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Where there's smoke, there's fire: focal points for risk communication

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ABSTRACT

Large fires involving hazardous materials are often characterized by failing crisis communication. In this study, we compared opinions of experts regarding the risks of major fires to lay beliefs using a mental models approach. Amongst lay people this revealed relevant knowledge gaps and beliefs in opposition to those held by experts. While, experts considered the chance of getting cancer from inhaling smoke from a chemical fire extremely small, most lay people thought that even at a great distance, the chance of getting cancer to be large. To improve crisis communication about risk in a case of large chemical fires, and reduce the potential for messages to be misunderstood, distrusted or dismissed, we recommend a clarification of cancer risk in communications about public health emergencies such as chemical fires, for which lay people equate even small exposures to carcinogenic chemicals make one more likely to get cancer later in life.

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Introduction

Crisis response in case of large fires involving hazardous chemical materials is not restricted to a mere technical response of the emergency services, but includes communication about the risks with the public. Apart from being credible, accurate and consistent, adequate crisis communication should be timely and relevant. That is, recipients of information must understand whether the information applies to them, understand whether they are at risk if they do not take protective action, and accept the actions that need to be taken (Glik 2007). Failed communications do not only lead to scepticism and misunderstanding among the public but may also adversely affect may also adversely affect a person's behaviour and decision-making in a crisis. Moreover, authorities face a complex and expanding communication landscape. Mass media and social networks in particular are becoming increasingly influential sources of risk information. These can shape the public's perception and quickly turn a local incident into a crisis on a larger scale. In this landscape, government communications often are met with scepticism and misunderstood or dismissed by the public (Frewer 2004).

In the Netherlands, a striking example of what can go wrong in crisis communication took place during and after a large fire in a chemical storage and packing company, in 2011. Although there were no casualties, the alleged presence of hazardous chemicals in the black smoke caused serious concern and was headline news for many days. One recurring topic was the failing crisis communication of

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local authorities. Risk messages from the crisis organisation were poorly coordinated and some even contained conflicting information (Dutch Safety Board 2012). Governmental communications with the public did not meet the public's information needs, and failed in it's attempt to properly explain the consequences and limited health risks of the fire and smoke. The main message that 'no dangerous levels of hazardous materials have been *detected*', indicating that the amount of materials released during the fire did not pose a threat to public health, was interpreted and communicated by some media outlets as 'no hazardous materials were *released*'. Because all fire smoke contains hazardous substances, this message caused disbelief and even suspicion among the public (Dutch Safety Board 2012). Such distrusted communications can have adverse effects on people's perceptions of risk and affect the decisions they make to mitigate these risks.

To improve communication about risk and mitigation in a case of large chemical fires, and to reduce the potential for messages to be misunderstood, distrusted or dismissed, we propose to adopt a more public orientation using a mental models approach (Morgan et al. 2002). This approach has been applied on a wide range of risks such as flooding (Morss et al. 2015), chemical exposures (MacGregor et al. 1999; Kovacs et al. 2001; Zikmund-Fisher et al. 2013), prescribed burns (Zaksek and Arvai 2004) and carbon monoxide (Galada et al. 2009). These studies were aimed to create more effective communications that better fit people's mental models of the underlying hazardous processes (Morgan et al. 2002). The mental models approach integrates a descriptive assessment and comparison of the science and insights of experts that are relevant for lay risk decisions with lay mental models. Key discrepancies between these two perspectives are candidate focal points for improving communication materials. In the present study, we apply the mental models approach to identify relevant elements for risk communication on smoke of major fires, and chemical fires in particular.

Methods

Design

We analysed and compared experts' and lay people's knowledge and beliefs of major fires and fire smoke, it's risks and crisis management responses following the mental models approach developed by Morgan et al. (Morgan et al. 2002). First, an expert model was constructed. Next, lay people were interviewed to assess key aspects of the lay mental model. Third, a confirmatory survey was developed and conducted in a larger study population. Below, the three consecutive steps are described in more detail.

Construction of the expert model

First, the main findings of epidemiological reviews and reports on the associations between health and exposure to smoke of fires, and of industrial or chemical fires in particular were evaluated and summarized. This resulted in a draft expert model describing the processes contributing to risk of fire smoke. Second, two researchers (LC and FG) carried out interviews with experts within relevant knowledge areas covering the key categories of major fires and several years of expertise on one or more of the processes contributing to crisis management of major fires. Experts were asked specific questions about their own field of expertise and to comment on the draft expert model. The semi-structured interviews were centred on open questions such as, 'what can cause a major fire and what are the risk factors?', 'how would you characterize exposure to smoke?', 'what are the main effects of fires?', 'what are the potential health effects of exposure to smoke?', 'what actions can and should be taken?', 'what should be communicated to the public, how and by whom?'. For these aspects, the experts were also asked whether and how chemical fires differed from non-chemical fires, such as wildfires.

Lay model

To assess key aspects of the lay mental model of risk in the Dutch population, participants were recruited from different regions in the Netherlands: Amsterdam, Groningen and the downwind area of the 2011 Moerdijk fire. To identify relevant aspects of the lay mental model we continued to include new participants until we reached saturation, i.e. the point of at which participants responses become highly repetitive (Morgan et al. 2002). Participants from the Moerdijk area were specifically added to include aspects that may come to mind due to experiencing a major chemical fire in the vicinity.

After receiving participants' permission, the interviews were tape-recorded. The interview consisted of open-ended questions about the causes of large fires, exposure to smoke, the effects of the smoke of the fires and the necessary actions to manage such an incident. The interview was centred on the following key questions: 'what comes to mind when you think about a major fire?', 'what do you think about the causes?', 'what do think about the smoke?' and 'what should be done when a major fire breaks out in your vicinity?'. Participants were encouraged to elaborate on everything that came to mind. In addition, they were asked to speculate about the differences between chemical fires and non-chemical fires. Next, the interviewer raised key aspects from the expert model that were not mentioned by participants of their own accord. Afterwards, participants were rewarded with a gift voucher of 25 Euros. The audiotapes were transcribed and the transcriptions were analysed.

To identify and analyse patterns we used a descriptive thematic analysis (Boeije 2005; Braun & Clarke 2006). To become familiar with the data and note initial observations, researchers LC and FG first listened to audio-recorded data and read transcriptions. Then they generated concise and informative labels for important conceptual features. All statements referring to risks and management of major fires were labelled. Thoughts that were expressed by the interviewees were matched with descriptions of the processes and categories identified in the expert model. Statements that were unrelated to aspects from the expert model received a separate code. All the codes were then ordered into coherent and meaningful patterns or themes, that 'tell the story of the data'. Next, researchers both independently coded 3 of the interviews to ascertain that all themes and accompanying codes were identified. All codes and themes were then compared. The differences between coders that arose in distinguishing (sub)themes, were discussed. These discussions resulted in the development of the final coding system. Subsequently, the remaining interviews were split between both researchers and coded using this coding scheme. The content of the lay mental model was then compared with the expert model by themes and overall impression.

Confirmatory survey

An online survey was developed covering the relevant aspects of the expert model and the significant lay beliefs. Participants were recruited through an online access panel (Flycatcher, 20,000 participants, ISO 20,252 and ISO 26,362). The survey contained statements corresponding with the expert model or with lay beliefs. Participants were asked to indicate whether they thought the statements were true using response categories 'definitely true', 'probably true', 'definitely false', 'probably false', and 'don't know'. We also asked participants whether they had ever experienced a large fire in their neighbourhood and about potential health effects of exposure to fire smoke.

Results

Expert mental model

First, the main findings of epidemiological reviews and reports on the associations between health and exposure to smoke of fires were summarized in a draft expert model of the processes contributing to risks (see references in this paragraph). The model is summarized in three interconnected processes: (I) the causes of and exposure to fire smoke, (II) effects; including environmental, socio-economic and human health effects and (III) response consisting of a variety of actions by emergency services and the government.

Second, interviews were carried out with experts ($n = 17$) with relevant knowledge and five years or more expertise on one or more of the processes contributing to crisis and risk management of major fires and in particular chemical fires.

The expert sample (n = 17) comprised three firefighters involved in hazardous materials mitigation, three regional environmental health specialists, two environmental health specialists from both the National Institute of Public Health and Environment and the national Environmental Incident Service, three occupational and environmental health scientists (expertise in pulmonology, occupational hygiene and environmental epidemiology), two senior social scientists (expertise in risk perception, crisis and risk communication and mass communication), one crisis communication advisor from an independent bureau, one managing director of a Safety Region[1] and two mayors with an active role during a crisis, especially communication with the citizens[2].

Although the interviewed professionals had different perspectives regarding some aspects, depending on their field of expertise, their responses were fairly consistent. Based on the expert interviews, we refined the expert model. Below, we describe the three processes in more detail.

Causes and exposure

All fires ignite when a fuel, any combustible material (whether it is stored chemicals or vegetation) in combination with a sufficient quantity of oxygen is exposed to a source of heat (Figure 1, left panel).

Most chemical fires emit relatively small quantities of smoke, particularly when compared to large wildfires, which often cover vast areas of land with large quantities of vegetation for burning and therefore exposing far more people to fire smoke. The concentration of gases and particles in the smoke quickly decreases with distance from the fire.

Effects

The upper part and the right side of Figure 1 display the potential effects of fires, such as harmful effects on flora and fauna, the economy and human health. In this study, we focused on the physical health effects and concerns of exposure to fire smoke. According to the interviewed experts, in the Netherlands, exposure to heat and mechanical injuries are mostly relevant in an occupational setting.

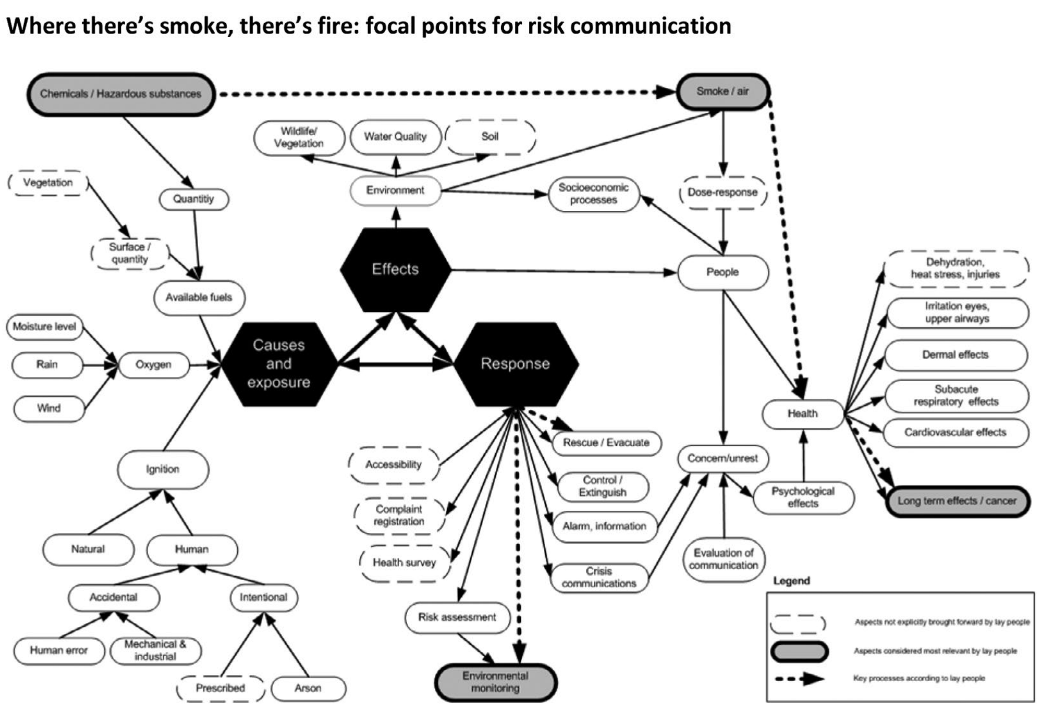

Figure 1. Composite expert and lay mental model of the processes contributing to risk and management of major fires.

Additionally, exposure via consumption of contaminated food only becomes relevant during the aftermath of a fire.

Adverse health effects of fire smoke depend on the dose (duration of exposure and concentration) and the exposure route (inhalation, skin or eye absorption or ingestion). The amount of inhaled smoke is generally more relevant than the source of the fire smoke. Smoke contains toxic substances injurious to airways (Naeher et al. 2007; Stefanidou et al. 2008). The most common effect of short-term exposure to fire smoke is irritation of the eyes and upper airways. In case of severe, long-lasting and repeated exposures, irreversible adverse respiratory effects, such as irritant induced asthma and alveolitis, may occur. Adverse respiratory effects are found in case of chemical or industrial fires (Hoek et al. 2007; Greven et al. 2009). Large wildfires are also associated with increased mortality and cardiovascular effects (Delfino et al. 2009; Analitis et al. 2012). Health effects due to chemical fire smoke mostly occur at relatively short distances and do not affect a large proportion of the population (Upshur et al. 2001; Greven et al. 2009). Long-term health effects, such as cancer, due to a single short-term exposure to any type of fire smoke, are considered very unlikely.

Experts thought that in the Netherlands public concerns in case of a major chemical fire would probably centre on the presence of chemicals with the predicate toxic, hazardous or carcinogenic substance, the presence of these substances in the smoke and the health risk associated with these substances, whereas concerns about wildfires are expected to focus mostly on loss of wildlife and vegetation. According to many of the interviewed professionals, in the Netherlands, such concerns may trigger psychological processes that can lead to serious adverse mental health effects (Laugharne et al. 2011).

Response

All experts agreed that the first actions to be taken are generally aimed at rescuing those at risk and extinguishing the fire. Risk assessment, a systematic process for gathering, assessing and documenting information to assign a level of risk, is essential for an appropriate response. The local Fire Service, equipped with gas detection tubes, first carries out environmental monitoring at the scene. The value of the result(s) of this detection method is restricted. Fire smoke consists of a large number of substances of which only one or a few can be identified with the use of these tubes. Moreover, in case of fire smoke, data from gas detection tubes hardly add information to the risk assessment by specialists based on their expert judgement. The Environmental Incident Service provides a more sophisticated approach in the Netherlands to monitor, collect, and analyse samples at a disaster site. However, it takes hours to days before the results are available. In a later phase of the incident this is useful, for example, to analyse the deposited material on food crops or playgrounds.

During a major fire, the mayor should ensure that communication with the public takes place. Such communications should address what happened, what caused the incident, the magnitude and the prognosis of the crisis and the potential risks for civilians. Furthermore, perspectives for actions should be communicated to the public as soon as possible. Process information, what is known and when the next update on information will be, is also important.

Lay mental model

Socio-demographic characteristics of the interview sample (n = 15) are shown in Table 1. There was considerable variation in socio-demographic background. However, youth and people with low levels of education were under-represented in this sample. Many (n = 10) had some personal experience with a major fire.

The lay mental model of the processes contributing to risk and management of major fires was mapped on the expert model and depicted in Figure 1. Compared to experts, the interviewees expressed a less elaborate and comprehensive perspective on risk management of major fires. Knowledge and beliefs of the interviewees from Moerdijk area were definitely more salient but did not markedly differ from those of the other interviewees.

Table 1. Socio-demographic characteristics of the interview sample ($n = 15$).

Label	Gender	Level of education[a]	Age	Region[b]	Profession/ main daily activity
L01	Male	Intermediate	60	Moerdijk	–
L02	Female	Intermediate	36	Moerdijk	Communications assistant
L03	Male	High	67	Moerdijk	Farmer
L04	Male	Intermediate	49	Moerdijk	Web advisor
L05	Female	Low	57	Moerdijk	–
L06	Male	Intermediate	40	Groningen	Logistics worker
L07	Female	High	59	Groningen	Manager HBO
L08	Male	Intermediate	27	Groningen	Student HBO
L09	Female	Intermediate	64	Groningen	Office worker
L10	Female	Intermediate	35	Groningen	Office worker
L11	Female	High	55	Amsterdam	–
L12	Female	Intermediate	54	Amsterdam	Auxiliary nurse
L13	Male	Intermediate	60	Amsterdam	Bank clerk
L14	Female	High	46	Amsterdam	Mother
L15	Female	Intermediate	49	Amsterdam	Office worker

[a]Low = no or primary education, Intermediate = secondary education, High = tertiary education.
[b]The 5 interviewees living in the potentially exposed area of the Moerdijk fire in 2011 were recruited from the population that contacted the Public Health Services either because of concerns or health complaints attributed to the exposure to smoke during and following the fire.

Causes and exposure

The interviewed laypersons' beliefs about the causes of the fire and the dispersion of smoke were similar to those of experts. When asked what first came to mind when they thought of the smoke of a major fire, nearly all mentioned 'hazard' and 'poisonous substances'. In their ideas on the composition of the smoke they clearly differed from experts, stressing the presence of chemicals present at the fire site and the hazardous characteristics of the stored chemicals.

> I think [smoke from wildfires] is different, because it is nature, just grass or heath… it does not contain noxious substances… it is more organic than the stuff in Moerdijk… I don't know what they produce, at least nothing beneficial (L09).

Interviewees rarely put forward the dose, concentration or quantities of hazardous substances but merely talked about the smell and the colour of the smoke. Several of the interviewees thought that the presence of hazardous substances in the smoke remain important even at great distances.

> That what is in the smoke [of the Moerdijk fire] has to come down to earth. Whether it is here, or it is in Germany [at least at 100 km distance] it has to come down (L01).

Effects

Most interviewees said that in the event of a major fire they would be concerned about acute personal danger, safety and health. In general, they considered the smoke from chemical fires as very potent in invoking adverse health effects even at a great distance.

> Immediately I thought of Chernobyl, because that was a fire at a huge distance, but nevertheless we experienced the consequences in the Netherlands (L07).

Respondents often referred to the unknown composition of the smoke and worried more about long-term health effects of chemical fires than about acute effects. Almost all respondents said that in case of a major fire, especially in case of a chemical fire, they would be concerned about getting cancer due to inhalation of the smoke.

> … substances released in the Moerdijk fire frighten me much more than smoke from a wildfire (L01).

> … which substances are discharged into the air, what are the health effects? And what type of cancer will be found a year later? (L05).

> I think that nowadays it is all carcinogenic diseases or asbestos… yes, could be, but you do not know. That's really the dreadful part (L15).

Response

The interviewees believed that the affected company, the emergency services, especially the Fire Services, and the government, should take immediate actions such as environmental monitoring, risk assessment and crisis communication. In particular, they considered environmental monitoring very urgent and seemed to have high expectations on the capacity and potential of environmental monitoring.

> Nowadays they can detect anything micro… nano things (L01).

All interviewees were familiar with the standard advice of closing windows and doors and answered they would certainly act on this advice. Some stated that in case of a large fire they would try to get away as far as possible from the fire and the interviewees in the Moerdijk area indicated that they would have preferred to evacuate.

> Afterwards I told myself that if it happens again, I plan to be miles away …and spend the day at sea (L04).

> If I didn't have animals, I am sure that I would have gone away, because it was frightening (L03).

In the event of a major fire, some respondents said they would wait for official information concerning the fire; others said they themselves would look for information on Twitter, social media and Internet. Many criticized official communications, especially when involved officials did not concur. The interviewed residents of the Moerdijk area found that the information provided by the official channels was incomplete and too slow and therefore they had looked for information elsewhere, on other (social) media. Another related issue was the lack of credibility of the authorities. Several interviewees even believed that the government purposely concealed information on potential risks.

> Then there is a lot of attention and they try to soothe things quite a bit…'No toxic substances have been released, no one has to worry'… while they actually do not know... (L12).

> Questions about what has been released, what are the health effects, what if a year later cancer will be diagnosed? There was a lot of beating around the bush. A first statement that no toxic substances were released just isn't right… it just is poisonous. I think they cover up things that cannot see the light of day...(L05).

Confirmatory survey

Of the 677 participants who were invited to complete the online questionnaire 437 responded (response rate = 66.5 %). Sample characteristics are presented in Table 2. Compared to the Dutch general population male respondents (54 % vs. 49 %) and people over 50 (52 % vs. 44 %) were overrepresented in the sample. Otherwise the sample was representative for the general population. More than a quarter of the participants (27.2 %) had personally experienced a major fire in their immediate vicinity.

The survey contained 17 statements, 12 corresponding with the expert model, such as 'the concentration of harmful substances in fire smoke quickly diminishes with increasing distance to the fire' and 5 referring to lay beliefs. To avoid response bias, we phrased four of the expert statements so that the statement was contrary to the expert consensus. Responses to the 17 statements corresponding to the expert model and to lay beliefs are summarized in Table 3.

Causes and exposure

Most respondents knew that fires, including wildfires, are mostly caused by human error (81 %). A smaller proportion knew that the concentration of harmful substances rapidly decreases with increasing distances (55 %).

Effects

A majority of the respondents understood that it depends mainly on the amount of fire smoke inhaled, whether health is affected adversely (78 %). For participants that reported to have experienced a major fire this proportion was even higher (83 %). However, many still thought that their health could be affected even at great distances whether it originated from a forest fire (45 %) or a chemical fire (84 %).

While a large majority (77 %) considered the chance of getting cancer due to inhaling chemical fire smoke large (even a larger majority of participants that reported to have experienced a major fire (82 %)), only a minority (18 %) assumed this was also true for forest fire smoke. Table 4 describes the health effects that were thought most important. Besides irritation, headache and problems of the airways, cancer was mentioned by 41 % of the respondents as an important health effect of inhaling smoke. A smaller group believed that there could be adverse health effects to an unborn child (32 %).

Response

Whereas only 49 % of the respondents agreed that experts don't need the results of measurements to be able to assess potential health effects of a chemical fire, almost all respondents (96 %) thought that in case of a chemical fire, harmful substances in the smoke should be monitored immediately (Table 3). They also seemed rather optimistic about the possibilities of environmental monitoring. A large majority of the respondents (86 %) believed that the statement 'monitoring the components of smoke provides clarity on the health risk' was true, while according to experts this statement is incorrect (Table 2).

Discussion and conclusion

In this study, three major discrepancies between expert opinions and lay knowledge and beliefs about smoke of fires were found. First, while experts stated that the risk of getting cancer through a single short-term inhalation of chemical fire smoke is negligible, lay participants assumed the chance of getting cancer to be large. Second, in contrast to expert opinion, interviewees and survey respondents thought that fire smoke, in particular from a chemical fire, might invoke serious adverse health effects even at a great distance from the fire. Third, lay participants overrated the possibilities and usefulness of environmental monitoring during the acute phase of a fire.

The first two findings refer to lay understanding of toxicology and dose–response relationships. Lay participants considered exposure to smoke from a chemical fire more harmful than smoke from a wildfire, and thought that there is a substantial chance of getting cancer due to a single short-term exposure to chemical fire smoke. This is in line with findings of previous studies on lay perceptions of exposure to hazardous substances(Kraus et al. 1992; MacGregor et al. 1999). According to these studies, how people think about exposure depends on their intuitive ideas about toxicology, the nature of exposure and the severity of the potential effects. Beliefs about potential effects lead to inferences about the seriousness of exposure and vice versa. Lay people mostly rely on their senses of sight, taste and smell to detect harmful substances and view chemicals as either safe or dangerous, there is nothing in between. They often equate even small exposures to carcinogenic chemicals with almost certain harm(Kraus et al. 1992). Kraus and colleagues(Kraus et al. 1992) showed that only a minority of lay people recognized that a small exposure to a carcinogenic chemical does not make one more likely to get cancer later in life. Also, almost half of the respondents in a study by MacGregor et al.(MacGregor et al. 1999) believed that a single exposure to a chemical that can cause cancer in humans would probably cause cancer someday.

Table 2. Population characteristics of the online panel.

	N (%)
Number of participants	437 (100)
Male	234 (53.5)
Age 49.0 ± 16.0 (18–85)	
Personally experienced a major fire in immediate vicinity	119 (27.2)
Level of education	
Low	154 (35.2)
Intermediate	175 (40.0)
High	108 (24.7)

Table 3. Lay knowledge and beliefs about major fires –responses to expert (E) and lay (L) statements (*n* = 437).

	Don't know n (%)	Probably or definitely true n (%)[a]	Probably or definitely not true n (%)[a]
I. Causes and exposure			
1. Most major fires in the Netherlands are the result of human error. (E)	56 (12.8)	355 (81.3)	26 (5.9)
2. Wildfires result mainly from natural causes, such as lightning and heating. (E[False])	45 (10.3)	116 (26.5)	276 (63.2)
3. The concentration of harmful substances in fire smoke quickly diminishes with increasing distance to the fire. (E)	86 (19.7)	242 (55.4)	109 (24.9)
II Effects			
4. White smoke is less harmful to health than black smoke. (E[False])	137 (31.4)	137 (31.3)	163 (37.3)
5. Smoke from a forest fire is as harmful as smoke from a chemical fire. (E)	59 (13.5)	75 (17.2)	303 (69.3)
6. *It depends mainly on the amount of fire smoke inhaled, whether health will be affected adversely. (E)*	23 (5.3)	299(68.4)	115 (26.3)
7. *Sometimes people experience persisting symptoms following smoke inhalation. (L)*	55 (12.6)	375(85.8)	7 (1.6)
8. There's a big chance of getting cancer due to inhaling forest fire smoke. (E[False])	216 (49.4)	82 (18.8)	148 (31.8)
9. Smoke from a wildfire often adversely affects health even at a great distance from a forest fire. (E[False])	128 (29.3)	198 (45.3)	111 (25.4)
10. *There's a big chance of getting cancer due to inhaling chemical fire smoke. (L)*	81 (18.5)	337 (77.1)	19 (4.3)
11. Smoke from a chemical fire often affects health adversely even at a great distance from a chemical fire. (L)	52 (11.9)	367 (84.0)	18 (4.1)
C. Response			
12. It is often better to allow the fire to burn until all the fuel is consumed than to extinguish the fire with water. (E)	156 (35.7)	194 (44.4)	87 (19.9)
13. It is possible to assess within a day whether harmful substances are present in the deposited soot particles. (E[False])	77 (17.6)	293 (69.4)	57 (13.0)
14. Monitoring the components of smoke provides clarity on the health risk. (E[False])	39 (8.9)	379 (86.3)	21 (4.8)
15. *In the case of a major fire, the mayor should ensure that communications with the public takes place. (E)*	30 (6.9)	394 (90.1)	13 (3.0)
16. *Harmful substances should immediately be monitored in the fire smoke in the case of a chemical fire. (L)*	13 (3.0)	421 (96.3)	3 (0.7)
17. An expert doesn't need the results of measurements to be able to assess potential health effects caused by a chemical fire. (E)	73 (16.7)	215 (49.2)	149 (34.1)

[a]Participants were asked to indicate whether they thought the statements were true using 5 response categories 'definitely true', 'probably true', 'definitely false', 'probably false', and 'don't know'.
E[False]False expert statement: to avoid response bias, we phrased some of the expert statements so that the statement was contrary to the expert consensus.
Statements in Italics: a significant greater proportion of participants that reported to have experienced a major fire in their immediate vicinity thought the statement to be probably or definitely true compared to those that did not.

The basic principle of toxicology that 'the dose makes the poison' means that any substance (even water) can cause a toxic effect if the dose is great enough(Klaassen 2008). Because of the relatively low concentrations of hazardous materials at a great distance of a fire, most experts consider the health

Table 4. Expected health effects of fire smoke inhalation.

According to you what are the most important physical effects of inhaling smoke of fires?[a]	N (%)
1. Transient irritation of eyes and airways	381 (87.2)
2. Headache	341 (78.0)
3. Persisting airways complaints	331 (75.7)
4. Cancer	181 (41.4)
5. Adverse health effects of unborn child	139 (31.8)
6. Cardiovascular complaints	82 (18.8)
7. Allergy	60 (13.7)
8. Complaints of the bowels	24 (5.5)
9. Other[b] …	9 (2.1)

[a]Multiple options possible.
[b]Respiration difficulties, dizziness and loss of consciousness, effects everything, exacerbation of COPD, inside burns, lungs, irritation of eyes, damage to airways, reduced lung capacity.

impact of a chemical fire as very limited(Upshur et al. 2001; Greven et al. 2009). While most lay participants knew that the concentration of hazardous materials in the smoke quickly dissipates with distance, a larger majority did not seem to fully understand the dose–response relationships. They focus on the alleged hazardous (i.e. carcinogenic) quality of involved substances and do not correctly adjust for the dissipation of the concentration with distance.

From studies on risk perception, we also know that people's ideas about hazards and risk centre around the unfamiliarity with and the dreaded nature of the situation (Fischhoff et al. 1978; Alhakami & Slovic 1994; Rohrman 1999; Siegrist et al. 2005; Siegrist and Sütterlin 2014; Slovic 2016). In general, people perceive risk of unfamiliar, unknown hazards to be higher. While wildfires are rather frequent events in human history with known consequences, people are less familiar with chemical fires. Also, negative outcomes of a human-made hazard are evaluated more negatively than a natural hazard with the same outcomes (Siegrist and Sütterlin 2014). Concerns about chemical fires are likely to be focused on the unknown health risk associated with the composition of the smoke and the presence of chemicals with the predicate toxic, hazardous or carcinogenic (see for example: Ho et al. (Ho et al. 2014)). Furthermore, if a person has no perspective for action and no possibilities to control the outcomes, he will more likely be afraid. These responses may be counteracted by the level of trust a person has in the agencies managing the risk (Siegrist et al. 2005). When people see these agencies as competent, reliable and believe they are acting in their interest they are less likely to be afraid.

The third finding refers to the practice of environmental monitoring. Many lay participants thought that in case of a major fire it is feasible to rapidly generate accurate air-sampling results, to cover the complete range of chemicals, and to convert the results in a solid health risk assessment and concrete advice. According to experts, the possibility of using an accurate environmental monitoring system that is able to generate information necessary for risk assessment within a short time is very limited. Moreover, it is not decisive during the acute phase of a fire. The overconfidence in the possibilities and accuracy of rapid environmental monitoring may impair trust in response management if risk assessment results are not quickly released.

A major strength of this study is the use of mixed methods to systematically analyse the perspectives of lay people (Boase et al. 2017). This approach provided rich qualitative data describing their knowledge and ideas about smoke of fires in relation to expert opinions. The qualitative data were confirmed and supplemented by representative quantitative data providing information about the frequency and strength of these beliefs in the target population. Although we only interviewed 15 lay participants this probably sufficed to identify the most relevant aspects of the lay mental model (Morgan et al. 2002). Guest et al. (2006) showed saturation generally occurs within the first 12 interviews and basic elements for metathemes are present as early as six interviews (Guest et al. 2006). But of course, it is possible that the interviews did not pick up on all relevant beliefs in the population. Another potential weakness in this study is the non-response in the online survey and the under-representation of people with no or restricted access to the Internet. However, we have no reason to assume that non-respondents or people with restricted Internet access would systematically have differed in their answers from respondents. Therefore, it is unlikely that this would have a substantial effect on our findings. A more serious limitation is the limited generalizability of the findings. Although we believe our main findings apply to most Western countries, we should point out that the study is performed in the Netherlands, a densely populated country with a relatively small risk of large wildfires. For many other countries wildfires pose a more serious risk to both experts and lay people.

The three main findings have important implications for risk communications during a public health emergency such as a major chemical fire. First, besides being timely and trustworthy, communication should provide information on all relevant health risks. This does not only include information on the most common effects people can expect, such as irritation of the eyes and airways in case of inhalation of fire smoke. We also propose to specifically address dominant concerns people may have when faced with a public health incident. According to many of the interviewed professionals, in the Netherlands, such concerns may trigger psychological processes that can lead to serious adverse mental health effects (Laugharne et al. 2011). For chemical fires, a major public concern, often highlighted on social and mass media, are the carcinogenic properties of the smoke and an increased risk of getting cancer. Public health communicators could specifically acknowledge these concerns and explain that the additional risk of getting cancer, due to a single short-term exposure to fire smoke, whether from a chemical fire or a wildfire, is very small. Second, communicators need to be aware of gaps in lay understanding of exposure and the dose–response relationships and use terminology and formats that are in line with lay perspectives on exposure and risk. In particular, communication needs to clarify that at great distances the concentrations of hazardous materials have greatly diminished and that a single exposure to such low concentrations hardly has any impact on people's health. One way of explaining both the small additional cancer risk as well as the exposure–effect relationship is using analogies that people are more familiar with, e.g. the additional risk of developing cancer from inhaling smoke of major fires is comparable to that of smoking a few cigarettes. A third implication is that risk communicators may need to stress that although rapid environmental monitoring is carried out with seemingly top-notch equipment, this equipment is not really suited to generate early health risk assessment in case of fire smoke.

In conclusion, regarding the risks of major fires we identified several typical lay beliefs as well as important gaps in lay knowledge contrary to opinions of experts. Focal points improving risk communication are 1) provide information on all relevant health risk, including cancer risk, 2) address gaps in lay understanding of exposure and dose–response relationship using terminology and formats that is more in line with lay perspectives on exposure and risk, 3) describe the limitations of measurements in the acute phase. More research is needed to assess the effects of addressing these focal points in alternative risk information messages in case of a public health emergency.

Notes

1. In the Netherlands, safety regions have been set up in order to facilitate cooperation among the emergency services.
2. Two of the last three interviewees were professionally involved in the management of the Moerdijk chemical fire.

Disclosure statement

No potential conflict of interest was reported by the authors.

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