Initial Fire Safety Analysis of Shelters in Zaatari and Azraq Refugee Camps

Citation for published version:
Alshawawreh, L & Rush, D 2024, 'Initial Fire Safety Analysis of Shelters in Zaatari and Azraq Refugee Camps', *International Journal of Disaster Risk Reduction*, vol. 108, 104557. https://doi.org/10.1016/j.ijdrr.2024.104557

Digital Object Identifier (DOI):
10.1016/j.ijdrr.2024.104557

Published In:
International Journal of Disaster Risk Reduction

Initial Fire Safety Analysis of Shelters in Zaatari and Azraq Refugee Camps

Lara Alshawawreh[a*], David Rush[b*]

[a] College of Engineering, Mutah University, Jordan, l.alshawawreh@mutah.edu.jo

[b] School of Engineering, University of Edinburgh, UK, d.rush@ed.ac.uk

*Corresponding authors

Abstract:

More than a decade had passed since the initiation of the Syrian refugee camps in Jordan. Many gray literature documents and some academic research had been produced around Zaatari and Azraq camps. However, none of the existing research has tackled the issue of fire safety in the camps extensively, despite the noticeable fire events that occur in them.

In this research, two methods are used to discuss the fire risk in the Jordanian Syrian camps of Zaatari and Azraq. The first is field assessment through visual analysis supported by observatory tours and field notes on five aspects of fire risk; ignition, fire development, fire spread within a structure, fire risk between structures, and accessibility of shelters. The second is through fire experiments on shelter materials using a cone calorimeter which aimed at seeing how the original shelter materials and the amendments that the residents make to these materials, react to fire. The results are recommendations and best practices to improve fire safety in these camps and at the same time help camp planners and shelter designers in taking more fire-conscious decisions in the future.

Keywords:

Azraq Camp; Cone Calorimeter; Fire Assessment; Fire Safety; Visual Assessment; Zaatari Camp.

1. Introduction

1.1 Global refugee situation

The number of forcibly displaced people had rapidly increased in the past decade (2012-2022). Specifically, in 2022 when there was an additional 19 million forcibly displaced persons; considered the highest in-between years increase. By mid of 2023, the number of forcibly displaced people around the world was 110 million, with Syria counting for most of the refugees worldwide for the 10th consecutive year with more than 6.5 million refugees (UNHCR, 2023c).

According to the United Nations high Commissioner for Refugees (UNHCR), most of refugees and displaced people remain as close as they can be to their origin countries, despite the risks they might face (UNHCR, 2023b). By mid of 2023, about 69% of the refugees, in refugee-like situations, and other people in need of international protection were being hosted in neighboring countries (UNHCR, 2023c). However, most of these countries are low or middle-income, which are already facing many challenges, such as political instability, natural hazards and disasters, economic difficulties, and climate change (Ahmed, 2023).

Climate change increases the frequency and intensity of natural hazards and disaster events, which can result in severe consequences for low and middle-income countries, specifically when they happen in conjunction with other socio-economic challenges, that prohibit the countries from adopting what is known as the “building back better” approach (Ahmed, 2023; UNISDR, 2017). Additionally, it is argued that the lack of sustainability considerations when dealing with the aftermath of disasters, including shelters, affects the frequency and intensity of these disasters in the long run (Davis & Lambert, 2002; Kwaylih et al., 2023; Pomponi et al., 2019). Major examples of such scenarios are the disastrous floods in Pakistan (fifth hosting country in the world) during 2022 which impacted 1 in 7 people, and the earthquake in Turkey (major hosting country in the world) and Syria (major source of refugees) during 2023 which resulted in widespread displacement. Unfortunately, in disasters, the most vulnerable people are the ones who are most affected, such as refugees and displaced people (Ahmed, 2023). In Turkey, about 19% of those who were affected by the earthquake were Syrian refugees, bear in mind that the same earthquake hit Syria and affected many internally displaced Syrians (Karlsen, 2023).

1.2 Research context: Zaatari and Azraq camps

In March 2011, and as part of the Arab Spring, protests in Syria led to an armed conflict that shortly turned into a full-scale ongoing civil war. The large influx of Syrian refugees to Jordan, forced the Jordanian Government and the UNHCR to set up the Zaatari camp in July 2012, and thereafter Azraq camp in April 2014. Both camps are hosting only Syrian refugees.

Jordan is known as the second most hosting countries of UNHCR refugees in the world per capita (MoPIC, 2020), and is also argued to be the most hosting country when counting the Palestinian refugees under the mandate of UNRWA (Alshawawreh, 2019) with a percentage of 25% from the total population (UNHCR, 2023c). However, Jordan is not a signatory of the 1951 refugee convention, (the main international instrument of refugee law), nor its 1967 protocol (Sharma, 2015). Notwithstanding, in 1998, Jordan signed a memorandum of understanding with UNHCR which adopts a very similar definition of ‘refugee’ and their basic rights including the non-refoulement (Janmyr, 2021). This means that there are no legal obligations on Jordan to host refugees, however, Jordan is committed to its moral obligations towards its neighboring countries (MoPIC, 2020), and bounded by customary international law to not force-return refugees to where their life or freedom could be threatened (Human Rights Watch, 2006).

Given these facts, the temporary status of the 1.36 million Syrian refugees in Jordan is crucial for the Jordanian government due to its limited resources (MoPIC, 2020), especially that by end of 2023, only about 649,000 of them were registered as refugees within the UNHCR records (UNHCR, 2023d). The Syrian formal camps in Jordan are hosting only about 10% of the Syrian refugees (MoPIC, 2020). However, their temporality of existence, similar to most formal camps in the world, is emphasized by the Jordanian government, as the status of the land is a major concern in such cases (Alshawawreh et al., 2020). The aforementioned contextual background is the main reason behind the temporary material choices for the shelters in the studied camps, which will be discussed in this paper.

Zaatari camp

Due to the urgent need of a formal camp for Syrian refugees in Jordan, Zaatari camp was initiated in 9 days on a land owned by the Jordanian armed forces. The camp is located in northern Jordan, about 10 km east of Mafraq Governorate. Though the camp started as a small area on the west of its current borders, it evolved within nine months to enclose a space of 5.3 sqkm of land with a ring road of 8.3 km (Ledwith, 2014). The Jordanian government and UNHCR jointly planned and coordinated the camp at the beginning (Ledwith, 2014). The planning of the camp depended on what are called 'districts' as the camp is divided into 12 districts, where each district has numbered blocks and numbered households (UNHCR, 2016). Today, Zaatari camp is under the joint administration of the Syrian Refugee Affairs Directorate (SRAD) and UNHCR (UNHCR, 2022b). The camp peaked in terms of number of residents during April 2013 with over 200,000 residents; however, since June 2014, the number stabilized to be around 85,000 residents (UNHCR, 2023e).

The original layout of Zaatari camp organization was linear, consisting of rows of tents which were replaced afterwards with prefabricated shelters (locally called caravans). However, shortly after the initiation of the camp, the refugees relocated their tents and caravans next to their relatives and previous neighbors in Syria to form U-shapes with in-between courtyards (Ledwith, 2014). Various countries and organizations have donated certain quantities of prefabricated shelters (REACH, 2014), which meant that the size and specifications of the camp's shelters were not unified. The Saudi model was the most used in the camp with the dimensions of 5 m x 3 m, however, other major donors such as UAE, Kuwait and Oman had donated shelters with the dimensions of (6.5 m x 3 m), (6 m x 3.5 m) and (6 m x 3 m) respectively (Dalal, 2022). Generally, the shelters are made of 40 mm sandwich panels, where the outer skin is made of steel sheets, the inner skin is either timber or steel, and the insulation in between is polyurethane (Albadra et al., 2018). The original design of the prefabricated shelter is a one-room with no indoor facilities or partitions, as the initial planning of the camp provided communal toilets, showers, and kitchens (Alshawawreh et al., 2017).

The residents of the camp face many challenges in their shelters such as lack of privacy, the cultural unsuitability of the communal kitchen and toilets, unsealed walls and roofs, lack of thermal comfort, unsuitable openings that do not provide the needed ventilation, insects and rats entry to the shelters, concerns regarding the flammability of the shelters, and lack of outdoor private facilities (Alshawawreh, 2019). Aburamadan (2017) points out and based on interviewing refugees from the camp, that many fire events resulted from the discontinuity of electricity provision due to sourcing unsafe alternative ways of lighting, while the use of flammable materials in the construction of the shelters worsened the effect of the events. However, throughout the years, some refugees who were able to secure some money, were able to solve some of these issues in regard to area by amending their shelters. They self-built spaces using corrugated sheets, such as private toilets, private kitchens, private outdoor areas, and extra room/s whenever possible. Other families were able to buy prefabricated shelters from refugees who had left the camp. This case was possible because at the beginning of the camp, the shelters' ownership was not clarified (Alshawawreh, 2019; Dalal, 2022).

ACTED (2017, p. 1) states that most of shelters in Zaatari camp are in critical situations. Their repair and maintenance team highlight "lack of proper floor, water leakages, flooding inside the shelters and rusted sandwich panels". They added that self-built private toilets are sanitary threats, estimating having about 3,922 toilets that do not meet the minimum hygienic standards.

Azraq camp

In April 2014, and due to the increasing number of Syrian refugees who entered Jordan, and the inability of Zaatari camp to host more refugees, Azraq camp was opened as the first purpose-built camp in Jordan. The camp is located 90 km from the Syrian border near a town called Azraq in Zarqa governorate, northeast of Jordan. The 14.7 sqkm area of Azraq camp has a grid layout that is divided into six villages. However, until today, only four of the villages are in use: three, six, five and two, besides the base camp that hosts the management teams (Dalal et al., 2018). Each village is divided into numbered blocks and streets. Similar to Zaatrai camp, Azraq camp is also under the joint administration of SRAD and UNHCR (UNHCR, 2019b).

The largest number of residents who were hosted at Azraq camp was in July 2016 with about 55,000 residents. However, the number of residents stabilized since May 2018 to be around 45,000 (UNHCR, 2023e). The camp was designed to contain 13,500 T-shelter (a term used to describe either a temporary or a transitional shelter (IFRC, 2013)). However, until March 2023, only about 8,700 shelters were in use (UNHCR, 2023a). According to IFRC et al. (2014), the original dimensions of the T-shelter are 4 m x 6 m for a family of up to six members (lately, the regulations were changed for the shelter to serve a family of up to 7 members). The T-shelter has a steel structure that is made off-site and transported to the camp, then covered with Aluminum coated foam insulation (10 mm – 15 mm) and has a metal cladding of Inverted Box Rib (IBR) from both sides. The original design came with an inner roof layer of plastic sheeting (Albadra et al., 2018; IFRC et al., 2014). In terms of flooring, the implemented design had a concrete floor that was poured over a metal rubber, which made the shelters fixed in the ground (UNHCR, 2015). The T-shelter has a one-room design, and while the camp offered communal toilets and showers, the residents were given kitchen tools to use inside their shelter. However, by 2019, and due to the continuous appeal from the residents (REACH, 2015), all shelters were upgraded with a kitchen extension of 8 sqm, making the shelter area reaches 32 sqm (UNHCR, 2019a)

Following the initiation of the camp, major drawbacks were noted in the shelters, specifically regarding the use of IBR cladding, which was difficult to be sealed-off and has high amount of heat gain (IFRC et al., 2014). Additionally, REACH (2015) found through a conducted assessment that the indoor temperature of the shelters is unsatisfying to about 90% of the residents during summer and to 45% of them during winter seasons. These results comply with the findings of Albadra et al. (2018), where the spot measurement they had done recorded a roof temperature of 46°C in summer. Other challenges that were discussed in existing literature are the unsuitability of the one-room design which leads to lack of privacy, lack of outdoor private area, and improper size and location of openings (Alshawawreh et al., 2017).

1.3 Fire Safety standards

One of the main learnt lessons from previous shelter projects is to plan for fire prevention by considering many perspectives, such as: site layout considerations, sanitation improvements, inclusion of firebreaks, conscious selection of materials, and using specific construction techniques (Shelter Centre & IOM, 2012).

There are some recommended standards and codes within the existing gray literature, such as the Sphere Handbook (Sphere Association, 2018a), Handbook for Emergencies (UNHCR, 2007), and the USA International Fire Code (IFC) (International Code Council, 2021). In the UNHCR (2007) Handbook of Emergencies, it is suggested to include a 30 m firebreak following every 300 m of built-up area in a camp setting to prevent spreading fire. It also states that the distance between each two dwellings should be double the height of the dwelling as a minimum and could be increased to be three or four times the height in the case of using extremely flammable materials. The Sphere Handbook (Sphere Association, 2018a), agrees with what the UNHCR handbook includes. However, despite its assurance of the ideal scenario of having a clear space of twice the height between any two structures, it also introduces the option of having a clear space of two meters as a minimum. In the IFC guidelines for the temporary tents and membrane structures and with certain conditions, it states that a clear fire break of about 3.7 m shall be provided on all sides of the tent/membrane structure (International Code Council, 2021).

There is a lack of detail within these guidance documents as to how these separation distance values are determined, whether it is a scientific or engineering judgment-based approach. As an example, previous work on informal settlements in Cape Town, showed that three meters might be a safe distance for their types of structures (Wang et al., 2021). Antonellis, Underhill, Cicione, et al. (2023) argue that there is no unified requirement for the minimum distance to prevent the spread of fire as there are many factors affecting that such as wind conditions shelter materials and contents, and opening sizes and locations.

1.4 Global fire in refugee camps and informal settlements situation

Worldwide, and based on the latest documented statistics in ‘Our World in Data’ that goes back to 2019, fire events result in an estimated 111,000 deaths per year. This number equals about 18 times the number of deaths due to natural disasters and about twice the number of deaths due to conflict and terrorism (Ritchie et al., 2019). It is also estimated that 90-95% of these global deaths occur in lower- middle- income countries (Rush et al., 2020).

The fact that refugee camps and informal settlements are more vulnerable to fire events go back to many factors, such as high density of structures and the use of combustible materials, due to their affordability and temporariness, which accelerate the spread of fire (ARUP, 2018). Antolellis, Underhill, Vaiciulyte, et al. (2023, p. 8) elaborated more with the reasons behind fire in humanitarian settings to include “limited land availability, restricted choices for building materials, energy poverty, insufficient knowledge, unclear roles and responsibilities, and limited systems of accountability”. ARUP (2018) has developed a framework for fire safety in informal settlements to reduce the number of fire events and, in cases of fire, reduce their potential risk. However, ARUP (2018) also emphasizes the importance of having holistic and localized considerations of fire safety that must be identified based on the context. Unfortunately, the fire safety in the humanitarian sector is only being largely considered following a serious disaster due to the many limitations that the sector face in terms of resources versus needs (Antonellis, Underhill, Vaiciulyte, et al., 2023). Antonellis, Underhill, Vaiciulyte, et al. (2023) argue that fire events will keep on being considered as accepted possible risk as long as no holistic and deep knowledge about the topic is being researched and widely shared.

Fire safety situation in Jordanian-Syrian camps

In Jordan, yearly, there are about 196 reported fire deaths, which exceeds the number in most of the countries in the Middle East and equals the same number of fire deaths in Venezuela which has a population of about 2.5 times the population of Jordan (Ritchie et al., 2019).

ARUP (2018) argues that fire events in informal settlements are rarely reported in international media. In the Jordanian context, this could also be easily noted for the formal camps. When searching the media in July 2023, it can be found that since the initiation of the Jordanian-Syrian camps, only about 16 fire events were reported or mentioned. About 14 of these events were in Zaatari camp; seven of them were in tents, five events occurred in the shelters (caravans), and the remaining two events involved shops. However, only two events were reported in Azraq camp (Table 1). Although, throughout the visits to the camps, there were many told stories about fire events, and it was one of the main concerns that the refugees have. While it could be that only events that included fatalities are shared with media, no clear criteria can be noted.

Table 1 also shows that in the 16 reported fire events, about 104 reported shelters (tent, caravan (prefabricated shelter), or T-shelter) were involved, which resulted in 16 deaths and about 22 injuries (announced numbers). These numbers mean, that in average, each event caused damage to about 6.5 shelters, death to 1.15 individual, and two injuries (excluding the cases with unknown numbers).

Table 1: Reported fire events in Zaatari and Azraq camps in media until July, 2023

No.	**Date of event**	**Location**	**Type of shelter**	**Cause**	**Number of deaths**	**Number of injuries**	**Source**
1	October, 2012	Zaatari camp	20 tents	Intentional by refugees	0	0	(AFP, 2012)
2	February, 2013	Zaatari camp	1 tent	*Unknown*	1	3	(Ammon News, 2013)
3	March, 2013	Zaatari camp	35 tents	Electric fault	0	*Unknown*	(Alhurra, 2013)
4	December, 2013	Zaatari camp	1 tent	Gas Canister	3	1 child	(AP News, 2013)
5	March, 2014	Zaatari camp	3 tents and one caravan	Candle	2 children	0	(Ammon News, 2014)

No.	Date of event	Location	Type of shelter	Cause	Number of deaths	Number of injuries	Source
6	December, 2014	Zaatari camp	1 tent	Candle	2 children	3 severely burned	(SANA, 2014)
7	January, 2015	Zaatari camp	1 tent	A gas cylinder	1	2 children	(FOX NEWS, 2015)
8	March, 2015	Zaatari camp	1 caravan	A gas cylinder	4	*Unknown*	(Reuters, 2015)
9	July, 2018	Zaatari camp	13 caravans	*Unknown*	*Unknown*	*Unknown*	(Damascus V, 2020)
10	April, 2019	Zaatari camp	3 caravans	*Unknown*	1	*Unknown*	(Jodan News Agency, 2019)
11	May, 2020	Zaatari camp	7 shops	Electric fault	*Unknown*	*Unknown*	(Orient News, 2020)
12	Nov, 2020	Zaatari camp	3 caravans	Electric fault	1 child	9	(Orient News, 2020)
13	March, 2021	Azraq camp	2 T-shelters	Electric fault	0	1	(Jfra News, 2021)
14	April, 2023	Zaatari camp	2 caravans	*Unknown*	1	3	(The Jordan Times, 2023)
15	May,2023	Zaatari camp	7 shops	Electrical short circuit	0	0	(Jordan News Agency, 2020)
16	April, 2023	Azraq camp	3 T-shelters	*Unknown*	0	0	(Ammon News, 2023)
		TOTAL:	104		16	22	
		AVERAGE per reported fire (excluding the unknowns):	6.50		1.15	2.00	

Fire information and data from local authorities.

Following the web search, informal interviews with local authorities in the camps (spokesmen and/or fire services) were conducted. The interviews in Zaatari and Azraq camp took place on the 4th of September 2023 and 12th of September 2023 respectively. During the interviews, the views of field workers who deal with fire events were represented. This is a unique input to this research as in related research documents such as Antonellis, Underhill, Vaiciulyte, et al. (2023), the absence of such voices was indicated as a limitation. Additionally, official numbers of fire events from January-August 2023 were obtained throughout the interaction with the officials. Despite that the numbers are only for a few months in 2023, they could be representative to the real situation of fire events in the camps.

In Zaatari camp, the spokesman reassured the researchers that fire ignition in the camp is a burning issue that needs to be urgently resolved. According to him, each month they deal with an average of 4-5 fire events. There is a fire station located inside the camp, and if they need support, they can get it from the neighboring stations such as Mafraq fire station which is about 10-15 minutes away. The civil defense unit gets the notification of events from the operations who usually gets the information from one of the residents. When notified, the firemen can get ready to move towards the fire in 30 seconds at daytime and 45 seconds at nighttime. The spokesman added: ‘the firemen can arrive towards the farthest point of the camp in 4 minutes’.

Nevertheless, there are some hardships that firemen face during the firefighting process and were shared during the interview:

1- The misdescription of the fire location from the informer, which leads to being unable to precisely identify the location of the fire.
2- The poor road conditions, which make reaching the fire location a longer process.
3- The narrow roads and pathways around the shelters affect the arrival of the firefighting vehicles.
4- The camps’ residents gather around the fire during the firefighting process. While it is mainly with good intentions due to the relative bonding between most of the residents (80% of the residents are originated from Daraa governorate in Syria), it hardens the job of the firefighters.
5- In districts 1, 2, and 12 (the old camp), the areas are very crowded which leads to a quick fire spread between shelters.

In terms of fire causes, the spokesman classified them into two main reasons: electrical faults and arson. According to the interviewee, the electricity was provided at the beginning of the camp only to main electricity points throughout the camp, but not to the shelters. Refugees hired people to get electricity from these points to their shelters, and due to their poor economic situation, they hired unprofessional electricians for the less cost. This situation resulted in having faulty wiring which made many shelters prone to fire ignition. Moreover, nowadays the electricity is provided in the camp through solar panels for about 10 hours per day, the inconsistency in electricity provision is behind the fire ignition in some events. The second mentioned cause is arson, as some fires were believed to be malicious burning. While the civil defense staff are well trained to know fire causes and use forensic labs if needed, the interviewee clarified that burned-out locations are the hardest to investigate because evidence is also burned out. Despite the cause, it was mentioned that the used prefabricated shelters worsen the effect of the events as they are vulnerable to fires and highly inflammable.

When asked about possible solutions, four suggestions were raised: reorganizing the electrical connections throughout the camp, inserting firefighting points in all districts where each of them is supervised by trained refugees, introducing mobile firefighting stations, and increasing the number of firefighting vehicles.

Table 2 shows the number of fire events that firefighting team of Zaatari camp had dealt with during the first eight months of 2023 (local authorities during an interview, 2023). The numbers for May were not obtained, however, for the other seven months of 2023, the number of fire events was 38, that resulted in losing one life and having 20 injuries. The number of damaged structures were not shared with the researchers; however, the high number of injuries can be an indication of a high number of damaged structures.

Table 2: Number of fire events in Zaatari camo Jan-Aug 2023 (obtained from local authorities, 2023)

	No. of events	**No. of injuries**	**No. of deaths**
January, 2023	5	0	0
February, 2023	2	0	0
March, 2023	6	2	0
April, 2023	7	5	1
May, 2023	N/A	N/A	N/A
June, 2023	4	5	0
July, 2023	8	1	0
August, 2023	6	7	0
Total	38	20	1

Similar to Zaatari camp, Azraq camp has a fire station located inside the camp, and the camp has water tanks that firemen can use in cases they needed extra water for large fire events. In such cases, and if needed support, there are two nearby fire stations to the camp (Showaiger and Azraq) which both are about 25 minutes away. Based on the interview, the firefighting team needs 7-8 minutes to reach the farthest fire event in the camp.

According to the spokesman, the main hardships they face while doing their job are:

1- The misdescription of the fire location from the informer
2- The poor road conditions, especially if shortcuts were taken through unpaved roads.
3- The large distances in the camp (almost 3 times the size of Zaatari camp). Village 6 was mentioned as the hardest to reach, due to its long distance from the civil defense center, and due to being the village with the most fire events.

The fire causes that were mentioned during the interview were divided into four categories: electric faults, gas cylinders, ignorance and negligence such as misusing the electric and gas heaters, and overcurrent due to excessive load. The electricity and electric boxes were installed in each shelter by professionals, however according to the spokesman, the residents do electrical additions that are not always well installed.

The suggested solutions by the interviewee were: conducting awareness sessions to residents, training representatives from the residents as public safety officers to do the initial safety measures in cases of fire before the arrival of the firefighting team, inserting extinguishing point for each village, and having fire alarm system in shelters.

Table 3 shows the number of fire events that firefighting team of Azraq camp had dealt with during the first eight months of 2023 as obtained from local authorities during an interview. The number of fire events was 19, and only one injury resulted from them. According to the local authorities, these events affected about 19 shelters, 11 of them were completely destroyed. These numbers show that while the firefighting system in the camp is able to save lives, the high flammability of the shelters amongst other mentioned factors, do not allow it to be as affective.

Table 3: Number of fire events in Azraq camp Jan-Aug 2023 (obtained from local authorities, 2023)

	No. of events	**No. of injuries**
January, 2023	3	0
February, 2023	2	0
March, 2023	0	0
April, 2023	3	0
May, 2023	2	0
June, 2023	0	0
July, 2023	3	0
August, 2023	6	1
Total	19	1

By comparing the numbers in table 2 and table 3 to the numbers in table 1, the gap between the announced fire events in the media and the official numbers can be easily spotted. While this could be due to sociopolitical reasons, the official numbers need to be announced and shared to allow better fire research and therefore conscious future decision making process for camps.

2. Methodology

This research aims at studying and analyzing the current refugee shelters in Zaatari and Azraq camps in terms of fire safety. To fulfil this aim, two methods were used: (1) field assessment that included visual analysis supported by observatory tours and field notes, and (2) fire tests via cone calorimeter. While the first method is qualitative and aimed at understanding the context and residents' behavior in terms of fire safety, the second method is quantitative and aimed at testing the shelter materials and how they might react in cases of fire. This combination of methods is important in field research generally, and when researching camps specifically, as the situation in the field is usually different than original plans. Similar combination of methods in fire safety research was used in researching informal settlement in South Africa by Wang et al. (2019).

The first stage of the research was to conduct fieldwork in Zaatari and Azraq refugee camps. The visits to Zaatari camp were conducted during September 2021, where a sample of seven shelters were studied, while visits to Azraq camp were conducted during June 2022, where three shelters were visited and analyzed. Moreover, follow-on visits during March and September 2023 were conducted to both camps to support the research with information and data from official spokesmen and to get additional street photos. The studied shelters were chosen with the help of the organizations who facilitated the visits based on ease of access and safety criteria. Despite the different sampling size in both camps due to accessibility limitations, patterns in the collected data (i.e. photos) were spotted in both camps, which means samples reached the saturation point.

Photos are the most famous form of visual research methods (Rose, 2015). The significance of photography in fieldwork research was emphasized by Bryman (2016) arguing that they act as aid memoire, whether they were used as main sources of data or as drivers for in-depth discussions with research participants. Pink (2004) explains that visual methods give us access to data that are not approached verbally. However, in order to interpret the narratives behind photos, a researcher needs to take into consideration the context, surroundings and his social position. This is echoed by Barrantes-Elizondo (2019) who clarifies that visual forms can only be considered as visual ethnography if they were surrounded by their culture and context. However, Pink (2004) argues that traditional methods such as observations or interviews, need to be used alongside the visual methods to complement them.

In each of the ten studied shelters, photos of the interior, exterior and street views were taken by the researchers. Moreover, informal conversations with shelters' inhabitants were conducted while touring and observing the shelters and field notes were taken to support the interpretation process of the photos. The photos in this paper are chosen from over 100 photos that were originally shortlisted from 500+ photos which were captured throughout the visits to both camps. The criterion for choosing the photos was to clearly show the observations that were noted. In order to organize the photos, the visited shelters are numerically numbered.

The second stage was to conduct cone calorimeter experiments on the used shelter materials. The resulted observations and interpretations of the first method helped shaping the type of tests that would be representative to the context, such as making holes and slots in some samples to mimic the current situation of the sandwich panels, or testing bare foam layer as it was used by the residents as internal lining. A total of 18 experiments were conducted; 12 of them on the sandwich panels that are used in Zaatari camp shelters, and the other 6 experiments on the materials of Azraq camp shelters, specifically on the insulation that is used in-between the walls and as an internal lining and polyethylene sheets that is used as external or internal lining. A more detailed description of these experiments and the used methodology is given in Section 4.

3. Photo analysis of Azraq and Zaatari refugee shelters

3.1 Ignition risk

Antonellis, Underhill, Vaiciulyte, et al. (2023) argue that daily activities are behind most of the ignition risks, specifically those which need sourcing energy, such as heating, cooking, and lighting. Antonellis, Underhill, Cicione, et al. (2023) adds other common causes, such as overloaded electrical connections, faulty electrical wiring, and electrical devices which are either old or non-compliant. Both, Antonellis, Underhill, Vaiciulyte, et al. (2023) and Antonellis, Underhill, Cicione, et al. (2023), elaborate on the risks that accommodate open flames, specifically in indoor context and when surrounded by combustible materials as the three elements of fire triangle, i.e. heat, fuel, and oxygen, are present in such scenarios, which increases the possibility of fire ignition and spread.

In Zaatari and Azraq camps, the causes of fire ignition are similar to fire causes in many refugee camps and informal settlements around the world. According to the residents of the researched shelters, the fire ignition goes back to: (1) electrical hazards, such as inadequate manual wiring or overloaded circuits, and (2) open flames, such as candles, cooktops, or heaters.

In a study by Mindset & UNHCR (2022) in Zaatari and Azraq camps where the acceptance of the electrical installation to the residents was surveyed, it was found that about 18% of shelters in Zaatari camp have sub-standard electrical installation conditions, whereas the percentage in Azraq camp was 7%. The sub-standard condition was defined in the report as exposed wires and improper electrical installation. According to UNHCR (2022a) the number of used shelters in Zaatari and Azraq camps until January 2022, was 26,000 and 8,797 respectively. This means that about 4,680 shelters in Zaatari and 615 shelter in Azraq, are prone to fire ignition.

During the visits to the camps, it was noted that each shelter has an electricity box, which provides a level of safety. However, in most cases, the refugees manually added extra wires, without necessarily having previous experience in doing electrical work. Figure 1(a) shows an example of the manual wiring where cords are hanging over each other on the shelter's wall, while Figure 1(b) shows an example of an overloaded circuit, that is adjacent to a fabric lining. In Figure 1(c), there is a source of open flame that is close to combustible fabric lining. These cases are evidence to what local authorities mentioned in the interviews, and to what was found in Table 1, about the main causes of fire being electric faults or gas canisters.

(a) (b) (c)

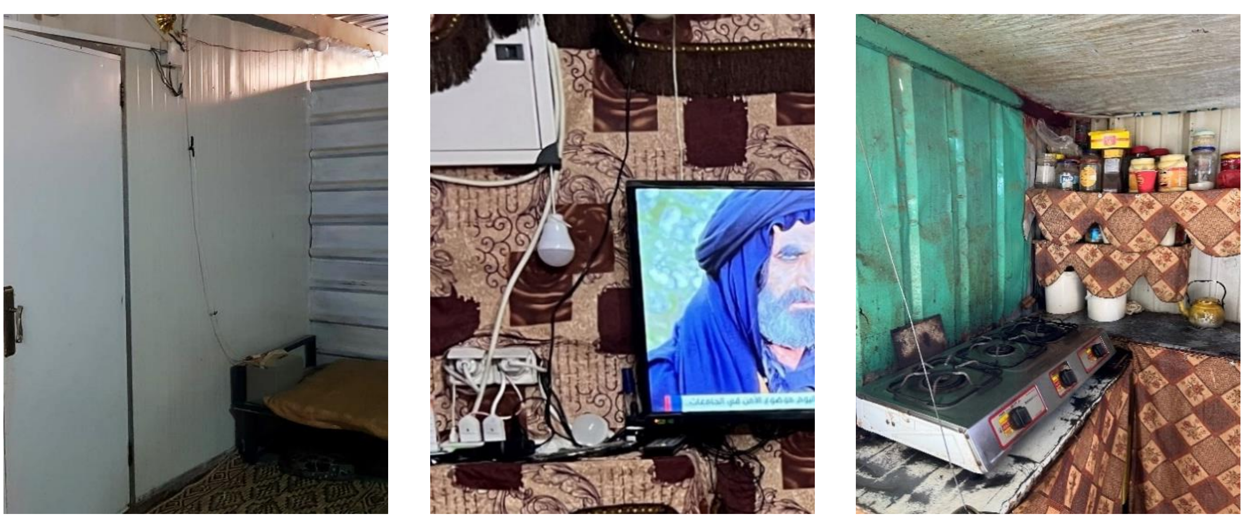

Figure 1: Examples of possible causes of fire ignition: a) Unsafe electric cords- Zaatari camp- Shelter 2 (Alshawawreh, 2021), b) Overloaded circuit close to fabric lining- Azraq camp- Shelter 3 (Alshawawreh, 2022), c) Open flame close to fabric lining in a kitchen- Azraq camp- Shelter 2 (Alshawawreh, 2022)

While no photos of candles or heaters were taken because the visits were conducted during the summer season and in the mornings, they are amongst the main causes of fire events in the camps. One of the shared stories by the refugees during the visits was of a burnt shelter in Azraq camp. An electrical heater was working when the electricity was cut in the camp. The shelter residents did not turn it off afterwards, and apparently, while the kids were playing in the shelter, the heater went upside down. When the electricity returned in the evening, the flame of the heater touched the combustible furniture and within seconds the whole shelter was burnt. Thankfully, no one was in the shelter at that time, but the shelter was completely burnt out. During the informal conversations, the refugees made it clear that this story, amongst many others, made the camps' residents in continuous fear of being the content of the next story of a burnt shelter in the camp.

3.2 Fire development

The fire ignition by itself does not cause harm, it must develop and potentially spread to do that. The growth of fire depends on the type of fuel within the shelter, assuming there is enough heat and oxygen.

The contents of shelters are major players in cases of fire, specifically on the heat release rate. However, this is highly contextual based on culture, humanitarian distributions, economic abilities, and personal preferences (Antonellis, Underhill, Cicione, et al., 2023).In the studied camps, the main source of fuel is that of loaded furniture, for instance, cushions, beds, and other household items such as tables and chairs.

An additional fuel source found in these refugee shelters is the insulation in the walls and ceilings. The fuel in Azraq camp is greater than in the Zaatari camp for this element, as most shelter residents cover the interior walls and roof with a combustible lining made either from plastic, fabric, or foam insulation with a layer of Aluminum foil; the same material as the insulation in the original shelter structure between the Inverted Box Rib (IBR) panels.

According to Antonellis, Underhill, Cicione, et al. (2023), and based on full-scale fire experiment in Cape Town, South Africa, it was found that internal lining layer has huge effect on the time to fire flashover as the layer decreases it significantly. The rapid flashover does not give people inside the structure the needed time to evacuate, especially if they were sleeping.

Figure 2(a) shows the interior of a shelter in Azraq camp with a fuel loaded foam mattresses, plastic floor mat (which emits more toxic fumes when burnt), and fully covered walls and roof with foam lining that is very combustible. While the refugees are aware of this fact, many of them still use this lining due to the unbearable indoor temperature, specifically during the summer seasons. However, as seen in Figure 2(b), some of the residents decided to minimize this risk, and covered the interior walls of their shelter with fabric instead, though still used the mattresses and plastic floor mat. The same residents added a self-built extension and covered the interior with plastic lining as seen in Figure 2(c). In Zaatari camp shelter example that is shown in Figure 2(d), the residents used the same mattresses, however, they used carpet flooring, and did not use any indoor lining. This goes back to the enhanced thermal comfort inside the Zaatari camp shelters (Albadra et al., 2018), which could be referred to the better weather conditions and shelter technicality, compared to Azraq camp shelters. However, both camps have high unsatisfaction levels of thermal comfort (Albadra et al., 2018).

Figure 2: The interior of some shelters that could affect the development of fire: a) Foam lining and fuel loaded furniture at Azraq camp- shelter 1 (Alshawawreh, 2022), b) Fabric lining and combustible furniture at Azraq camp- shelter 3 (Alshawawreh, 2022), c) Plastic lining at Azraq camp- shelter 3 (Alshawawreh, 2022), d) A shelter's interior at Zaatari camp- shelter 4 (Alshawawreh, 2021)

The insulation layer in the sandwich panels of Zaatari camp shelters and in-between the IBR in Azraq camp shelters, by and large, is not accessible. However, if the steel sheets or the IBR panels are damaged, due to holes resulting from hanging items on the walls or roof, making amendments to the shelter such as relocating windows, or from previously fixated screws as seen in Figure 3(a,b,c), then the insulation could be exposed which would contribute significantly to the available fuel for combustion. Figure 3(d) shows a case in Azraq camp where the aluminum foil cover of the added indoor lining is ripped off, which fully exposes the fuel loaded foam. In Azraq camp specifically, the air gaps can be found in all shelters; around doors, windows and in the roof-walls intersections due to the corrugated nature of the IBR sheets (Figure 3(e)). Fosas et al. (2020) state that doors and windows in Azraq camp shelters have gaps around them of up to 20 mm, as they are custom-made in the camp. Air gaps can also be found on every intersection between self-built extensions and original shelter walls as seen in Figure 3(f).

Figure 3: Examples of cases where walls and roofs have holes and gaps: a) An external wall with holes- Zaatari camp- Shelter 7 (Alshawawreh, 2021), b) An indoor wall with slots from relocating the window- Zaatari camp- Shelter 3 (Alshawawreh, 2021), c) An external wall with holes and slots- Azraq camp- Shelter 3 (Alshawawreh, 2022), d) An indoor lining with a ripped-off aluminium foil layer- Azraq camp- Shelter 1 (Alshawawreh, 2022), e) Door with holes and air gaps around- Azraq camp- Shelter 1 (Alshawawreh, 2022), f)) Air gaps in the connection between the self-built wall and the provided shelter- Zaatari Camp- Shelter 3 (Alshawawreh, 2021).

The high concentration of stored items inside the shelters, such as plastic, wood, fabric, or even fuel, specifically in corners, mezzanines, and hanging from walls, can also accelerate the possible hazards, due to rapid growth of fire and the release of toxic fumes. Figure 4(a) shows a shelter at Zaatari camp, where the residents self-built an extension out of corrugated sheets and used it as a storage. The shelter shown in Figure 4(b) is at Azraq camp, where plastic containers of water and fuel are stored in a self-built kitchen. Figure 4(c) is for a shelter in Azraq camp that shows a very common amendment that refugees do in both camps, where the residents enclose the space in-between their two shelters with a pitched roof made out of corrugated sheets and plastic sheeting lining. In this space shown in the figure, they added a storage mezzanine where unused items are stored, which makes it a concentrated source of fuel in cases of fire.

Figure 4: Examples of stored items inside the shelters: a) self-built storage at Zaatari camp- shelter 2 (Alshawawreh, 2021), b) Stored containers in a self-built kitchen at Azraq camp- shelter 2 (Alshawawreh, 2022), c) Self-built mezzanine at Azraq camp- shelter 3 (Alshawawreh, 2022).

3.3 Fire spread within the shelter

Generally, fire spread in three ways, radiation (heat transfer through electromagnetic waves), convection (heat transfer from a fluid to another body or transportation of energy by heat driven movement of the fluid) or conduction (heat transfer through a solid material) (Antonellis, Underhill, Cicione, et al., 2023). All are possible to happen in the studied shelters.

The original shelters in both Zaatari and Azraq camps have one-room designs, therefore, hypothetically, there would be no other rooms for the fire to spread into. However, as mentioned earlier, the residents add spaces whenever they could. These extensions depend on the available adjacent vacant areas and on the financial abilities of the residents. In some cases, when the residents could not add extra spaces, they tended to divide the original room with materials they secure by themselves.

The self-built extensions and adaptations, in most cases, were made out of corrugated sheets with wooden or steel poles. However, these extensions have no insulation layer as shown in Figure 5(a, b). In cases of internal partitions, they were mainly made out of fabric or corrugated sheets, and fixed either on steel or on wooden poles such as the case in Figure 5(c) where a corrugated partition is dividing the shelter. As mentioned in the previous section, refugees in Zaatari camp who were given two shelters, relocated their shelters in a way that kept a separation distance between them of about 3-4 meters, and when they had the financial ability, they enclosed this space with a pitched roof and corrugated sheet walls, as seen in Figure 5(d).

The main concern about these cases is that in most of them, the separation wall does not reach the roof, while in other cases, plastic or fabric are used to complete the new partition or wall as seen in Figure 5(b,c,d,e,f). In cases where the partition reaches the roof, there would still be air leakage due to the nature of the corrugated sheets that alternates ridges and grooves, which makes sealing them a hard job (Figure 5(a)). By not having a solid, full height partition, fire and smoke can easily spread within these shelters, if not by conduction, it could be spread by radiation or convention.

Figure 5: Interior photos of some shelters where additions could accelerate the fire spread within the shelter: a) Self-built toilet- Azraq camp- shelter 3 (Alshawawreh, 2022), b) Self-built kitchen- Zaatari camp- shelter 4 (Alshawawreh, 2021), c) Self-built partition dividing a shelter- Zaatari camp- shelter 5 (Alshawawreh, 2021), d) Self-built hall and toilet- Azraq camp- shelter 1 (Alshawawreh, 2022), e) Self-built short wall enclosing a toilet- Zaatari camp- shelter 7 (Alshawawreh, 2021), f) Self-built short partition enclosing a storage- Zaatari camp- shelter 5 (Alshawawreh, 2021).

3.4 Fire spread between structures

Despite the common recommendation of having a fire spread between structures that equals twice the height, and the sphere handbook reconfirmation of this recommendation, while setting a minimum recommended distance between structures of two meters (Sphere Association, 2018b; Sphere Project, 2011), the current situation in both camps do not fulfil these guidelines.

Whereas the shelters in Zaatari camp were movable, and therefore, were relocated and extended by refugees as shown in Figure 6(a,b), the shelters in Azraq camp are fixed in the ground and the refugees could not relocate them. However, refugees in Azraq camp extended their shelters when they had the financial ability by enclosing the two-meters space in-between shelters, and with time, they were able to enclose more space depending on vacant adjacent land. These changes made the shelters proximate to each other and in many cases, adjacent. Figure 6(c) shows how the rows of shelters in one of the streets are fully connected where each in-between distance is enclosed and used privately. This hazard of proximate structures is exacerbated by the fact that they are not well sealed (as seen in Figure 3 and Figure 5) which allows many possible pathways for a fire to spread into another structure.

Additionally, what makes the shelters and settlements more vulnerable in cases of fire, is the material storage located in the added outdoor private areas between the structures, such as the case in Figure 6(d) and over the roofs (Figure 6(e,f)). These “ladder fuels” allow fires to spread from structure to structure with relative ease.

Figure 6: Exterior photos in the camps that show how fire could spread between different structures: a) Self-built extensions- Zaatari camp- Shelter 5 (Alshawawreh, 2021), b) Narrow pathway between shelters- Zaatari camp- Shelter 6 (Alshawawreh, 2021), c) Rows of shelters- Azraq camp- Street view (Alshawawreh, 2023), d) Outdoor stored materials- Zaatari camp- Shelter 7 (Alshawawreh, 2021), e) Over-roof materials- Azraq camp- Shelter 2 (Alshawawreh, 2022), f) Over-roof materials- Azraq camp- Street view (Alshawawreh, 2022).

3.5 Access/ Human behavior in case of fire

As mentioned in the introduction section and through camp visits and interviews with local authorities, both camps have branches of the Jordanian civil defense directorate which includes the fire station, and most shelters have fire extinguishers, such as the case in Figure 5(f). Additionally, the shelters in both camps have a one floor design, which makes escaping them in cases of fire is a relatively easy task. However, escaping the shelter would not guarantee being in a safe zone. Therefore, a separation distance in front of shelters is important. This distance is different than the fire break between shelters in the same row, which is important to stop the spread of fire. Figure 7 clarifies the accessibility of shelters in both camps.

(a) (b)

Figure 7: Photos clarifying the accessibility of the shelters: a) Narrow street entrance between shelters- Azraq camp- street view (Alshawawreh, 2023), b) Stored materials in front of the door- Zaatari camp- Shelter 5 (Alshawawreh, 2021), c) Self-made sanitary extension- Zaatari camp- Shelter 1 (Alshawawreh, 2021), d) Sand-filled bags on shelters' entrances- Azraq camp- Shelter 3 (Alshawawreh, 2021).

In Azraq camp, the front separation space is provided in most cases, albeit some amendments such as the one shown in Figure 7(a) violate this space, where refugees extend their shelters by not only enclosing the in-between space, but also front street space. In Zaatari camp, and due to the rapid initiation and development of the camp, the relocation of shelters, and due to the unplanned self-built extensions, this separation space does rarely exist.

However, even in the areas that have this space in both camps, some of the refugees' behavior causes obstruction on their way out in cases of fire. These behaviors include storing materials outside the door gate (Figure 7(b)), self-making sanitary extensions above the ground (Figure 7(c)), and adding a layer of stone or soil-filled bags to prevent the rain water from entering their shelters (Figure 7(d)). These narrower separation distances inhibit the safe egress from a fire but may also impede any firefighting attempts.

3.5 Photo analysis results

While section 3 provided detailed photo analysis of fire risk evidence from Zaatari and Azraq camps, Table 4 summarises the findings in relation to the five aspects of fire risk that were adopted in this research.

Table 4: Summary of findings from photo analysis

	Aspect of fire risk	**Main reason**	**Existing element/ behavior**
1	Ignition	Electrical Hazards	• Sub-standard electrical installation due to inadequate manual wiring. • Overloaded circuit. • Inconsistent electricity provision – accompanied with users' misuse.
		Open flames	• Use of candles, cooktops, or heaters – accompanied with users' misuse.
2	Fire development	Fuel loaded furniture	• Foam mattresses, cushions, plastic floor mats, beds, and other household items such as tables and chairs.
		Stored fuel loaded items	• High concentration of unused stored items inside the shelters.
		Fuel loaded insulation/ lining	• Whether as part of the structure/s insulation or added as a lining by the residents to enhance the indoor thermal comfort.
		Unsealed junctions	• Due to shelters reaching their end of useful life (Zaatari case) or due to the corrugated nature of the IBR sheets (Azraq case).
		Holes and gaps in walls	• Due to purposefully made holes for hanging items, previously fixated screws, or slots from relocating openings.

	Aspect of fire risk	Main reason	Existing element/ behavior
3	Fire spread within the shelter	Unsealed self-built extensions	• Air gaps can be found on wall-roof and wall-wall intersections.
		Incomplete walls	• Self-built walls that do not reach the roof.
4	Fire spreads between structures	Proximate/ adjacent structures	• Extending the shelters by occupying the designated in-between shelters space.
		Outdoor stored materials	• Random materials are being stored in the private outdoor spaces, and above roofs.
5	Access/ Human behavior in case of fire	Narrow separation distance	• Violating the front street space by enclosing its land or relocating shelters on it.
		Blocking the exist route	• Storing furniture or materials in a way that blocks the way out.

4. Behaviour in fire of materials from Azraq and Zaatari refugee shelters

Given the vulnerable nature of these shelters and camps to fire and fire spread as noted in sections 2 and 3, it is of paramount importance to understand the specific reaction to fire of the materials that are used in these structures. Combustible materials, such as those found inside the shelters, and the shelters themselves, undergo a series of stages and behaviours in a fire, reacting to heat and flames. Various factors, such as composition, thickness, density, and exposure to heat flux (the rate of heat transfer), influence the behaviour of combustible materials during a fire event. Initially, when a material is exposed to sufficient heat transfer, it undergoes pyrolysis, which is the decomposition of the material into smaller molecules, often in the form of gases. These gases can mix with air, creating a flammable mixture. If there is either a pre-existing ignition source, such as a candle, or enough heat flux to cause spontaneous ignition, the flammable gas mixture ignites, resulting in a flame. Under favourable conditions, the flame can spread along the material's surface.

Different combustible materials exhibit unique behaviours during these stages and release energy as heat at different rates. The heat release rate (HRR) directly impacts the intensity and growth rate of the fire. As the material combusts, it loses mass, and the mass loss rate is proportional to the HRR under certain conditions. The mass lost during combustion not only includes pyrolysis gases but can also consist of other toxic gases and soot particles. The behaviour of a combustible material in a fire is influenced by the heat flux to which it is exposed. Heat flux represents the amount of heat energy transferred per unit area per unit time. Higher heat flux intensities lead to more rapid reactions of the material, potentially affecting its fire behaviour in various ways, such as faster pyrolysis, quicker ignition, rapid flame spread, shorter flaming duration, increased heat release rates, and greater production of soot and toxic gases.

To develop a comprehensive understanding of materials and products in fire scenarios, several standard reaction-to-fire tests are available. These tests, such as the single burning item (SBI) test (BSI, 2023) and flame spread tests (ISO, 2011) assess various combustion-related properties of a material during the different stages outlined above. They are essential for determining the flammability and fire performance of materials and help in ensuring fire safety in different applications.

In this section, one such standard test arrangement, namely the cone calorimeter (ISO, 2002a) is used to start to understand the materials behaviour in fire of samples taken from the Azraq and Zaatari refugee camps. During a cone calorimeter test, a small sample of the material (usually a square or circular shape) is exposed to a controlled heat flux in the range of 20 to 100 kW/m^2. The heat flux replicates the heat exposure that a material may experience during a real fire event. The cone calorimeter can be used to calculate various parameters, including: HRR, Time to Ignition, total burning time, mass loss and mass loss rate, smoke and gas production (namely CO and CO_2) with time, and total heat released.

Therefore, these experiments aim at understanding, initially, what the fire hazard might be, which is essentially how easy it is to ignite the material, and how quickly the material burns and thus contribute to the fire intensity. However, these experiments cannot indicate what real-world performance of the material and systems they are within, or how flames and fires would spread at a larger scale. The tested samples are small and tested in controlled laboratory conditions that do not fully replicate the complex conditions of an actual fire scenario, such as varying heat exposure, airflow, and fuel loads.

4.1 Method and testing matrix

The cone calorimeter tests within this paper should be considered as initial scoping experiments to understand three main parameters for the specimens we are exposing to radiant heat, namely: time to ignition; burning time; and heat release rate (HRR). Each specimen type will be exposed to incident radiant heat fluxes of 25 and 50 kW/m^2; these fluxes simulate fluxes present in a growing fire scenario, and in an established fire scenario, respectively. All specimens were exposed to the heat fluxes in a horizontal orientation and an electronic spark used as a pilot ignition source. The specimen was considered as ignited after sustained flaming for 4 s in each test (ASTM, 2007). The smouldering, glowing or flash were not considered as ignition, as the visible flame and its radiation are normally more important to the fire spread in camps.

The cone calorimeter at the University of Edinburgh was used to measure the parameters as per ISO 5660 (ISO, 2002b). Before each test, the exhaust flow, gas analysers, cone heater height, load cell and heat flux were calibrated. The materials were cut into the dimension of 100 mm×100 mm for the exposed face. The specimen sides were wrapped with aluminium foil and well placed in the metal holder, as shown in Figure 8a.

The selection criteria for the tested materials were either used in the original shelter provided to the refugees or distributed to them by aid agencies. Therefore, three materials were sourced from the refugee camps, namely: the structural steel-foam-steel sandwich panel (SP) used in the Zaatari camp's shelters, aluminium coated foam insulation (AL) used in Azraq camp's shelters as insulation in the original shelter and as indoor lining, and polyethylene sheets (PE) used as inner roof and lining in Azraq camp. The thickness of each material type was 50 mm, 12.5 mm, and <0.5 mm, respectively. According to the requirements set out in (SFPE, 2016), the exposed materials should be 50 mm in thickness, therefore ceramic insulation was used behind the AL and PE materials to ensure the correct thickness was obtained. This followed similar studies, such as (Wang et al., 2019).

The key question that we were aiming to gain some understanding over is how these materials, as they are used over their lifetime, react in fire. Therefore, as a result to the findings from the photo analysis and to mimic the current situation of the materials, we induced specific and controlled defects/alterations to the SP samples as stated in Table 4- aspect 2- holes and gaps in walls and as seen in Figure 3(a,b,e). We also looked at how the AL and PE materials worked in isolation and as a system as stated in Table 4- aspect 2- Fuel loaded insulation/ lining and seen in Figure 2(a,c) and Figure 3(d). Therefore, in total there were 12 SP specimens used: six variations under each of the two heat fluxes. The variations can be seen in Table 5, which are: a control set with no hole in the steel plate; a 5 mm (20 mm^2 area exposed), 9.5 mm (71 mm^2 area exposed), and 12.5 mm hole (122 mm^2 area exposed) in the centre of each top plate; a 1.5 mm slot across the 100 mm width of the top plate; and specimens where the entire top plate is removed. These are shown in Figure 8 below. In addition to the SP specimens, three other specimens were used, AL (Figure 8g), PE (Figure 8h), and with the AL first exposed to the heat. All specimen types were exposed to 25 and 50 kW/m^2 heat fluxes apart from the PE specimens which was only exposed to 25 kW/m^2 for reasons described below. Unfortunately, due to limited material, no repeats were conducted, therefore results should be treated with this in mind.

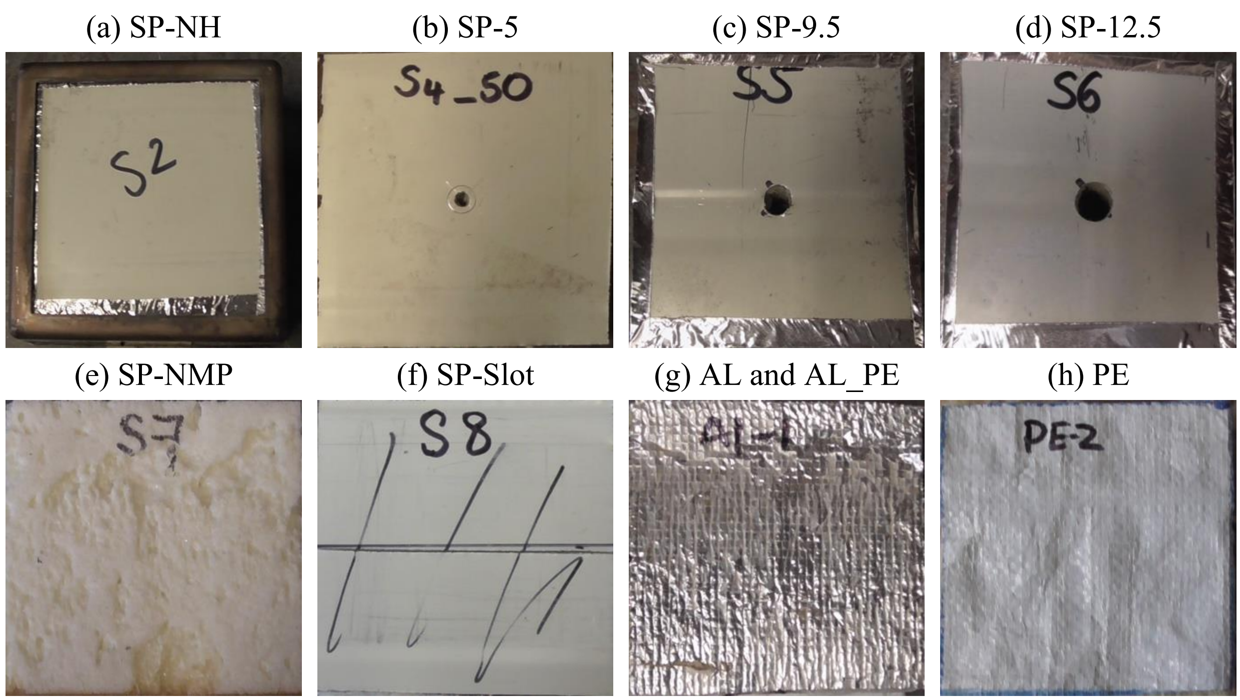

Figure 8: Selection of sample images of (a) SP-NH in specimen holder, (b) SP-5, (c) SP-9.5, (d) SP-12.5, (e) SP-NMP, (f) SP-Slot, (g) AL (and by inference AL-PE), and (h) PE.

4.2 Results

4.2.1 Overall visual observations of how samples reacted.

There are many things to note visually on how these samples reacted during exposure to the radiant heat fluxes. This will also help explain, in part, the quantitative data shown in Table 5.

With regards to the very initial heating stages, most of the SP samples showed little reaction to the heat source. The two samples without the plates (NP) immediately showed signs of pyrolysis. Under the 50kW/m^2 incident heat flux spontaneous ignition of those pyrolysis gases was observed (i.e., there was flaming combustion before the electronic spark igniter was engaged). It was also noted that during the early stages of heating, before the igniter was engaged, that the AL and PE based specimens melted from a solid foam into a liquid away from the heat source.

All the SP samples prior to ignition showed the creation of flammable gases being ejected from the exposed surface of the sample. For those with the hole or slot – the pyrolysis gases exited these. However, for the control, no hole, samples pyrolysis gases were seen to escape round the edges of the sample where the aluminium tape used to seal the samples failed. This failure is assumed to be caused by a) the bond being weakened due to the heat exposure, and b) due to the pressure increase inside of the sandwich panel sample caused by the decomposition of the foam from a solid state into a hot gaseous state.

Once the samples were ignited, steady and sometimes laminar flames were established for all the SP hole experiments, with the smaller holes had smaller flames, larger holes had larger flames. The NMP samples had very large and turbulent flames, while the AL, and AL+PE samples had sustained medium sized flames. The PE specimens melted away before ignition started so no flames were recorded. The largest observed flames for each experiment can be seen in Figure 9.

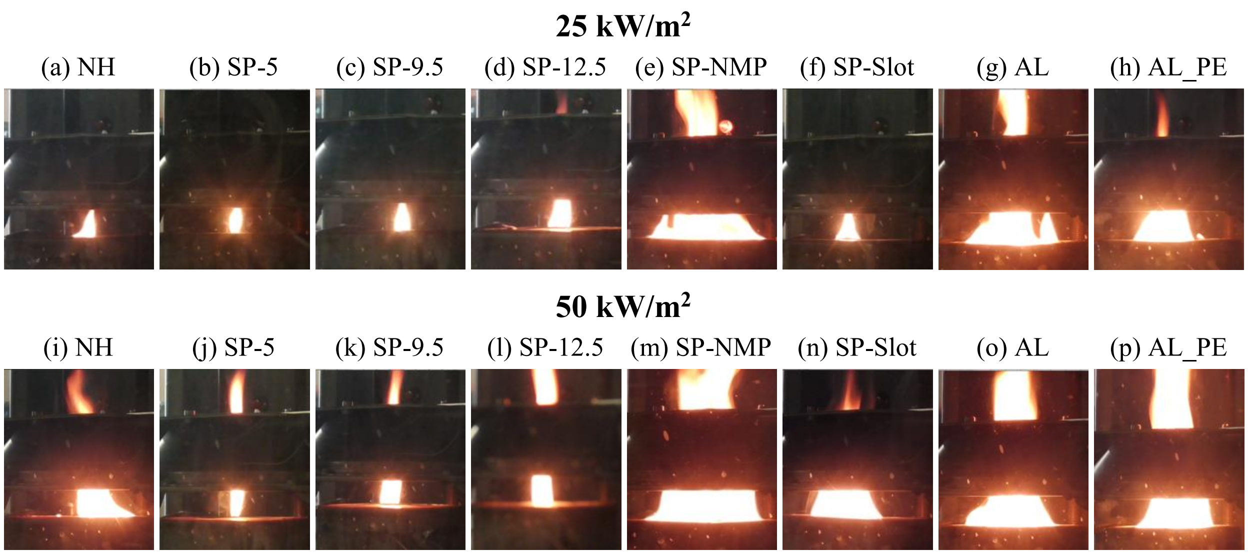

Figure 9: Images of largest flame observed for each experiment (25 kW/m^2 top row a-h, 50 kW/m^2 bottom row i-p)

After the experiment, the top plates of the SP samples were removed to examine the response of the foam behind. There was consistent evidence of charring of the foam insulation (Figure 10). This can be either due to flaming combustion or smouldering combustion (i.e., combustion without flames), however there was no mechanism to check this during the experiments. For the AL and PE experiments – no material remained as all was consumed during burning.

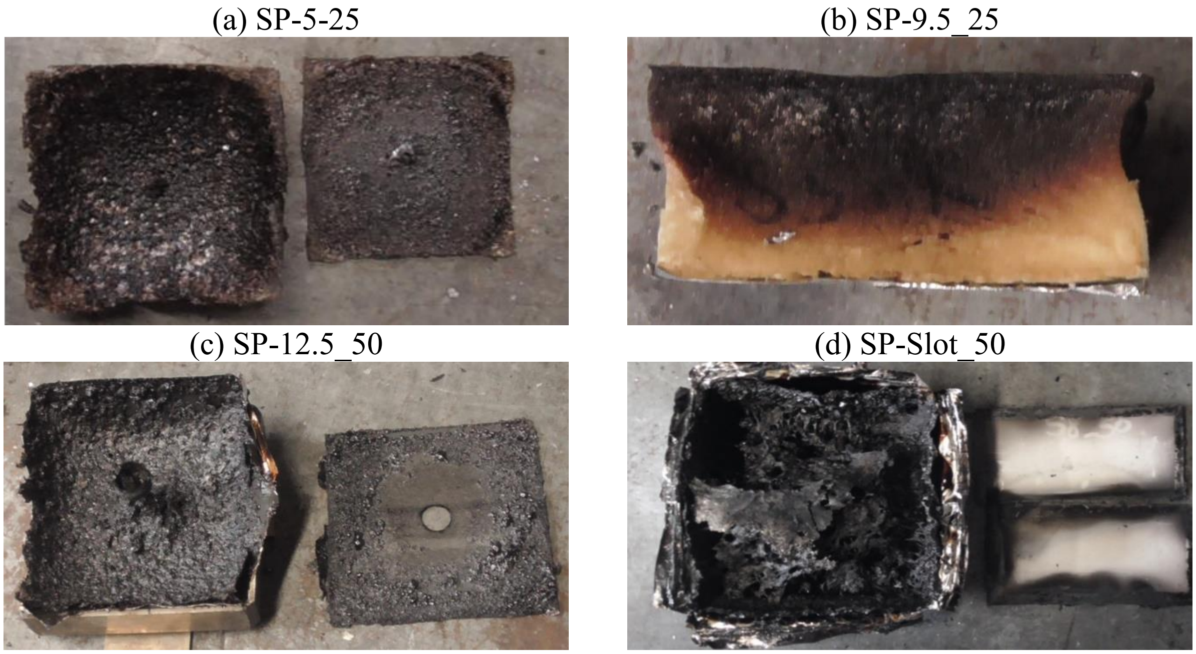

Figure 10: Photos of charred foam after cooling from selected experiments.

4.2.2 Quantitative results

The next section will describe the quantitative results from the experiments. It should be noted that to have more rigorous data, experiments for each specimen type should be repeated at least three times to have a repeatability in the data. Due to specimen volume limits only one iteration of the experiments of each specimen type were conducted so the quantitative data and the trends they point to need to be treated carefully by the reader.

Firstly, as expected the general trend is that the specimens exposed to the higher heat flux of 50kW/m^2, ignited quicker, had higher heat release rate per unit area (HRRPUA), consumed more of the material, and released more energy in total, than the similar specimens exposed to 25 kW/m^2. This can be seen by comparing, for instance, experiments SP-5_25 and SP-5_50 in Table 5 and in Figure 11.

Table 5: Summary results for cone calorimeter experiments

Experiment	Hole Ø	Heat flux exposure	Time to ignition	Time of visible flaming	Total Mass loss	Max. HRRPUA	Total energy released	Total energy released per mass loss
	(mm)	(kW/m^2)	(s)	(s)	(g)	(kW/m^2)	(kJ)	(kJ/g)
SP-NH_25	-	25	798	1162	5.71	4.14	9	1.58
SP-NH_50	-	50	82	480	10.33	61.08	81	7.84
SP-5_25	5.00	25	126	885	4.36	4.97	25	5.73
SP-9.5_25	9.50	25	139	682	4.91	12.29	57	11.61
SP-12.5_25	12.50	25	63	3361	10.30	19.24	107	10.39
SP-5_50	5.00	50	41	449	13.87	40.61	158	11.39
SP-9.5_50	9.50	50	42	1599	11.15	30.98	110	9.87
SP-12.5_50	12.50	50	19	1878	14.22	53.30	184	12.94
SP-Slot_25	-	25	171	438	2.13	7.20	11	5.16
SP-Slot_50	-	50	25	1296	12.56	54.92	151	12.02
SP-NMP_25	-	25	27	507	7.78	87.60	92	11.83
SP-NMP_50	-	50	*17*†	846	17.02	137.12	268	15.75
AL-25		25	84	361	4.24	108.70	99	23.35
AL-50		50	28	314	5.32	172.39	118	22.18
PE-25		*25*	*#N/A*	*#N/A*	*0.30*	*3.35*	*1*	3.33
AL_PE-25		25	108	544	6.52	60.70	162	24.85
AL_PE-50		50	30	421	7.79	164.73	198	25.42

SP = Sandwich Panel. AL=Aluminium coated foam; PE=Polyethylene sheet; -5, -9.5, -12.5 = diameter size OR -slot/-NMP/-NH = slot, No metal plate, No hole (control); _25/50 - flux level, HRRPUA = Heat release rate per unit area, † - video evidence suggests this closer to 3 seconds before spontaneous ignition, 17 seconds was what was recorded in the data acquisition system.

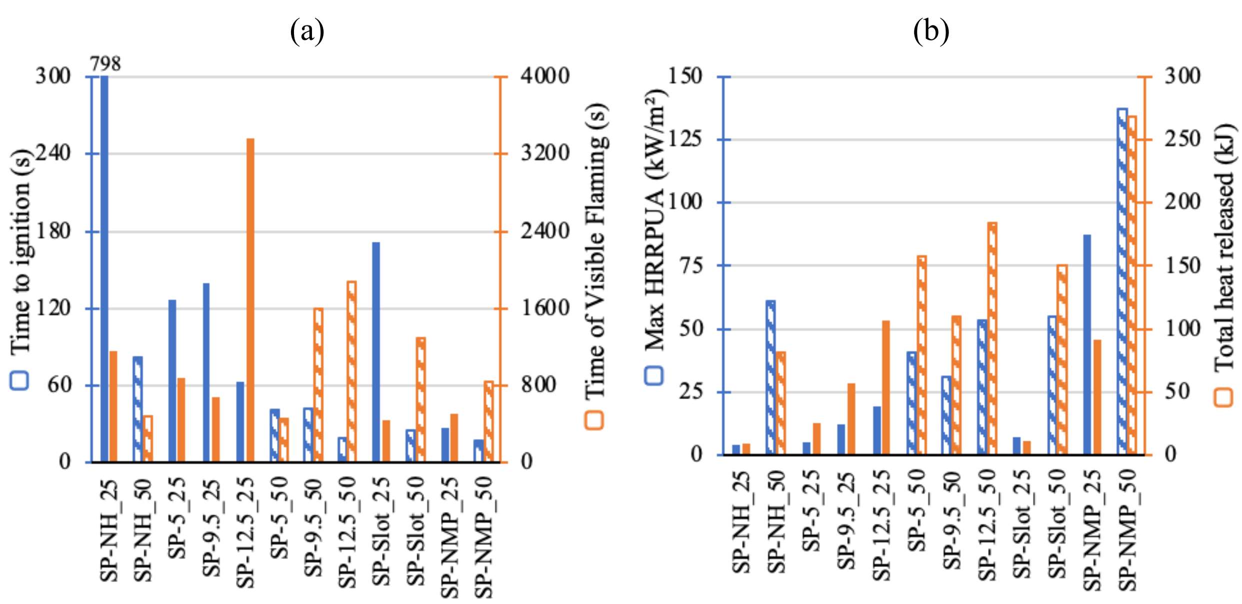

Figure 11: Comparison of: (a) time to ignition and time of visible flaming, and (b) Max HRRPUA and the total heat released for the sandwich panel (SP) experiments (Solid bars - $25kW/m^2$, hatched bars - $50kW/m^2$)

In general, as the diameter of the hole increases, the time to ignition decreases, while the peak HRRPUA, time of visible flaming, and total released energy all increase. Note that this is not fully shown in the data, highlighting the need to conduct repeats of these experiments to provide a statistically robust set of data and thus understanding. The HRR vs Time response of the specimens was relatively consistent with no significant heat released until ignition had occurred, with a sharp increase then occurring, followed by a gentle decline until extinction. This can be seen in the HRR vs Time curves in Figure 12 and Figure 13.

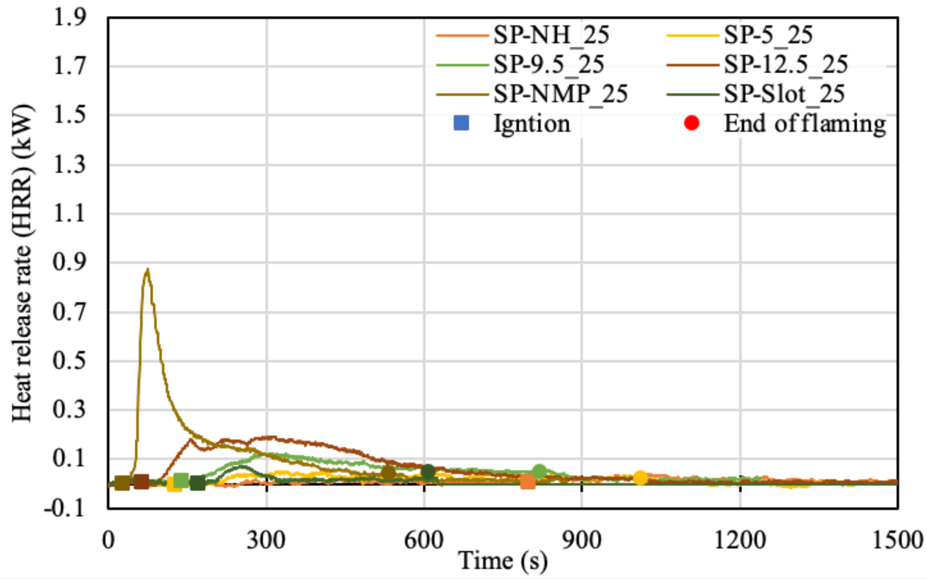

Figure 12: Heat release rate versus time curve for the SP experiments exposed to 25 kW/m^2 incident heat flux (x-axis time limited to 25 minutes (1500 seconds) to focus on the early stages of reaction to heat)

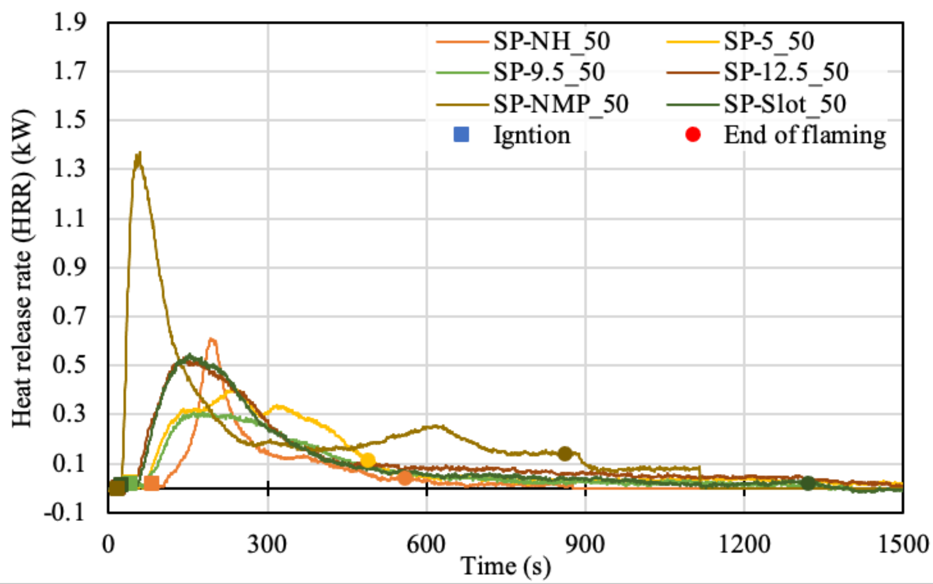

Figure 13: Heat release rate versus time curve for the SP experiments exposed to 50 kW/m^2 incident heat flux (x-axis time limited to 25 minutes (1500 seconds) to focus on the early stages of reaction to heat)

The SP samples with no metal plate, as expected showed the highest values of HRRPUA, compared with those with holes or slots, with the greatest variance being seen at the 25kW/m2 heat exposure, as can be seen in Table 5 and Figure 11(b). The HRR vs Time response was similar between the two heat exposure levels, but with differing peaks and times to ignition and extinction, as would be expected, as seen in Figure 12 and Figure 13, respectively.

The reaction of the SP-Slot_25 with the slot across its width, showed some similarity to SP-5_25 experiment while the SP-Slot_50 showed remarkable similarity to the SP-12.5_50 experiment. This can be seen in the HRR with time curves in Figure 12 and Figure 13, respectively.

The specimens with no hole, as expected were the slowest to ignite, however the max HRRPUA for SP-NH_50 was the highest for the SP samples under the 50kW/m2 samples barring that of NMP. This can be understood by looking at the HRR vs Time curves in Figure 13, where the NH curve shows similar trend to that of NMP, a very rapid increase in HRR followed by a sharp decline. This indicates that could have been a build-up of pyrolysis gases inside the panel which, as the aluminium tape degraded, had that pressure released causing the response and higher than expected peak HRRPUA. The HRR vs Time responses of the other specimens should a much more gradual decline after the peak HRR was reached.

The aluminium foam (AL) and the combined aluminium foam and polyethylene sheet (AL_PE) experiments showed that these materials have higher peak HRRPUA, and release similar amounts of total energy compared to the most severe of the sandwich panel experiments, those with no metal plate (NMP).

Comparing the AL to the AL_PE experiments, the data may suggest that the addition of the PE may delay ignition, and decrease the peak HRRPUA, but significantly increase the total amount of energy released during combustion and increase burning time. This can be seen in Figure 14.

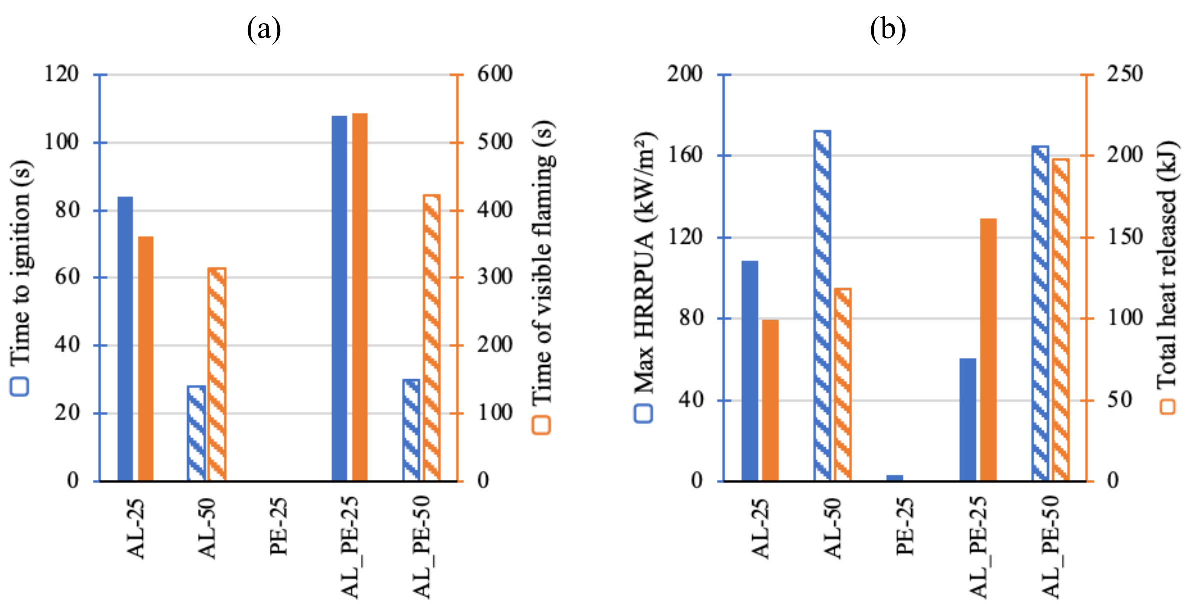

Figure 14: Comparison of: (a) time to ignition and time of visible flaming, and (b) Max HRRPUA and the total heat released for the Aluminium coated foam (AL) and Polyethylene (PE) experiments (Solid bars - 25kW/m^2, hatched bars - 50kW/m^2)

The HRR vs Time response of the AL and AL_PE experiments, as seen in Figure 15, showed similar response as to the SP-NMP experiments, however, with greater peaks. The sharp increase in heat release rate, and the effect of the PE can be seen to delay the peak HRR at both 25 and 50 kW/m^2, with the 25 kW/m^2 seeing the most significant impact with the peak HRR being delayed by approximately 100 seconds. This could have a significant affect in a real scenario by slowing the growth of a fire.

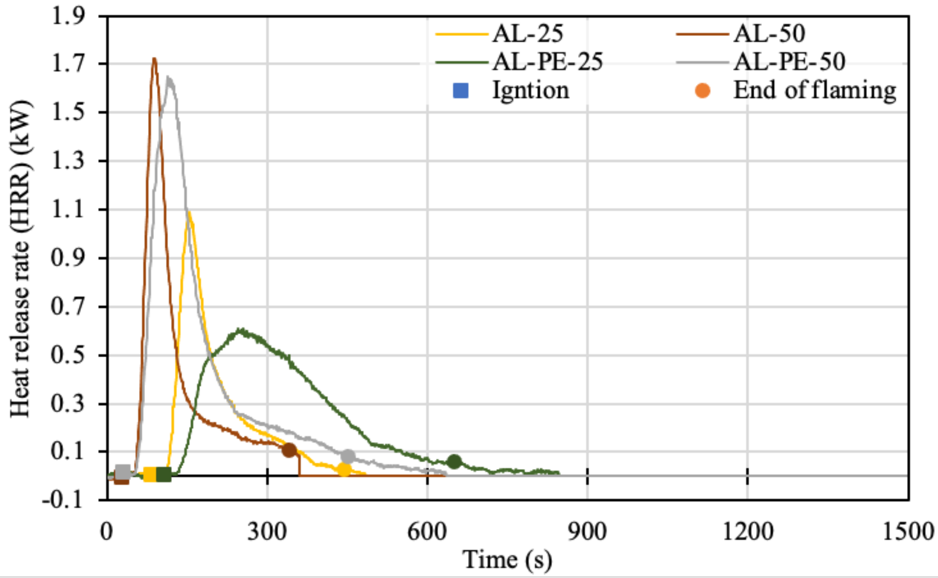

Figure 15: Heat release rate versus time curve for the AL and PE experiments exposed to both the 25 and 50 kW/m^2 incident heat flux (x-axis time limited to 25 minutes (1500 seconds) to focus on the early stages of reaction to heat)

Looking holistically at the data, the materials being tested suggest that they are polyurethane foams (either rigid in the sandwich panels (SP) specimens, or flexible for the AL specimens) (Petrella, 1994). These may or may not have flame retardant in them (n.b. flame retardants do not stop fire entirely; they do slow the rate of pyrolysis making fires harder to establish in a compartment/shelter. However, once established, they only provide minimal assistance). Additionally, we can see that, for the specimens with holes/slots, doubling the heat exposure intensity, more than doubled the reaction to fire intensity, while for the fully exposed foams (SP-NMP, AL, and AL-PE) these reactions still increased significantly, but not to the same degree as for the samples with holes.

In terms of the fire safety of the refugee shelters, we can see that small defects and damage to the sandwich panels (e.g., screw holes) can cause fires to readily establish and burn with a high intensity, contributing to both fire development and spread. The use of plastic sheeting and the aluminium coated foam mats as a form of insulation and weather proofing was shown to burn with a higher intensity than the SP specimens. This is particularly concerning given that it is so commonly used on all surfaces of Azraq camp's shelters.

5. Conclusions & discussion

Providing shelters in refugee camps is a hard task, especially when their temporality is a governmental requirement, such as the case of the Jordanian-Syrian camps. However, the fire safety in refugee camps is a vital topic that cannot be compromised as the consequences could be worse than what the refugees originally escaped in their home countries. This research highlighted the main issues that could decrease the fire safety in the Jordanian- Syrian camps in three themes: shelter materials, shelter design, and camp planning.

In terms of materials, the SP in Zaatari camp shelters, and the IBR, foam insulation, and plastic sheeting internal roof layer in Azraq camp shelters, all are highly flammable. The SP of Zaatari camp shelters were noted to have many holes and slots, which were mimicked in the specimens tested using the cone calorimeter. It was found that these defects have clear effect on the speed of ignition by increasing it, while the NH specimens were the slowest to ignite. In a real fire event, having panels with no defects can save lives by giving more time for the occupants to deal with the event. However, the high HRRPUA that were shown for SP-NH_50 is threatening and could cause death. Additionally, in Zaatari camp, most refugees laid fabric, plastic sheeting, and excess materials over the shelters to seal the gaps which adds more fuel in cases of fire.

The IBR material in Azraq camp was found to be hardly sealed, in addition to the general lack of thermal comfort in the camp. Therefore, the refugees added an internal insulation lining such as fabric or the highly inflammable aluminium coated foam roll (where in many cases, the aluminium layer was ripped off and bare foam was exposed to the interior). In the cone calorimeter tests, one of the most notable results was that AL and PE based specimens melted before the igniter was engaged in the experiments. This is important because in a real situation where these materials are on the walls and ceilings of the shelters, there could be significant amounts of dripping of ignited combustible materials, which could spread the fire faster within and out with the compartment/shelter of origin. The PE layer had an effect in delaying the ignition and the peak HRR in the experiment. This means that adding a PE layer is of benefit in slowing the growth of fire, especially if fire is caught in early stages.

In terms of design, the one-room shelter forces the refugees to self-extend them using the affordable, yet flammable materials to build unsealed walls and roofs. Moreover, the inconsiderate and inflexible shelter design forces the refugees to amend the shelters to fulfil their needs, such as relocating openings, which resulted in having wall panels filled with gaps and holes, which can potentially increase the fire spread.

The third theme, which is the camp planning, focuses on the space in-between shelters to stop the fire spread and on having a clear space around the shelter to escape fire, if happened. The designated two meters of fire distance that were supposed to stay vacant between shelters is not enough to prevent fire from spreading. However, due to the need of extra spaces, the refugees enclose these two meters and use them as indoor or outdoor spaces with stored materials. While in Azraq camp, there is enough area in front of the main door of the shelters to escape, in Zaatari camp, it is rarely present due to the extensions made by refugees.

Despite the aforementioned issues that can be solved by decision makers, there are also some aspects that can minimise the fire-risk potential by spreading awareness within the refugees themselves which are related to how they are using their shelters:

a- The original shelter: In the walls and roofs, it is important to avoid making holes or slots as they accelerate the growth and thus the potential spread of fire. Whether they were made on purpose for hanging items and decorations, or because of relocating doors and windows.

b- Storage: A habit of many refugees is storing all materials they can get (and do not use) in hope that one day they will be of use. This habit is present inside, outside and on the roofs of the shelters. Besides the main danger of having additional fuel load and materials that might spread toxic gases in cases of fire, these materials are often stored in the egress path for the shelter, obstructing the refugees from escaping the shelter in cases of fire. Therefore, it is recommended that doorways and access routes to safe spaces should always be clear.

c- The self-made extensions: While the extensions are self-built by refugees without any consultations with the organisations, the refugees should ensure that they have an agreement with their neighbours to leave enough clear separation distance to minimise the possibility of fire spread. Additionally, these extensions need to be well-sealed to avoid fire spread, and therefore should not be built until all the needed materials have been sourced.

d- The indoor lining: The used foam lining by the refugees to cover the indoor walls and roofs is highly flammable. Other types of affordable lining are recommended to be used such as fabric or plastic sheeting, even if they were not as effective as the foam in insulating the interior. That does not mean that they are not flammable or do not spread toxic flames when in fire, but at least, they would delay fire development and spread allowing for easier escape and suppression of the fire.

e- Electrical wiring and flames: Based on UNHCR reports, this study concluded that a minimum of 4,680 shelters in Zaatari and 615 shelter in Azraq, could be sources of fire ignition in the camp due to exposed wires and improper electrical installations. These numbers should not be ignored in camps where all causes of fire development are present. The events of fire in the camps would decrease if the main causes of fire ignition are controlled. It is strongly recommended that all wires are insulated. Another common reason behind fire ignition is the use of open flames, whether they were used for cooking, lighting, or heating, they should always be well-observed and away from all flammable materials.

This study presented recommendations for policy makers and some best practices for refugees in camps. It is a unique study as the fire safety in the refugee camps generally and in the Jordanian Syrian camps specifically is not a well-researched topic and still needs a lot of exploration. This study was limited due to challenges in accessing camps and restrictions in obtaining data. Getting data and conducting interviews with local authorities regarding fire was a very hard mission as fire is viewed to be a sensitive and confidential topic. This miscommunication and mistrust between all stakeholders, including aid organisations, governmental representatives, researchers and beneficiaries, shall be working on, as they lead to missing out many opportunities to enhancing the living conditions of the displaced population, which is a common aim between them all.

Finally, the limited availability of shelter materials for the fire tests, narrowed them to only use the cone calorimeter, and prevented the repetition of the experiments. Future studies can explore further with interviewing refugees, agency workers, and fire fighters, and tracking previous fire events, while also doing extensive lab and outdoor fire test.

Acknowledgements

The authors would like to thank Mutah University- Jordan for funding the research visit of the first author to the University of Edinburgh- UK which opened doors of collaboration with the second author. This paper is a result of that research collaboration.

The authors would also like to express their gratitude towards Professor Sean Smith from the University of Edinburgh, for seeing this potential collaboration and introducing the authors to each other.

References

Aburamadan, R. (2017). *Developing user-informed specifications for refugees shelter in hot-dry climates : a study of the Al Za'atari Camp in Jordan*. https://salford-repository.worktribe.com/output/1390739/developing-user-informed-specifications-for-refugees-shelter-in-hot-dry-climates-a-study-of-the-al-zaatari-camp-in-jordan

ACTED. (2017). *Shelter intervention snapshot*. *March*, 2017.

AFP. (2012, October 23). *Syrians burn Jordan camp tents in protest*. https://english.alarabiya.net/News/2012/10/23/Syrians-burn-Jordan-camp-tents-in-protest

Ahmed, S. (2023). *A perfect storm of crises: Why refugee-hosting countries need more support*. International Centre for Migration Policy Development. https://www.icmpd.org/file/download/59245/file/Policy_Commentary_A%2520perfect%2520storm%2520of%2520crises_Why%2520refugee-hosting%2520countries%2520need%2520more%2520support.pdf

Albadra, D., Coley, D., & Hart, J. (2018). Toward healthy housing for the displaced. *The Journal of Architecture*, *23*(1), 115–136. https://doi.org/10.1080/13602365.2018.1424227

Alhurra. (2013, March 8). *حريق هائل يلتهم 35 خيمة في مخيم الزعتري للاجئين السوريين*. https://www.alhurra.com/syria/2013/03/08/%D8%AD%D8%B1%D9%8A%D9%82-%D9%87%D8%A7%D8%A6%D9%84-%D9%8A%D9%84%D8%AA%D9%87%D9%85-35-%D8%AE%D9%8A%D9%85%D8%A9-%D9%81%D9%8A-%D9%85%D8%AE%D9%8A%D9%85-%D8%A7%D9%84%D8%B2%D8%B9%D8%AA%D8%B1%D9%8A-%D9%84%D9%84%D8%A7%D8%AC%D8%A6%D9%8A%D9%86-%D8%A7%D9%84%D8%B3%D9%88%D8%B1%D9%8A%D9%8A%D9%86

Alshawawreh, L. (2019). *Architecture of emergencies in the Middle East: Proposed shelter design criteria* [Edinburgh Napier University]. http://researchrepository.napier.ac.uk/Output/2005914

Alshawawreh, L., Pomponi, F., D'Amico, B., Snaddon, S., & Guthrie, P. (2020). Qualifying the Sustainability of Novel Designs and Existing Solutions for Post-Disaster and Post-Conflict Sheltering. *Sustainability*.

Alshawawreh, L., Smith, R. S., & Wood, J. B. (2017). Assessing the sheltering response in the Middle East: Studying Syrian camps in Jordan. *International Journal of Humanities and Social Sciences*, *11*(8), 2016–2022. https://waset.org/publications/10007596/assessing-the-sheltering-response-in-the-middle-east-studying-syrian-camps-in-jordan-

Ammon News. (2013). *Syrian child refugee dies in Zaatari tent fire*. https://en.ammonnews.net/article/20274

Ammon News. (2014, March 16). *2 Syrian children die in Jordan camp fire*. https://en.ammonnews.net/article/24611

Ammon News. (2023, April 21). *حريق يلتهم 3 كرفانات في مخيم الأزرق*. https://www.ammonnews.net/article/760840

Antonellis, D., Underhill, H., Cicione, A., Vaiciulyte, S., & Stevens, S. (2023). *Fire Risk Reduction Guidance for Humanitarian Shelters and Settlements*. www.sheltercluster.org

Antonellis, D., Underhill, H., Vaiciulyte, S., Cicione, A., Twigg, J., Gibson, L., Hirst, L., & Stevens, S. (2023). *The State of Fire Safety in Humanitarian Shelter and Settlements: A story of Unintended Consequences*. www.sheltercluster.org

AP News. (2013, December 17). *Fire at refugee camp in Jordan kills 3 Syrians*. https://apnews.com/a82f7e0169d247f783577c6d0bd30ea9

ARUP. (2018). *A Framework for Fire Safety in Informal Settlements* . https://www.arup.com/perspectives/publications/research/section/a-framework-for-fire-safety-in-informal-settlements

ASTM. (2007). *E1354 Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*. https://doi.org/10.1520/E1354-23

Barrantes-Elizondo, L. (2019). Creating space for visual ethnography in educational research. *Revista Electronica Educare*, *23*(2), 1–15. https://doi.org/10.15359/ree.23-2.19

Bryman, A. (2016). *Social research methods* (5th ed.). Oxford University Press.

BSI. (2023). *Reaction to fire tests for building products- Building products excluding floorings exposed to the thermal attack by a single burning item*.

Dalal, A. (2022). *From Shelters to Dwellings - The Zaatari Refugee Camp*.

Dalal, A., Darweesh, A., Misselwitz, P., & Steigemann, A. (2018). Planning the Ideal Refugee Camp? A Critical Interrogation of Recent Planning Innovations in Jordan and Germany. *Urban Planning*, *3*(4), 64–78. https://doi.org/10.17645/UP.V3I4.1726

DamascusV. (2020, November 14). *حريق في مخيم الزعتري بالأردن يودي بحياة طفل سوري لاجئ*. https://damascusv.com/archives/32277

Davis, J., & Lambert, R. (2002). *ENGINEERING IN EMERGENCIES*. www.itdgpublishing.org.uk

Fosas, D., Moran, F., Natarajan, S., Orr, J., & Coley, D. (2020). The importance of thermal modelling and prototyping in shelter design: Transforming shelter design for the displaced. *Building Research and Information*. https://doi.org/10.1080/09613218.2019.1691489

FOX NEWS. (2015, January 13). *Jordan says fire at refugee camp in north has killed Syrian man*. https://www.foxnews.com/world/jordan-says-fire-at-refugee-camp-in-north-has-killed-syrian-man

Human Rights Watch. (2006). *“The Silent Treatment”: Fleeing Iraq, Surviving in Jordan*. https://www.hrw.org/reports/2006/jordan1106/3.htm#_ftn11

IFRC. (2013). *Post-disaster shelter: Ten designs*.

IFRC, UN-HABITAT, & UNHCR. (2014). *Shelter Projects 2013–2014*.

International Code Council. (2021). *International Fire Code (IFC-USA)*.

ISO. (2002a). *ISO 5660-1:2002 - Reaction-to-fire tests — Heat release, smoke production and mass loss rate — Part 1: Heat release rate (cone calorimeter method)* (pp. 1–8). https://www.iso.org/standard/35351.html

ISO. (2002b). *ISO 5660-1:2002 - Reaction-to-fire tests — Heat release, smoke production and mass loss rate — Part 1: Heat release rate (cone calorimeter method)*. https://www.iso.org/standard/35351.html

ISO. (2011). *ISO 5658-2:2006/Amd 1:2011 - Reaction to fire tests — Spread of flame — Part 2: Lateral spread on building and transport products in vertical configuration — Amendment 1*. https://www.iso.org/standard/54327.html

Janmyr, M. (2021). The 1951 Refugee Convention and Non-Signatory States: Charting a Research Agenda. *International Journal of Refugee Law*, *33*(2), 188–213. https://doi.org/10.1093/ijrl/eeab043

Jfra News. (2021, March 30). *الدفاع المدني يخمد حريق كرفانين داخل مخيم الازرق*. https://jfranews.com.jo/article/312245

Jodan News Agency. (2019, April 24). *One Syrian dead in Zaatari refugee camp fire*.

Jordan News Agency. (2020, May 4). *No injuries reported in Zaatari refugee camp fire*. https://petra.gov.jo/Include/InnerPage.jsp?ID=24882&lang=ar&name=en_news

Karlsen, V. (2023). *The earthquakes in Türkiye and Syria: A crisis within the crisis – UNHCR Northern Europe*. https://www.unhcr.org/neu/97487-the-earthquakes-in-turkiye-and-syria-a-crisis-within-the-crisis.html

Kwaylih, A., Alshawawreh, L., & Pomponi, F. (2023). Sustainability Trends in Humanitarian Architecture Research: A Bibliometric Analysis. *Sustainability 2023, Vol. 15, Page 11430*, *15*(14), 11430. https://doi.org/10.3390/SU151411430

Ledwith, A. (2014). Zaatari : The Instant City. *An Affordable Housing Institute Publication*, *1*, 1–95.

Mindset, & UNHCR. (2022). *Vulnerability Assessment Framework Population Survey for Refugees Living in Camps*. https://microdata.worldbank.org/index.php/catalog/5303

MoPIC. (2020). *Jordan Response Plan for the Syria Crisis 2020-2022*.

Orient News. (2020, November 13). *حريق يودي بحياة طفل سوري في مخيم الزعتري بالأردن (صور)*. https://orient-news.net/ar/news_show/185953

Petrella, R. V. (1994). The Assessment of Full-Scale Fire Hazards from Cone Calorimeter Data. *Journal of Fire Sciences*, *12*(1), 14–43. https://doi.org/10.1177/073490419401200102/ASSET/073490419401200102.FP.PNG_V03

Pink, S. (2004). Visual Methods. In *Qualitative Research Practice* (pp. 361–377). SAGE Publications Ltd. https://doi.org/10.4135/9781848608191.d30

Pomponi, F., Moghayedi, A., Alshawawreh, L., D'Amico, B., & Windapo, A. (2019). Sustainability of post-disaster and post-conflict sheltering in Africa: What matters? *Sustainable Production and Consumption*, *20*, 140–150. https://doi.org/10.1016/j.spc.2019.06.007

REACH. (2014). *Al Za'atari Refugee Camp Shelter Assessment*. https://data.unhcr.org/en/documents/details/70965

REACH. (2015). *Azraq Camp Shelter Assessment*. http://data.unhcr.org/syrianrefugees/regional.php

Reuters. (2015, March 2). *Four Syrian refugees killed in fire at camp in Jordan*. https://www.reuters.com/article/us-mideast-crisis-jordan-idUSKBN0LY0YF20150302

Ritchie, H., Spooner, F., & Roser, M. (2019). *Causes of death - Our World in Data*. https://ourworldindata.org/causes-of-death#citation

Rose, G. (2015). *visual research methods in an expanded field: what next for visual research methods? | visual/method/culture*. https://visualmethodculture.wordpress.com/2015/09/25/visual-research-methods-in-an-expanded-field-what-next-for-visual-research-methods/

Rush, D., Bankoff, G., Cooper-Knock, S.-J., Gibson, L., Hirst, L., Jordan, S., Spinardi, G., Twigg, J., & Walls, R. (2020). Fire risk reduction on the margins of an urbanizing world. *Disaster Prevention and Management*. https://doi.org/10.1108/DPM-06-2020-0191

SANA. (2014, December 14). *Two Syrian children killed in fire at Zaatari Camp in Jordan*. https://sana.sy/en/?p=21656

SFPE. (2016). SFPE handbook of fire protection engineering, fifth edition. In *SFPE Handbook of Fire Protection Engineering, Fifth Edition*. Springer New York. https://doi.org/10.1007/978-1-4939-2565-0

Sharma, B. B. (2015). Revisiting the United Nations' 1951 Convention Relating to the Status of Refugees: A Critical Analysis of the International Refugee Law. *Social Development Issues*, *37*(2), 80. https://ezp.sub.su.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edo&AN=108486742&site=eds-live&scope=site

Shelter Centre, & IOM. (2012). Transitional Shelter Guidelines. In *Shelter Center*. https://doi.org/10.1007/s13398-014-0173-7.2

Sphere Association. (2018a). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response* (Fourth). www.practicalactionpublishing.org/sphere

Sphere Association. (2018b). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response*. www.spherestandards.org/handbook

The Jordan Times. (2023, April 28). *1 dead, 3 injured in Zaatari camp fire*. https://jordantimes.com/news/local/1-dead-3-injured-zaatari-camp-fire

The Sphere Project. (2011). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Disaster Response*. The sphere project. http://www.ifrc.org/PageFiles/95530/The-Sphere-Project-Handbook-20111.pdf

UNHCR. (2007). *Handbook for Emergencies*.

UNHCR. (2015). *T-Shelter for Azraq Refugee Camp (3D Diagrams)*. https://data.unhcr.org/en/documents/details/46026

UNHCR. (2016). *Site planning and shelter: Camp Restructure*.

UNHCR. (2019a). *AZRAQ FACT SHEET*. http://data.unhcr.org/syrianrefugees/regional.php-www.facebook.com/UNHCRJordan-twitter.com/UNHCRJordan

UNHCR. (2019b). *Jordan: Azraq Refugee Camp - Factsheet - January 2019*. http://data.unhcr.org/syrianrefugees/regional.php-www.facebook.com/UNHCRJordan-twitter.com/UNHCRJordan

UNHCR. (2022a). *Azraq and Zaatari Camps Dashboard*. www.unhcr.org/jo

UNHCR. (2022b). *Jordan: Zaatari Refugee Camp - Factsheet - January 2022*. www.unhcr.org/jo

UNHCR. (2023a). *Camp Dashboard*. https://reliefweb.int/report/jordan/unhcr-jordan-azraq-zaatari-camps-dashboard-january-2022

UNHCR. (2023b). *Global Trends: Forced Displacement in 2022*. https://www.unhcr.org/global-trends-report-2022

UNHCR. (2023c). *MID-YEAR TRENDS 2023*.

UNHCR. (2023d). *Syria Regional Refugee Response*. https://data.unhcr.org/en/situations/syria/location/36

UNHCR. (2023e, May). *Syria Regional Refugee Response*. https://data2.unhcr.org/en/situations/syria/location/53

UNISDR. (2017). *Build Back Better*. https://www.unisdr.org/files/53213_bbb.pdf

Wang, Y., Bertrand, C., Beshir, M., Kahanji, C., Walls, R., & Rush, D. (2019). Developing an experimental database of burning characteristics of combustible informal dwelling materials based on South African informal settlement investigation. *Fire Safety Journal*, *111*(102938). https://doi.org/10.1016/j.firesaf.2019.102938

Wang, Y., Gibson, L., Beshir, M., & Rush, D. (2021). Determination of Critical Separation Distance Between Dwellings in Informal Settlements Fire. *Fire Technology*, *57*(3), 987–1014. https://doi.org/10.1007/S10694-020-01075-W/FIGURES/15