PIC would be beneficial. SWEA should put great emphasis on the chemicals appearing at the science classroom besides followed laws and legislation and more school inspections focusing on safer laboratory work are needed. Exposures to chemicals occur daily in all parts of the school not only during laboratory work and it should be taken seriously. Students are exposed to different types of chemicals such as acids and bases through different routes of exposures with major risks as seen during this study. Not all of the incidents involving children are reported to SWEA although many seem severe enough to require such reporting, such as eye exposures to alkali or/and acids or when several students are exposed/or could be exposed. Incidents occurring at school may not always prompt a call to PIC either because most of the incidents may be taken care by the teacher or school nurse, as suggested by the teachers. For this reason, it is likely that the PIC records still present a major under-estimate of chemical incidents at school. This issue has been shown and discussed previously by several researchers in relation to work injury reporting for adults [11]. In previous study Schenk et al,2017. (manuscript) presented an overview of call records to Swedish PIC 2010-2014 where they could identify 8240 occupational incidents concerning adults, and the number of incidents were found to be higher compared to the official injury statistics [23]. At present we are not aware of any previous studies specifically treating the under-reporting of chemical incidents at schools.

*4.1 **Applied methodology***

Mixed methods research was applied for the current study by combining quantitative and qualitative research approaches. This approach provides rich datasets and gives in-depth information and broader perspective of the issue and more data can be collected by using two types of methods. The integration of qualitative and quantitative results is the main challenge in this type of approach because the collected data has to be completed into a meaningful contact which takes much effort.

It is first time where data from Swedish PIC has been used for this kind of study and consequently the current study was an exploratory study in order to identify chemical incidents at schools rather than hypothesis-testing study.

4.1.1 Strengths and weaknesses of this study

In this study chemistry teachers were interviewed where different questions were posed. There are both limitations and strengths of interviews as a data collection method. The strength is the large basis in reality; the collected material is rich, detailed and in-depth despite a limited participation size. A survey could have been applied but data collection by interviews can in many situations be better than surveys although survey reach a larger population as interviews give opportunities to pose context-dependent follow-up questions. Furthermore, the teachers are able to ask for clarification, allowing more complex questions to be posed. In surveys, complex questions may not be answered at all or may be answered randomly. The author visited schools for the interviews which allowed visual inspection of the science classrooms, the availability of safety and protective equipment, documented risk assessments and safety data sheets.

The difficulty of replication is one limitation, because the interviews were semi-structured following an interview guide. First, there are different ways to go for forming an interview guide drawing on several issues which depends on author's interest. Secondly, the semi-structured nature makes is interview context-dependent. Furthermore, the interpretation of the results obtained by the interviews may be different depending on persons and the interest as well. The obtained results may be difficult to generalize and apply to other types of environment and the results may not always represent the whole country limited number of and non-randomly selected participants.

The reliability and validity is high in PIC database and considered as the main strength and obtained results may be replicated. Occupational exposures- and settings may be found using PIC data. A major strength is that PIC experts have access to an extensive database on product ingredients and have received a targeted training in clinical toxicology, improving reliability of assessment of chemical hazard and risk. Despite this there are some limitation factors of PIC call records. Calling to PIC in case of chemical exposures is voluntary and not everybody calls to PIC as confirmed by the interviewed teachers, making the database not comprehensive. By this reason PIC data may not provide hard number of incidents, but only an indication of the types of incidents and relative frequency of those. The database contains some incomplete calls such as interrupted calls or calls with lack of information. Furthermore, the recorded data is based on the callers' self-reported exposure and symptoms. The telephone consultations are done by several PIC experts, and although they receive special training in coding of cases, there are differences in recording between PIC experts.

4.2 Ethical concerns

As PIC data in a few instances contain personal data, ethical permit was applied for the analysis of the PIC call records and approved by the regional ethical board in Stockholm. Any personal identifiers were removed from the database excerpt used in the present study. Interviews did not collect personal data except for the name and age of the teachers, hence not requiring ethical vetting. However, informed consent was obtained prior the study making it possible to give proper information regarding the study and to increase the ability of free choice of participation. The informed consent allowed participants to play a collaborative role in the decisions regarding their ongoing participation. The names of the teachers and schools were confidential and the confidentiality of the data was ensured and respected in this study.

4.3 Societal perspectives

Good health, wellbeing and safe work environment is important for the students. Safety is important aspect at school, especially in today's complex and demanding educational settings as well as increased number of hazardous chemicals in the environment. Students have higher demands at schools than before; they shall know and gain knowledge regarding several processes and are taught in different subjects handling several chemicals which might be hazardous to them. Hence, chemical safety and management have been improved and prioritized. When inspecting schools, SWEA are not looking at chemical incidents directly, they rather identify inadequate safety equipment or even lack of protective or/ and safety equipment which could lead to incidents. In this study we analysed chemical incidents and involved chemicals, i.e. cases when insufficient safety management has manifested in accidental exposures. Hence, this study may be seen as a complement to SWEA's school inspections where we have identified types of incidents and chemicals involved. In addition, the interviews with teachers focused specifically on chemicals safety issues, and offer a more detailed view on strategies for safe chemicals handling in the lab as well as organizational obstacles identified by these teachers. The results from this study could be used to design information and intervention efforts. Furthermore, this study shows that there are more incidents taking place each year than are reported to the SWEA and that data from the PIC could be used to complement our knowledge about the nature and severity of accidental chemical exposures at school.

4.4 *Future research and developmental needs*

PIC data may be useful for SWEA for the purpose of monitoring of school exposures. In the future this type of information should be used in larger extend than it is today. Incidents occurring at schools are not included in the reporting towards the official statistics, and the reporting of severe accidents and near-accidents seems to yield very little data.

A survey study could be conducted in the future, because it is easier to send to a larger and randomly selected sample of schools allowing statistical analysis of the results, which the present interview study did not due to the small participation size. However, one disadvantage of survey research is typically a low response rate, and drop-out rates may be skewed with respect to relevant factors, such as school size or the school's incident-rate. One other hand, using surveys one can gather a wider range of information regarding types of chemicals and products used and area as well as types of incidents.

Vocational training was the second most frequently occurring category in the investigated PIC material. Students at vocational schools get training in occupational health and safety but the knowledge is difficult to be implemented by the students in practice. Hence, it would be useful to closely investigate risk and chemical management in vocational schools. This could be done in form of interviews or/and questionnaires answered by the students and/or teachers.

5. Conclusion

PIC data may serve as a source of information about accidental exposures to chemical agents at school. From PIC call records we may take relevant lessons regarding improved risk assessments and management may be taken for chemicals in school environment. By analysing PIC call records, we have observed gender differences and age-group differences in number of chemical incidents at school. The most common route of exposure across both age-groups were eyes. However, ingestion was significantly more common among juveniles than adolescents, and inhalation more common in adolescents than juveniles(Fig. 2).

The records showed that several incidents occurred during laboratory work, often related to eye exposures of corrosive acids or alkali indicating inadequate use of goggles. The frequencies of incidents at school noted in the present study is low compared to the total number of children and young adults during same time-period in Sweden. Calling to PIC in case of chemical exposures is voluntary and might not always be done. Regardless of the likely underestimate presented by the PIC database concerning chemical incidents at school, the service gives a rich dataset for investigation of exposures and incidents compared to what can be obtained from SWEA's official statistics.

The interviews with chemistry teachers showed some deficiencies in chemical safety and management among the schools. Required time and resources are not given to the teachers for education in laboratory safety and chemical management, neither for chemical maintenance, labelling and documentation of risk assessment for laboratory exercises. The teachers are forced to have many students in the science classrooms at one time making the teachers feel unsafe and consequently they request legislation on limitation of number of students allowed in laboratory class room at one time. The students are not made aware of updated chemical symbols and signs because the course materials such as textbooks are not updated in relation to the new legislation regarding chemical symbols. For this reason, the teachers prefer to work with old labelling scheme rather than the new one.

The teachers clearly state the challenge of working with students, because they do not always follow given instructions. All reasons and deficiencies together illustrate the importance of organisational support for the teachers as restrictions in time and resources were major barriers to risk management.

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Appendix 1.

Table 3: Overview of exposure agents categorized and subcategorized into different groups against routes of exposure with the number of cases obtained from PIC database analysis.

Exposure agents	**Routes of exposure**						
	Eyes	**Ingestion**	**Inhalation**	**Skin**	**Several**	**Nasal**	**Total**
Grand total	**224**	**169**	**125**	**107**	**16**	**6**	**648**
Acids	**17**	**3**	**13**	**27**	**3**	**-**	**63**
Formic acid	-	-	2	5	-	-	7
Hydrochloric acid	6	2	2	4	1	-	15
Nitric acid	-	-	-	4	-	-	4
Sulfuric acid	2	1	4	10	1	-	18
Others	9	-	5	4	1	-	19
Alcohols & glycols	**27**	**19**	**4**	**5**	**-**	**-**	**55**
Alkali	**48**	**17**	**7**	**17**	**6**	**-**	**95**
Calcium hydroxide	10	-	-	-	1	-	11
Sodium hydroxide	10	6	3	11	1	-	31
Others	28	11	4	6	4	-	53
Chemical, others	**63**	**50**	**21**	**24**	**1**	**2**	**161**
Bleach	1	1	1	2	-	-	5
Cosmetics	17	3	1	1	-	-	22
Cyanoacrylate	2	1	-	2	-	-	5
Paint	5	6	1	-	-	-	12
Tensides	15	19	-	-	-	2	34
Others	23	20	18	19	1	-	83
Fire extinguisher	**5**	**2**	**7**	**-**	**1**	**-**	**15**
Fumes, gases & vapors	**5**	**-**	**50**	**1**	**1**	**1**	**58**
Ammonia	**2**	**-**	**7**	**-**	**-**	1	10
Chlorine gas	**-**	**-**	**7**	**-**	-	-	7
Exhaust fumes	-	-	1	-	-	-	1
Fire fumes	-	-	5	-	-	-	5
Welding fumes	-	-	5	-	-	-	5
Others	3	-	25	1	1	-	30
Household products	**18**	**29**	**3**	**12**	**1**	**1**	**63**
Hydrocarbons	**24**	**17**	**12**	**9**	**-**	**1**	**63**
Gasoline & diesel	4	2	1	-	-	-	7
Halogens	1	-	2	1	-	-	4
Hydraulic oil	-	1	-	1	-	-	2
Petroleum	7	7	3	3	-	1	21
Solvent	11	7	2	4	-	-	24
Others	1	-	4	-	-	-	5
Metals & metal compounds	**11**	**24**	**2**	**11**	**2**	**2**	**52**
Pesticides	**1**	**2**	**4**	**-**	**-**	**-**	**7**
Pharmaceuticals	**2**	**2**	**1**	**-**	**-**	**-**	**6[a]**
Unknown chemicals	**3**	**4**	**1**	**1**	**1**	**-**	**10**

[a]One case with injection as route of exposure was included