Fire safety of ventilation systems and fire incidence reports in Norwegian schools

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Abstract. School fires are causes of concern in many countries. Although most of these fires are minor in terms of heat release rate, the amount of smoke produced can be substantial and cause significant damage beyond the room of origin. Currently, Norwegian schools have a wide spread of different ventilation strategies and systems, and building owners struggle with how to test, maintain and keep them fire safe. A systematic survey of fire incidences and ventilation strategies in schools for three municipalities in Norway was done to gain better insights into fire safety in schools. The results indicated that the place of origin is often in locker rooms/toilets, kitchen, or outdoors, and the fires were usually deliberately set. For non-arson fires, electrical failure was the most common cause. The majority of the fire incidences were small but would often result in smoke damage and spread of soot in the building, leading to high restoration costs for the local municipality. A lack of documentation of the fire safety and the function of the ventilation system was also identified, indicating a need for improved routines and systems for registering fire incidences and documentation of the technical systems.

1 Introduction

School fires are causes of concern in many countries, and these fires are often deliberately set. A recent report on arson fires in Sweden reported an increase in the number of school fires since 2012, with more than 150 fires annually [1]. These fires are often small or moderate, in terms of heat release, and occur frequently in secluded spaces like toilets and corridors [2]. Nevertheless, the amount of smoke produced can be substantial and spread to other areas than the room of origin. The costs of these school fires can become quite costly due to the restoration work of the building [3], [4].

The ventilation system can be an integral part of a building's fire strategy. There are two dominating smoke control strategies for large buildings in Norway: compartmentation and extraction. Compartmentation involves installing fire dampers that will close both the exhaust and supply air ducts in case of fire. However, a high over-pressure can be expected inside the room of fire origin, resulting in smoke leakages through walls to neighboring rooms and could potentially prevent the occupants from evacuating during a fire and pose a risk to the structural integrity of the building [5]. The extraction strategy entails keeping the fans in operation during a fire, venting out the smoke, and is effective in controlling pressure, especially for airtight buildings which are built more airtight. This strategy is currently being explored in a research project to assess its suitability for small-sized and confined fires.

To find representative testing conditions for function testing of the ventilation system and to gain a better insight into the fire incidents in Norwegian schools, a survey was done. The aim was to gather information on previous fire incidents and the maintenance issues of the ventilation systems after a fire. This paper presents some of the findings from the survey, with a focus on the cause of the fire incidents, and where available, the impact on the ventilation system after the fire and the restoration costs.

2 Methods

A systematic survey was done to gather information about fire incidences in schools in three municipalities (Oslo, Bergen, Trondheim) in Norway. However, none of the municipalities had a system for registration of fire incidences, but a more general registration of unwanted incidents or deviations in the daily operations of the schools. Oslo municipality has such a system (ORRA) that involves the registration of unwanted with a given rank of 1 to 3, where 3 is the most severe. Most of these events are registered by the building operations managers in the respective schools. Depending on the scope of the incident, the technical manager will also be involved in the case measures need to be taken. Events

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dating back to 2012 were available and searchable. However, the quality of the information provided regarding the fire incidences, restoration costs and building information, function of the ventilation system during fire varied between schools. Information for fire incidents in Oslo that had major financial consequences (> approx. 30k Euro) was provided by the insurance company.

Statistics about fires in public databases, such as BRIS, were also gathered for comparison. BRIS contains reports on fire and rescue services and was established in 2016 by The Norwegian Directorate for Civil Protection (DSB). Statistics from insurance companies are available in the database BRASK and cover more than 90% of the Norwegian market. The following factors were retrieved:

- Place of fire origin
- Cause of fire
- Spread of fire/fire load
- Damage and restoration costs
- Building property (ventilation system, age)

3 Results and discussion

3.1 Place of origin

Of the incidences extracted from ORRA for the 188 schools in the Oslo municipality, the place that triggered the fire alarm most frequently is in the toilet and locker room (27%) as shown in fig. 1. These incidences always involve fire play or arson, but were in most cases small, confined fires that were put out rather quickly. The second place of origin is in kitchen and cooking areas (21%); however, these incidences were often accidental and resulted in very little damage. Quite a few of the reported fires started in the technical areas (8%), due to electric failures or malfunctions.

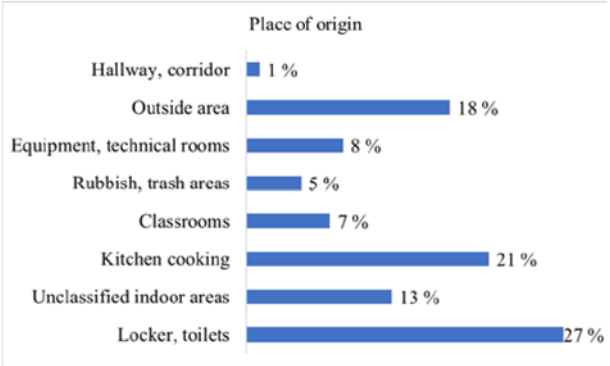

Fig. 1. Reported fire incidences in ORRA for schools in Oslo by place of origin, 2012-2021.

The results from schools in Oslo are consistent with the statistics from BRIS for schools in entire Norway (N=251, data not shown), where 20% of the fires took place in the toilet/locker rooms. The second place of origin however was the hallway (11%).

Looking solely at arson fires, the item most often first ignited was papers in trash bins, followed by fireworks, papers/books, and fabrics/textile. The findings in our study are consistent with the case studies on arson fire in Sweden [6].

3.2 Cause of fires

Table 1 shows that for Oslo municipality, a total of 35 school fire incident claims were sent to the insurance company between 2011 - 2021. Ten of these were not registered in the deviation reporting system of Oslo municipality. Detailed reports of the fire incidences were also received from the insurance company for seven schools in Oslo. In addition, the technical managers also provided information for five schools in Oslo, three in Bergen, and two in Trondheim (data not shown).

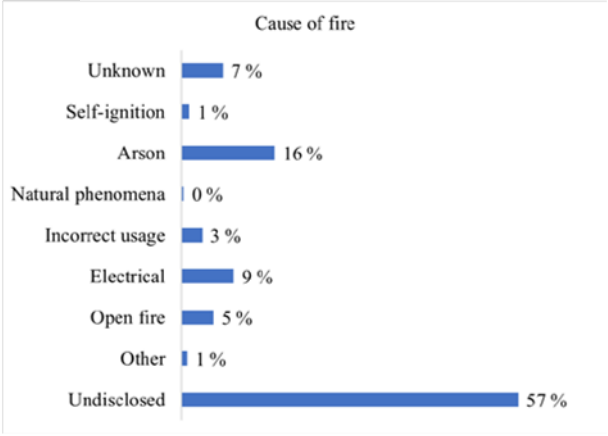

Fig. 2. Cause of fire for all educational buildings in Norway, between 2000-2021. N=1608. Source: BRIS.

Five of the cases happened in technical rooms and mostly after school hours, due to failure or malfunction in the electric equipment. Although the fires were brought under control rather quickly, the spread of soot and smoke were not limited to the areas beyond the place of origin. In one of the fire cases, the smoke and fire were spread with the ventilation system when the firefighters turned on the fans after the fire was controlled. The fire cause being electrical equipment amount to 9% for all fires in educational buildings in Norway, as shown in fig. 2.

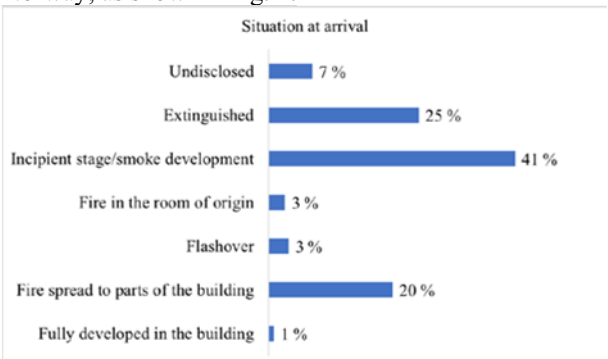

Fig. 3. The situation at arrival, fire statistics of all educational buildings between 2000-2021. N=1608. Source: BRIS.

The fire incidents indoors during school hours happen mostly in areas where one can act without being disturbed or observed (toilet, locker rooms, closed rooms). In most of these cases, the fire is generally kept small and well-contained. This is seen in fig. 3, where 41% of the fires are at the incipient stage/smoke development and 25% of the fires are already extinguished when the firefighters arrive. Fig. 4 shows an overview of the BRIS statistics for schools only

(N=251) where for majority of the fire incidences, the smoke did not spread beyond the fire cell (42%) or beyond the fire section (26%).

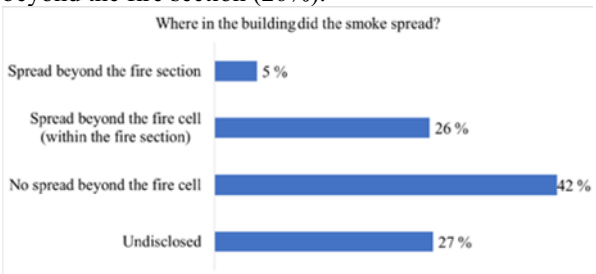

Fig. 4. Overview of where in the building the smoke has spread, data for schools only (N=251) in entire Norway. Source: BRIS.

3.3 Restoration costs

As seen in Table 1, the insurance company indicated that during 2011-2021, approximately 94.6 million NOK was paid out. The costliest fire incident in Oslo amounted to more than 72 million NOK, as the fire spread resulted in a part of the school being heavily damaged. As seen in fig. 5, the payments from the insurance companies vary each year, but on average more than 1 mill. NOK is paid out annually. The actual costs of school fires are probably much higher since every building owner has a deductible sum. For Oslo municipality, the deductible is 300 kNOK, consequently, the costs of small school fire incidents would not be included in these statistics.

Table 1. Overview of the fire incidents in Oslo schools and related costs (including 300k NOK deductibles for the municipality), from the insurance company. *Indicates that the ventilation system is not connected to the fire alarm system.

School building	Building age	Ventilation on during fire?	Cause	Costs (kNOK)	Available info
1	1990	NA	Unknown	3.375	Fire in the basement started in cables
2	1972	Yes*	Arson	315	Toilet
			Arson	412	Several fires in a room used for resting
			Arson	857	Ignition of pillow in the resting room
3	1978	Yes*	Arson	≤300	NA
			Unknown	4.025	Fire in a cabinet in sloyd hall spread to the entire room of origin
4	2000	Yes	Unknown	507	Fire in bookshelf, classroom partially burned, extensive smoke damage
5	1895	NA	Arson	≤300	Trash can in the building where toilets are located
6	1958	No, stops	Arson	804	The oldest building, in the trash can or paper dispenser
8	1967	Yes	Arson	307	Trash can in the locker room
			Arson	559	Toilet, no fire detector in the room
9	1984	No, stops	Unknown	2.309	PC-room: laptop or power plug. A wide spread of smoke/soot. Occurred in 2012. Building upgraded in 2017/18.
10	1940, upgraded the late 90s	Yes	Arson	305	Toilet
			Arson	309	Toilet
11	Sports hall, 1974	Stops if detection in the supply air	Arson	538	Started outside, exterior wall
12	1935	No	Arson	302	Fire in the building
			Arson	306	Fire in the building
13	1988	Yes		≤ 300	Fire in the gym building
14	2004	Yes/no depending on area	Negligence	≤ 300	
			Negligence	318	NA
15	1959	Yes	Negligence	317	Fire at the rooftop of the building
16	1921	Yes	Failure/lack maintenance	832	Electric boiler in the basement
17	1986/1989/ 2000	Yes	Other	472	Indoors
			Unknown	311	Toilet hallway between two classrooms
			Arson	≤ 300	Broke window in classroom, lit curtains
			Arson	≤ 300	Broke window, fireworks, curtains lit
18	1967	Yes	Negligence	766	Box where forgotten clothes are stored
			Unknown	940	NA
19	1938	Yes	Arson	757	NA
20	1978	Yes*	Arson	270	Exterior
21	1965	Yes*	Arson	428	Toilet
22	1988	Yes	Arson	73.574	Building heavily damaged
23	1970	Yes/no depending on the building	Electric	129	Electric system on the top floor
24	1966	Yes/no depending on the building	Unknown	≤ 300	Exterior wall, garbage can
25	1926	Yes	Electric	3.882	Fire in cables of the heating coil in AHU

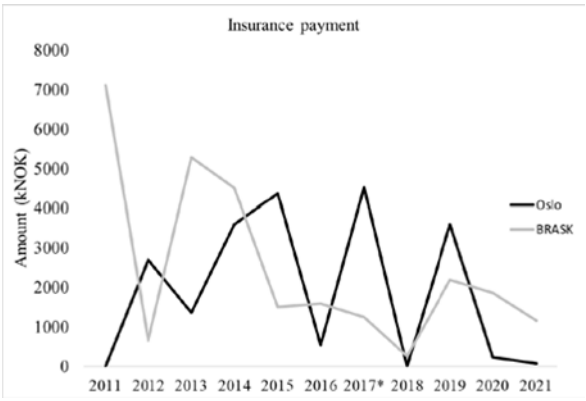

Fig. 5. Annual costs of school fires for Oslo (excluding the cost of school 22 in 2017) and according to the database BRASK (all educational buildings).

3.4 Impact on the ventilation system

Generally, the fire damage restoration reports mostly include odor and soot removal in the place of origin, and usually cleaning and repainting of the fire damaged areas. Smoke and soot generated during the fire were reported to spread to the ventilation air ducts or to adjacent rooms. For the ventilation system, the filters and the fire detector in the air ducts are often replaced, while odor and soot in the air ducts are removed. For well-developed fires and/or the ingnition of more fire hazardous materials, these incidences would result in the replacement of the entire air handling unit (AHU), air ducts, dampers, and supply/extractor vents. Usually, ventilation systems with extraction strategy has control systems to bypass the smoke past the heat-recovery system and filters in the event of a fire.

3.5 Documentation

In the process of gathering information about fire safety and fire incidences in schools in the three municipalities, it was found that the documentation on fire reports and the function of the ventilation systems during the fire were generally lacking. Although Oslo municipality had a system for registering fire incidences, the level of details added was lacking and the related documents for the more severe fires were also not available. The fire investigation reports that were received also varied in quality. Many of the schools consisted of several buildings of different ages. Oftentimes, the information about the fire strategy, the type of ventilation, or the function of the ventilation system during a fire incident was not easily found or unavailable. The majority of the schools had balanced mechanical ventilation with heat recovery, but whether the ventilation control principle was constant air volume (CAV), variable air volume (VAV), or DCV was not easily found. Few of the older schools in this study had a bypass control system. In addition, the fire strategy would also vary depending on when the school was upgraded/built.

Most of the schools included in this study in Oslo use the extraction strategy, where the AHU continues operating during a fire event, except if the fire is detected in the supply air ducts. Newer or upgraded schools (after 2017) would use the compartmentation strategy with fire dampers, or a combination of both. It was also found in some schools, mostly older ones, that the fire alarm system was not connected to the ventilation, which resulted in a "light" version of the extraction strategy. This entailed a continued operation of the AHU without increasing to maximum airflow rates.

4 Conclusions

Surveys of school fires in the municipalities of Oslo, Bergen, and Trondheim showed that the place of origin is often in locker rooms/toilets, kitchen, or outdoors, and the fires were usually deliberately set. For non-arson fires, electrical failure was the most common cause. Indoor fires with smoke damage and spread of soot in the building result in high restoration costs for the local municipality. A lack of documentation of the fire safety and the function of the ventilation system was also identified. This indicates a need for improved routines and systems for registering fire incidences and documentation of the technical systems in the municipalities.

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