# RESEARCH

Archives of Public Health



# Mental health impact of a large-scale industrial fire on exposed residents in France: the post fire 76 health survey

Anne-Laure Perrine<sup>1\*</sup>, Gaëlle Pédrono<sup>1</sup>, Pauline Morel<sup>2</sup>, Pascal Empereur-Bissonnet<sup>3</sup>, Jean-Baptiste Richard<sup>1</sup>, Franck Golliot<sup>2</sup>, Abdelkrim Zeghnoun<sup>1</sup>, Myriam Blanchard<sup>2</sup>, Abdessatar Saoudi<sup>1</sup>, Emmanuelle Le Lay<sup>3</sup>, Maria El Haddad<sup>1</sup> and Yvon Motreff<sup>4</sup>

# Abstract

**Background** Little is known about the mental health consequences of large-scale industrial fires without fatalities but with persistent odors for several months. One such fire occurred in 2019 in Rouen, France. This survey aimed to assess the impact of the fire on the mental health of the exposed population fifteen months later.

**Methods** A random representative stratified sample was selected from the exposed population in Rouen and a nonexposed population in a nearby city. Three probable mental health disorders were assessed with self-administered psychometric scales: PCL-5 for probable post-traumatic stress disorder, GAD-7 for probable generalized anxiety, and PHQ-9 for probable depression. Different types of exposure were self-reported: perceived odors, black smoke, visual or auditory fire perception, soot deposits, or fibrocement roof debris. The prevalence of probable mental health disorders and the associated factors were examined.

**Results** A total of 1,968 people participated (overall response rate of 20%). In the exposed area, 6% (5-7%) of people presented probable post-traumatic stress disorder attributable to the fire, 15% (13-17%) probable generalized anxiety, and 18% (16-20%) probable depression. The prevalence of all three was significantly higher in participants living close to the fire. Probable post-traumatic stress disorder and probable generalized anxiety were both associated with auditory perception of the fire or explosions. Probable generalized anxiety was also associated with the duration of exposure to unpleasant odors. Probable depression was associated with the duration of exposure to odors, and the presence of fibrocement roof debris.

**Conclusion** Even though there were no fatalities and no injured people, the industrial fire had a mental health impact on people living in the exposed area in the medium term. The results of this work were used to implement further adequate medico-psychological care for the exposed population.

Keywords Industrial accident, Depression, Anxiety, Post-Traumatic stress disorder, Epidemiology

\*Correspondence: Anne-Laure Perrine anne-laure.perrine@santepubliquefrance.fr <sup>1</sup>Data Science Division, Santé publique France, Saint-Maurice, France <sup>2</sup>Regional Division, Santé publique France, Saint-Maurice, France



<sup>3</sup>International Scientific Division, Santé publique France, Saint-Maurice, France

<sup>4</sup>Non-Communicable Diseases and Trauma Division, Santé publique France, Saint-Maurice, France

© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creative.commons.org/licenses/by-nc-nd/4.0/.



## Text box 1. Contributions to the literature

• Little is known about the mental health consequences of large-scale industrial fires without fatalities but with persistent odors for several months. One such fire occurred in 2019 in France.

• One year after the industrial fire, 6% of people in the exposed area presented probable PTSD attributed to the fire.

 Probable generalized anxiety and probable depression were more common in the exposed area than in the non-exposed area and even more in people living close to the fire.

 Auditory perception of the fire was associated with probable PTSD and probable generalized anxiety. The duration of exposure to unpleasant odors was associated with probable generalized anxiety and probable depression.

# Background

People exposed to disasters may develop mental health disorders such as post-traumatic stress disorder (PTSD), anxiety, and depression [1-3]. Among the various types of possible disasters, industrial accidents are unique because they can have immediate effects (deaths, injuries, pollution, etc.) as well as medium- and long-term effects due to the consequences of the disaster, the potential pollutants that may result, and the trauma experienced by those exposed. Thus, the medium-term psychological impacts on people exposed to industrial accidents are significant, as shown by some studies. For example, eighteen months after the AZF chemical factory explosion in 2001 in Toulouse (France), PTSD prevalence in closest residents (< 3 km) was 19% and 8% among women and men, respectively [4]. Eighteen months after the firework disaster in 2000 in Enschede (Netherlands), 19% of exposed residents had symptoms of PTSD. Anxiety and depressive symptoms were more prevalent in exposed residents than in a non-exposed group [5]. Many factors are associated with psychological disorders after disasters, including exposure intensity [6, 7], proximity to the event [4], intentionality of the event [8], socio-demographic characteristics and socioeconomic status [4, 6], social support [9], personality traits [10], resilience [9], and history of psychological disorders [4].

On the night of September 26, 2019, a large-scale industrial fire occurred inside the warehouses of Lubrizol and NL Logistique in Rouen, France. Approximately 9,500 tons of chemicals and other materials were burned [11]. These included hydrocarbons, additives for oils, and engine fluids. Additionally, more than 2,500 tons of various materials stored at the NL Logistique site burned, including 2,400 tons of food gums, 116 tons of construction materials, 7 tons of tires, 6,000 pallets. According to the French National Institute for Industrial Environment and Risks (Ineris), the combustion by-products that may have been dispersed into the environment during and after the fire were mainly carbon compounds (carbon dioxide and carbon monoxide), aliphatic hydrocarbons, mono- and poly-aromatic hydrocarbons, aldehydes, nitrogen and sulfur compounds including mercaptans, dioxins, and furans [12, 13]. The fire generated huge flames and a large plume of black smoke. The latter spread in a northeasterly direction over hundreds of kilometers and left soot deposits. Barrels exploded and roof fragments containing fibrocement were dispersed over several kilometers. The fire was controlled a few hours later but a smoldering fire continued for several days. It generated strong and persistent odors for several months. More than 300,000 people were exposed to the plume. Almost 21,000 people were living in a radius of 1,500 m around the location of the fire. For several days, there was great uncertainty about exposure to pollutants and their consequences. No fatalities or injuries were reported [14]. Nevertheless, a psychological support unit [15] was set up after the fire which assisted a few dozen people [14].

To our knowledge, few studies in the literature have investigated the mental health impact of non-nuclear industrial accidents, and no study has focused on an industrial fire that did not result in fatalities or physical injuries. However, people exposed to this type of disaster are at risk of mental health problems as they may have feared for their lives and their loved ones. They may also fear the long-term consequences, especially with such a big plume, and when odors are persistent and strong for several months, as was the case in Rouen.

Therefore, further research is needed to better understand how this type of industrial disaster and its associated factors affect the mental health of exposed individuals. This knowledge is essential to inform public health actions aimed at reducing the mental health burden.

The survey presented in this paper aimed to assess the mental health impact of exposure to the industrial fire in Rouen in 2019 and associated factors. Specifically, the prevalence of probable PTSD, probable generalized anxiety, and probable depression were described. We also aimed to estimate the associations between each probable disorder and different types of exposure, especially the influence of odors.

# **Materials & methods**

#### Data collection

"Post Fire 76 Health, 'A Study That Listens to Your Health" is a cross-sectional epidemiological survey. It was conducted in the general population to assess the health impact of the Rouen industrial fire over the short and medium terms. Data on participants' perceived exposure, symptoms experienced during the fire, and health-related quality of life one year after the fire, are described elsewhere [16–18]. The survey was conducted between September and December 2020, twelve to fifteen months after the fire. It took place in two areas, one

exposed and the other non-exposed [19]. The exposed area was divided into four exposure strata around the burnt warehouses: proximity stratum for people living less than 1500 m from the fire, South-West stratum which concerned people not exposed to smoke but exposed to odors and close or far North-East stratum for people living in the plume of smoke (Fig. 1).

The non-exposed area, comprising Le Havre city and its northern periphery, was selected as an industrial city that reflected the Rouen area, and which had similar socioeconomic characteristics [19]. A stratified singlestage random sampling design was used to select adults from each of the four exposure strata. The sampling was performed by the French National Institute of Statistics and Economic Studies (Insee) using the 2019 edition of the national fiscal database called 'The Demographic Files on Households and Individuals' (Fidéli) [20]. This address-based sampling frame included socioeconomic and geolocation data for each household. It allowed people to be selected based on the exact location of their dwelling. The Proximity stratum (0-1500m) was overrepresented [21]: 58% of people living within 700m of the fire were sampled (613 people), while9% of those in the 700-1500m range were sampled (1,326 people). In contrast, the overall sampling rate for the exposed area was 3%. One adult per household was selected. The survey comprised two parts. The first was completed online (self-administered questionnaire) or by phone. It collected data on the different types of exposure reported by the participants, their socio-demographic characteristics, and their health and lifestyle habits. The second part of

the survey [22] was dedicated to mental health and was completed between November and December 2020. It comprised of a self-administered questionnaire, either online or on paper. Only participants who completed the first part were invited to participate in the second.

# Types of exposure to the industrial fire

Various types of exposures were selected after consultation with representatives of the exposed population and local stakeholders in the days following the fire. Some of them came from Fideli: the survey area (exposed or nonexposed area), the geographic dwelling stratum (Fig. 1), and the distance from the dwelling to the fire. Other exposition variables were self-reported exposures collected in the first part of the survey: unpleasant odors and duration, black smoke and duration, visual or auditory perceptions of the fire, soot deposits, and fibrocement roof debris containing asbestos in the nearby environment.

#### Mental health outcomes

The second part of the survey measured probable PTSD, probable anxiety, and probable depression fifteen months after the fire. As we aimed to assess probable PTSD attributed to the fire, probable PTSD was only assessed in the exposed area.

Probable PTSD was measured using the French version of the PTSD Checklist for DSM-5 (PCL-5) [23, 24]. Participants were asked to complete this checklist for PTSD symptoms they experienced in the previous month which were related to the fire. The PCL-5



Fig. 1 Location of the burnt warehouses, exposed and non-exposed areas, and exposure strata, in France and Seine-Maritime region

comprises 20 items (each answer coded from 0 = not at all" to 4 = "extremely"). Each item with a rating of 2 (i.e., "moderately" or higher) was defined as a PTSD symptom. PTSD is considered probable for people who have at least one symptom of the checklist's criterion B (intrusion: questions 1–5), one symptom of criterion C (avoidance: questions 6–7), two symptoms of criterion D (negative alterations in cognition and mood: questions 8–14) and two symptoms of criterion E (Alterations in arousal and reactivity: questions 15–20).

The French version of the Generalized Anxiety Disorder-7 (GAD-7) was used to assess respondents' probable anxiety. This scale consists of seven items. Participants estimate the frequency of anxiety symptoms in the previous two weeks. Each item is rated 0 (never), 1 (several days), 2 (more than half the time) or 3 (almost every day). The GAD-7 score, which is the sum of the ratings, varies between 0 and 21 and measures the severity of the disorder. People with a score greater than or equal to 10 probably suffer from moderate to severe generalized anxiety [25]. We used this value in our survey.

Probable depression was assessed using the French version of the Patient Health questionnaire-9 (PHQ-9). This comprises nine items to estimate the frequency of depressive symptoms in the previous two weeks. Each item is rated 0 (never), 1 (several days), 2 (more than half the time) or 3 (almost every day). The PHQ-9 score is the sum of the ratings and ranges from 0 to 27. A threshold of 10 was used in our survey, as it is considered to reflect probable moderate to severe depression [26].

## Adjustment factors

Income level and household size came from the sampling database [20]. Other socioeconomic and demographic elements were collected in the first part of the survey: age, gender, education level, socio-professional category, financial difficulties, and professional connection with the burned warehouses. Information on tobacco and alcohol use habits was collected. Additional parameters were collected during this part of the survey: probable or confirmed SARS-CoV-2 infection, lockdown experience, and social isolation. The COVID-19 pandemic started between the time of the fire and the survey and may have had an impact on mental health [27]. Social isolation was assessed using the following question: "In general, would you say that you feel: very alone, alone, supported, very supported?" [28]. Answers were grouped into two modalities (very alone or alone vs. supported or very supported). Subsequent variables were collected in the second part of the survey. History of potentially traumatic events was asked and was then grouped as follows: potentially traumatic sexual event, other potentially intentional traumatic event (non-sexual physical assault, attack, etc.), potentially traumatic non-intentional event (natural disaster, life-threatening illness, etc.). Experiencing at least one significant life event during the previous twelve months (divorce, dismissal, robbery, etc.) [29] was also collected. Finally, mental healthcare history was collected by two items asking whether the participant had been followed by a psychotherapist or had taken a psychotropic drug for at least six months [30].

# Statistical analysis

Sample weights were corrected for nonresponse, using both socioeconomic and geolocation variables from the fiscal sample database, along with data on exposure, symptoms, and health-related quality of life reported in the first part of the survey. Statistical analyses took into account the sampling design of the survey including nonresponse adjusted weights, strata, and the finite population correction factor [21]. Missing data were handled using the chained equation imputation method [31] and concerned less than 2% of the data. The socioeconomic representativeness of the study participants, compared to the initial random sample, was evaluated after correcting for nonresponse. Additionally, the comparability of respondents between the exposed and non-exposed areas was described. For the exposed area, questionnaire variables were compared between the first part and the second part sample. The descriptive analyses consisted of estimating the weighted percentages and their 95% confidence intervals. Comparisons were made using confidence intervals.

The analysis of probable PTSD attributed to the fire included only participants in the exposed area, while probable generalized anxiety and probable depression were studied in both areas. Co-occurrences of probable mental health disorders in the exposed area were described.

The associations between fire exposure and each of the three probable mental health disorders were studied using robust variance Poisson regression models [32].

Modeling was conducted as follows: socio-demographic and socioeconomic variables were first selected, followed by the selection of other general adjustment factors. All mental health-specific adjustment variables (social isolation, history of potentially traumatic event or significant life event, and history of mental healthcare) were then added without selection. Exposure variables were selected afterward. A step-by-step descending procedure was used at each of the three selection steps. Variables were chosen using the following statistical criteria: significance at the 5% threshold, minimization of the Akaike information criterion, and absence of collinearity (variance inflation factor less than three). In the final models, relevant statistical interactions were tested (between age and sex, exposure variables and sex, and exposure variables and psychological variables). Finally,

sensitivity analyses were performed by reintroducing exposure variables not retained (duration of exposure to odors and exposure strata). The results are presented as relative risks (RR) and their 95% confidence intervals.

The analyses were performed using the 'survey' package of R software version 4.0.4 and the SAS 7.1 surveymeans and surveyfreq procedures.

# Results

## **Participants**

A total of 1,968 participants (1,627 in the exposed area and 341 in the non-exposed area) completed both parts of the survey (Fig. 2), representing an overall response rate of 20%. The mean age of participants was 49 years old, 55% of them were women, 34% had an education level below a high school diploma, 19% had a high school diploma, and 47% had a higher education level. Characteristics were the same for most of the socioeconomic variables between respondents and the overall population of the exposed area, except that the former were more likely to belong to higher-income households and less likely to belong to a household with two members (Additional file 1). The socio-demographic characteristics of participants from the exposed and non-exposed areas were also similar for the majority of variables, except for a higher level of education and professional category among people in the exposed area.

Furthermore, for the exposed area, the description of the questionnaire variables showed that the sample of the second part was similar to the first part in terms of socioeconomic, exposure, symptoms, and perceived quality of life one year after the fire (Additional file 2). Similar characteristics were also observed between those two groups in terms of a history of a potentially traumatic event, social isolation, mental healthcare history, and significant life events over the previous twelve months. The



Fig. 2 Participation of people drawn at random in each part of the survey

only difference regarded intentional potentially traumatic events, where the exposed group was more likely to have a history of them (data not shown).

# Prevalence of probable mental health disorders fifteen months after the fire

In the exposed area, 6% (95% confidence interval (5-7%)) of the population had probable PTSD, 15% (13-17%) probable generalized anxiety, and 18% (16-20%) probable depression (Fig. 3).

The prevalence of each of these probable disorders was higher in the Proximity stratum than in the other three exposure strata, specifically, 13% (7-18%) vs. 5% (4-7%) for probable PTSD, 24% (17-30%) vs. 14% (12-16%) for probable generalized anxiety, and 29% (22-35%) vs. 17% (15-19%) for probable depression. These differences persisted after adjustment for variables mentioned in the methods.

The population of the non-exposed area had a lower prevalence of probable generalized anxiety (9% (6-13%)) and probable depression (12% (7-17%)) than the exposed population. This difference was only statistically significant for the Proximity stratum.

Among inhabitants of the exposed area, 23% (21-25%) had at least one of the three probable disorders, and 5% (3-6%) had both probable PTSD and probable depression (Fig. 4).

Among inhabitants of the exposed area, 78% (75-80%) had neither probable generalized anxiety nor probable depression vs. 86% (81-90%) of those living in the non-exposed area.

# Associations between exposure to the industrial fire and probable mental health disorders after adjustments for the confounding factors

Hearing or being awakened by the fire was associated with probable PTSD with an RR of 1.8 (95% confidence interval (1.2–2.8)). The following variables were statistically significantly associated with probable PTSD: financial difficulties, professional links with the warehouses burnt in the fire, history of a potentially traumatic sexual event, and social isolation (Fig. 5).

Residents who heard or were awakened by the fire were 1.4 (1.1–1.8) times more likely to have probable generalized anxiety. The following variables were significantly associated with probable generalized anxiety: being a woman, a higher number of adults in the household, possible SARS-CoV-2 infection, having had a difficult COVID-19-related lockdown experience, social isolation, and a history of a potentially traumatic event of an unintentional nature (Fig. 5). The risk of probable generalized anxiety was also significantly higher in those who reported long-term exposure to odors: the RR were 1.6 (1.1–2.3), 1.9 (1.3–2.9), and 1.7 (1.2–2.5) for exposure

to odors lasting several weeks, several months, and one year, respectively, in the sensitivity analysis.

Perceived exposure to unpleasant odors related to the fire and the presence of roof debris in the surrounding area were significantly associated with probable depression, with an RR of 2.0 (1.2–3.3) and 1.6 (1.1–2.4), respectively. The following other variables were significantly associated with probable depression: a history of a potentially traumatic sexual event, social isolation, and a history of mental healthcare (Fig. 5). People exposed to odors for at least several days were twice as likely to have probable depression, with a RR of 1.9 (1.1–3.5), 1.8 (1.1–3.2), 2.2 (1.3–3.9) and 2.4 (1.4–4.1) for exposure to odors lasting several days, several weeks, several months, and one year, respectively, in the sensitivity analysis.

#### Discussion

Fifteen months after the fire, notably higher prevalence of probable depression and probable generalized anxiety were found in residents living in the exposed area compared to those in the non-exposed area. 15% of the exposed population had probable generalized anxiety (vs. 9% in the non-exposed area) and 18% probable depression (vs. 12%). Differences were higher for people living closest to the fire. In addition, 6% of the exposed population had probable PTSD attributable to the fire. These results show the strong impact on mental health fifteen months after this industrial fire, even though no fatalities or injuries occurred. The observed prevalence of probable mental disorders was of the same order of magnitude as in other post-accidental studies [5, 6, 33]. In our survey, 23% of exposed persons had at least one of the three probable mental health disorders studied; 12% had at least two of these probable disorders. Co-occurrences of disorders have also been found elsewhere [6]. The prevalence of probable depression in the non-exposed area (12%) in our survey was higher than that found in France in 2019 before the COVID-19 pandemic (10.5%) but lower than the prevalence during the country's first COVID-19-related lockdown in May 2020 (13.5%) [34].

In line with other studies [4, 33], the prevalence of the three probable mental health disorders studied were all significantly higher in persons living within 1,500 m of the fire than in those living further away or persons in the non-exposed area. These differences persisted after adjustment for confounding. Further analysis made it possible to distinguish the various types of exposure — such as odors or soot deposits—associated with mental health degradation after adjustment. These types of exposure could have occurred beyond the Proximity stratum. Hearing or being awakened by the noise of the fire was associated with probable PTSD and probable generalized anxiety, which reflects findings from another study [6]. Similarly, exposure to odors was associated with probable



#### Probable Post-Traumatic Stress Disorder prevalence





# Probable depression prevalence



Fig. 3 Weighted prevalence and 95%Cl of people suffering from (i) probable PTSD attributed to the Rouen fire (in the exposed area only), (ii) probable generalized anxiety (score GAD-7 ≥ 10) (in both the exposed and non-exposed areas), and (iii) probable depression (score PHQ-9 ≥ 10) (in both areas), and according to the exposure stratum



Fig. 4 Co-occurrence of probable PTSD, probable generalized anxiety, and probable depression: count, weighted prevalence, 95%Cl in exposed people

depression and probable generalized anxiety, in particular when the exposure duration was long. This result is novel in a post-disaster context but is consistent with the literature in other contexts where associations between odors and psychological disorders were found [35-37]. The sense of smell is related to the emotional system [35] and the perception of odors may be affected by the state of anxiety [36]. In addition, debris from the warehouse roof falling near the respondent's dwelling was associated with probable depression. A public warning was published about touching fibrocement fragments. Awareness of one's exposure to asbestos has been associated with mental disorders [38]. In contrast, probable PTSD, probable generalized anxiety, and probable depression did not seem to be associated with the presence of soot, seeing flames, or the location of the fire.

Other risk factors associated with probable mental health disorders that we identified are well-known in the literature, such as social isolation [39–41], a history of mental healthcare [4, 6], a history of potentially traumatic events [41], financial hardship [6], and female gender [42, 43]. Professional link with the warehouses burnt in the fire was also a risk factor. Assessing all these factors is useful to identify at-risk populations.

Several studies have shown that mental health disorders can persist for several years after a disaster [1, 7]. In addition, many people exposed to disasters do not seek mental healthcare [44] for different reasons, including avoidance behavior which is one symptom of PTSD. Given all these points, and to improve medicopsychological care, a webinar meeting was set up by the Regional Health Authority, the Normandy regional psychotraumatology center, and Santé publique France, to inform general practitioners and other healthcare providers in the exposed area about the mental health impact of this industrial fire, and how to screen patients for PTSD. Patients in need of trauma-related mental healthcare will be referred to the Normandy Regional Psychotraumatology Center [45]. This kind of approach has proven useful in other post-disaster contexts [46].

# **Strengths and limitations**

Despite the attrition observed during both parts of the survey nonresponse correction based on objective variables from the sampling database allowed to minimize nonresponse bias and to assume that the potential impact of selection bias was limited. Indeed, a literature review [47] has shown that nonresponse rate is not the primary concern in nonresponse bias but the relevance of the data used to correct for nonresponse bias. Our nonresponse correction was performed using a fiscal database and variable of the first part of the survey. After correcting for nonresponse, the respondents sample from the second part was similar both to the random sample in terms of

	Adjusted RR	95%CI	p-value		
Probable Post-Traumatic Stress Disorder model *					
Heard or was awakened by the fire	1.79	[1.16-2.77]	0.01		
Get by (vs comfortable)	1.41	[0.60-3.33]	0.43		·
Just get by, need to be careful (vs comfortable)	2.20	[0.95-5.10]	0.07		•
Cannot make ends meet without going into debt (vs comfortable	2.68	[1.11-6.49]	0.03		·
Professional link with the burnt warehouses	1.70	[1.01-2.84]	0.05		<b>⊢</b> −−'
History of potentially traumatic sexual event	2.30	[1.39-3.79]	<0.01		·
Very alone or alone (vs. supported or very supported)	2.00	[1 48-3 93]	<0.01		
tery alone of alone (15 supported of very supported)	2.42	[1.40-5.55]	40.01		
				0	1
Probable generalized anxiety model **					
Heard or was awakened by the fire	1.40	[1.08-1.82]	0.01		<b>⊢</b> ● - 1
Woman (vs Man)	1.53	[1.15-2.03]	< 0.01		<b>-</b>
Number of >18 in the dwelling	1.15	[1.00-1.33]	0.06		-•-
SARS-CoV-2 infection yes, certain (vs no)	0.77	[0.37-1.64]	0.51		⊢ <b>−</b> −
SARS-CoV-2 infection yes, not certain (vs no)	1.64	[1.14-2.35]	0.01		
SARS-CoV-2 infection - do not want to answer (vs no)	1.09	[0.68-1.75]	0.72		<b>⊢</b>
Difficult lockdown experience score 4-7 (vs score 0-3)	1.31	[0.92-1.86]	0.14		ı <b>∔_●</b> i
Difficult lockdown experience score 8-10 (vs score 0-3)	1.64	[1.14-2.35]	0.01		
History of potentially traumatic sexual event	1.37	[0.98-1.92]	0.07		<b>⊢</b> •−-i
History of potentially non intentional traumatic event	1.45	[1.09-1.95]	0.01		<b>⊢</b> ●−−1
Very alone or alone (vs supported or very supported)	2.20	[1.65-2.95]	< 0.01		
				0	1
Probable depression model ***					
Perceived unpleasant odors	1.96	[1.18-3.25]	0.01		
Roof debris surrounding home	1.61	[1.07-2.42]	0.02		, <b>—</b> •
History of potontially traumatic served avent	1 70	[1 22.2 41]	<0.01		
history of potentially traumatic sexual event	1.79	[1.33-2.41]	0.01		<b>⊢</b> ●−1
History of potentially non-intentional traumatic event	1.34	[1.01-1.//]	0.04		<b>⊢</b> ●1
very alone or alone (vs supported or very supported)	2.15	[1.66-2.79]	<0.01		<b>⊢</b> ●'
History of significant life event during the previous 12 months	1.27	[0.98-1.66]	0.08		<b>⊢</b> ●'
History of mental healthcare	1.33	[1.03-1.72]	0.03		<b>⊢</b> ●1
				0	1
				Adjusted	relative risk and 95%CI (log scale)

Fig. 5 Factors associated with the presence of probable PTSD, probable generalized anxiety, and probable depression, fifteen months after the Rouen fire \* This model was also adjusted on gender, suffering from chronic disease, history of potentially intentional or non-intentional traumatic events, and history of significant life event during the previous 12 months. None of these factors were statistically significant

\*\* This model was also adjusted on age, suffering from chronic disease, worries about the SARS-Cov-2 epidemic, history of potentially traumatic sexual event, history of significant life event during the previous 12 months, and history of psychiatric troubles. None of these factors were statistically significant \*\*\* This model was also adjusted on gender, BMI, suffering from chronic disease, worries about the SARS-Cov-2 epidemic, history of potentially intentional or non-intentional traumatic events, history of significant life event during the previous 12 months, and heard or awakened by the fire. None of these factors were statistically significant

socio-economic status and to the first part respondents in terms of exposures to the fire, symptoms linked to the fire, and health-related perceived quality of life. Thus, it can be assumed that the weighted respondents' sample was representative of the random sample.

Given the deteriorating mental health of the general population in France during the COVID-19 pandemic [27], it was crucial to compare the fire-exposed area's results to another geographic area that had not been exposed to the fire, but that had - like the exposed area - been exposed to this pandemic. Characteristics were similar between the respondents from the exposed and non-exposed areas, except for education level, socio-professional category, and history of a potentially traumatic event of an intentional nature. These variables were all introduced for adjustment in each model. Reporting and social desirability biases were limited owing to the self-administration of the questionnaire [48]. As the survey took place approximately one year after the fire, recall bias on self-reported exposures is also possible [49]. However, recall bias did not impact the mental health assessment in this study, as all questions referred to the time of the self-evaluation. Because of the cross-sectional design, causal relationships cannot be established between mental health outcomes and associated factors.

We can assume that being personally affected by the fire in some form may have had a mental health impact. While no one had been injured and to our knowledge, no one lost their jobs due to the industrial fire, concerns may have been experienced such as farmers who may have been worried about their income. However, these aspects were not assessed in the survey.

Finally, the survey design was based on self-administered scales: PCL-5, GAD-7, and PHQ-9. Although these validated scales have good psychometric qualities and are widely used in epidemiological studies [23–26] to assess prevalence, they do not provide psychiatric diagnoses as structural clinical interviews do, therefore we referred to "probable disorders".

# Conclusion

The present survey highlighted a medium-term mental health impact of the industrial fire on people living in the exposed area with a notably higher prevalence of probable depression and probable generalized anxiety in residents living in the proximity area compared to those in the non-exposed area. Co-occurrence of probable disorders was also substantial, with 23% of participants presenting at least one probable mental health disorder, and 5% suffering from both probable PTSD and probable depression. Exposure to persistent odors was associated with probable anxiety and probable depression, highlighting the importance of attenuating odors to reduce the psychological impact of such an accident.

This result suggests that, in addition to short-term measures, greater attention needs to be paid to exposed people in the medium term. Priority should be given to residents close to the site of the event, economically disadvantaged and socially isolated individuals, those with a history of mental healthcare, and individuals with a history of a potentially traumatic event, as the study found these groups to be more affected by mental health impacts.

#### Abbreviations

CI Confidence Interval

- DSM-5 Diagnostic and Statistical Manual of Mental Disorders, fifth edition Fideli Demographic Files on Households and Individuals, the sampling database GDPR General Data Protection Regulation
- GDPR General Data Protection Regulation
- GAD-7 Generalized Anxiety Disorder 7

PCL-5 Post-Traumatic Stress Disorder Checklist for DSM-5

- PHQ-9 Patient Health Questionnaire 9
- PTSD Post-Traumatic Stress Disorder
- RR Relative Risk

# **Supplementary Information**

The online version contains supplementary material available at https://doi.or g/10.1186/s13690-025-01602-7.

Additional file 1: Exposed and non-exposed areas population characteristics, among respondents and among the reference population when available in the sampling database Fideli

Additional file 2: Characteristics, among respondents of the first part of the survey, compared to respondents of the second part of the survey in the exposed area

#### Acknowledgements

The authors are most grateful to all the survey participants from Rouen and Le Havre for their involvement, to Imane Khireddine for her help with mental health indicators, Mélanie Martel for her help in designing the survey and administering the questionnaires to Travelers, as well as all members of health advisors group and the scientific council, particularly: Marcel Calvez, Michel Chadelaud, Alain Rouzies, André Cicolella, Yvon Graïc, Patrick Daimé, Bruno Burel, Martine Fleury, Robert Garnier, Anne Maître, Maria Melchior, Olivier Borraz, Jean-Claude Pairon. Finally, we would like to thank the IPSOS Observer institute, Melissa Arneton for her careful rereading, Jude Sweeney (Milan, Italy) and Emilie Schwarz for their careful copyediting of the manuscript.

#### Author contributions

ALP, PEB, JBR, FG, AZ, MB, AS, ELL and YM made substantial contributions to the conception of the survey. ALP, GP, PM, MEL and YM designed the present work and wrote the main manuscript text. ALP, GP, PM and MEL analysed the data. All authors substantively revised and approved the submitted version.

#### Funding

This survey was conducted by Santé publique France in the framework of its missions as the national public health agency. Santé publique France is publicly funded by the French Health Insurance System.

#### Data availability

The datasets analysed during the current study are available in the CASD, Secure Data Access Center repository, https://www.casd.eu/en/source/sant e-post-incendie-76-une-etude-a-lecoute-de-votre-sante-en/.

#### Declarations

#### Ethics approval and consent to participate

The survey received approval from the French Council For Statistical Information (CNIS, n° 178 / H03) and the Committee of Public Statistics (N°2020\_17077\_DG75-L002). Personal data processing was performed in compliance with the General Data Protection Regulation (GDPR). Specifically, data collection was based on the participants' consent (article 9.2.1 GDPR) and only pseudonymized data were used for the analyses. At the end of the questionnaire, a personalized message was displayed depending on the answers given. Whenever needed, this message encouraged them to consult a general practitioner or a mental health professional so that their emotional state could be assessed.

# **Consent for publication**

Not applicable.

#### **Competing interests**

The authors declare no competing interests.

Received: 10 February 2025 / Accepted: 15 April 2025 Published online: 07 May 2025

#### References

- Bryant RA, et al. Longitudinal study of changing psychological outcomes following the Victorian black saturday bushfires. Aust N Z J Psychiatry. 2018;52(6):542–51.
- 2. Laugharne J, van der Watt G, Janca A. After the fire: the mental health consequences of fire disasters. Curr Opin Psychiatry. 2011;24(1):72–7.
- Lowe SR, et al. Posttraumatic stress and depression in the aftermath of environmental disasters: A review of quantitative studies published in 2018. Curr Environ Health Rep. 2019;6(4):344–60.
- Rivière S, et al. Predictors of symptoms of post-traumatic stress disorder after the AZF chemical factory explosion on 21 September 2001, in Toulouse, France. J Epidemiol Community Health. 2008;62(5):455–60.
- 5. Grievink L, et al. A longitudinal comparative study of the physical and mental health problems of affected residents of the firework disaster Enschede, the Netherlands. Public Health. 2007;121(5):367–74.
- Belleville G, et al. Psychological symptoms among evacuees from the 2016 fort McMurray wildfires: A Population-Based survey one year later. Front Public Health. 2021;9:655357.
- van der Velden PG, et al. Persistent mental health disturbances during the 10 years after a disaster: four-wave longitudinal comparative study. Psychiatry Clin Neurosci. 2013;67(2):110–8.
- Santiago PN, et al. A systematic review of PTSD prevalence and trajectories in DSM-5 defined trauma exposed populations: intentional and non-intentional traumatic events. PLoS ONE. 2013;8(4):e59236.
- U.S. Department of Veterans Affairs. PTSD: National Center for PTSD. Resilience and Risk Factors After Disaster Events. Last updated: March 26, 2025. Available from: https://www.ptsd.va.gov/disaster\_events/for\_providers/resilie nce\_risk\_factors.asp
- Reis AM, de Francisco Carvalho L, Elhai JD. Relationship between PTSD and pathological personality traits in context of disasters. Psychiatry Res. 2016;241:91–7.
- Barpi. Incendie Sur Deux sites industriels aux zones d'entreposage Mitoyennes 26 septembre 2019. Rouen et Petit-Quevilly (Seine-Maritime) France. Ministère de la Transition écologique/Direction générale de la prévention des risques; 2020. p. 10.
- 12. Institut national de l'environnement industriel et des risques (Ineris). Analyse de l'Ineris suite à la saisine du 2 octobre 2019 sur la gestion post-accidentelle de l'incendie sur l'usine Lubrizol à Rouen. Ineris-DRC-19-200506-07144A. Verneuil-en-Halatte, Ineris. 4 octobre 2019:16.
- 13. Institut national de l'environnement industriel et des risques (Ineris). Complément à l'analyse de l'Ineris suite à la saisine du 2 octobre 2019. Ineris-DRA-19-200616-07263A. Verneuil-en-Halatte, Ineris. 10 octobre 2019:2.
- Assemblée, Nationale. Rapport d'information Sur L'incendie D'un site industriel à Rouen N° 2689. Assemblée Nationale: Paris; 2020. p. 729.
- 15. Prieto N, et al. [Defusing of victims of the terrorist attacks in Paris. Elements of assessment one-month post-event]. Encephale. 2018;44(2):118–21.
- El Haddad M, et al. Health-related quality of life 1 year after a large-scale industrial fire among exposed inhabitants of Rouen, France: 'the post fire 76 health' study. Eur J Public Health. 2024;34(3):550–6.
- Empereur-Bissonnet P, et al. Santé PostIncendie 76 Une étude à l'écoute de votre santé. Etude épidémiologique par questionnaire sur L'incendie industriel du 26 septembre 2019 à Rouen (France). Rapport principal. Santé publique France: Saint-Maurice; 2021. p. 81.
- Empereur-Bissonnet P, et al. Impact sanitaire à court et Moyen termes de L'incendie industriel de Rouen En 2019: matériels et méthodes d'enquête. Volume 20. Environnement, Risques & Santé; 2021. pp. 185–90. 2.
- 19. Santé publique France, Santé Post Incendie 76. Une étude à l'écoute de votre santé. Etude de santé et de qualité de vie auprès des habitants exposés à l'accident industriel de Rouen du 26 septembre 2019. Protocole d'étude. Version du 28 décembre 2020. 2020, Santé publique France: Saint-Maurice. p. 61.
- Insee. Fichier démographique d'origine fiscale sur les logements et les personnes (Fideli). March 09 2023; Available from: https://www.insee.fr/fr/information/38 97375
- 21. Richard J-B, et al. Santé Post-Incendie 76: Une étude à L'écoute de votre Santé. Bilan méthodologique. Saint-Maurice; 2022.
- 22. Santé P, France. Santé Post-Incendie 76: Une étude à L'écoute de votre Santé. Questionnaire. Santé publique France: Saint-Maurice; 2021. p. 22.
- 23. Ashbaugh AR, et al. Psychometric validation of the english and French versions of the posttraumatic stress disorder checklist for DSM-5 (PCL-5). PLoS ONE. 2016;11(10):e0161645.
- 24. Weathers F et al. The PTSD Checklist for DSM-5 (PCL-5). Scale available from the National Center for PTSD. 2013; Available from: http://www.ptsd.va.gov

- Spitzer RL, et al. A brief measure for assessing generalized anxiety disorder: the GAD-7. Arch Intern Med. 2006;166(10):1092–7.
- 26. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med. 2001;16(9):606–13.
- 27. Chan-Chee C et al. The mental health of the French facing the covid-19 crisis: prevalence, evolution and determinants of anxiety disorders during the first two weeks of lockdown (Coviprev study, March 23–25 and March 30 April 1st, 2020). Bull Epidémiol Hebd; 2020:2–9.
- Robert S, et al. Health and access to health care of 18–25 years old people not in employment, education or training (NEETs) attending the French 'missions locales'. Rev Epidemiol Sante Publique. 2017;65(4):265–76.
- 29. Khireddine-Medouni I, Rabet G, Cohidon C. Expositions psychosociales Au travail et risque Suicidaire: programme Samotrace, volet En Entreprises, départements du Rhône et de L'Isère, 2007–2009. Santé publique France: Saint-Maurice; 2019. p. 20.
- Verger P, et al. The psychological impact of terrorism: an epidemiologic study of posttraumatic stress disorder and associated factors in victims of the 1995–1996 bombings in France. Am J Psychiatry. 2004;161(8):1384–9.
- 31. Azur MJ, et al. Multiple imputation by chained equations: what is it and how does it work? Int J Methods Psychiatr Res. 2011;20(1):40–9.
- 32. Zou G. A modified Poisson regression approach to prospective studies with binary data. Am J Epidemiol. 2004;159(7):702–6.
- Gissurardóttir Ó. Mental health effects following the eruption in Eyjafjallajökull volcano in Iceland: A population-based study. Scand J Public Health. 2019;47(2):251–9.
- Hazo JB, et al. [Spring 2020 lockdown: an increase in depressive syndromes, especially in people aged between 15 and 24 years]. Etudes Et Résultats. 2021;1185:1–8.
- Bushdid C, Topin J, Golebiowski J. Quand l'atmosphère sent Le soufre. Perception des pollutions odorantes. [When the atmosphere smells like sulfur. Perception of malodors]. Pollution atmosphérique; 2017. p. 234.
- Krusemark EA, et al. When the sense of smell Meets emotion: anxiety-statedependent olfactory processing and neural circuitry adaptation. J Neurosci. 2013;33(39):15324–32.
- Kwok RK, et al. Mental health indicators associated with oil spill response and clean-up: cross-sectional analysis of the GuLF STUDY cohort. Lancet Public Health. 2017;2(12):e560–7.
- Mounchetrou Njoya I, et al. Anxious and depressive symptoms in the French Asbestos-Related diseases cohort: risk factors and self-perception of risk. Eur J Public Health. 2017;27(2):359–66.
- Ge L, et al. Social isolation, loneliness and their relationships with depressive symptoms: A population-based study. PLoS ONE. 2017;12(8):e0182145.
- 40. Liu CH, et al. Factors associated with depression, anxiety, and PTSD symptomatology during the COVID-19 pandemic: clinical implications for U.S. Young adult mental health. Psychiatry Res. 2020;290:113172.
- Rivière S, et al. Psychosocial risk factors for depressive symptoms after the AZF chemical factory explosion in Toulouse, France. Eur J Public Health. 2010;20(6):625–30.
- 42. Dyb G, et al. Post-traumatic stress reactions in survivors of the 2011 massacre on Utøya Island, Norway. Br J Psychiatry. 2014;204:361–7.
- 43. Pietrzak RH, et al. Psychiatric comorbidity of full and partial posttraumatic stress disorder among older adults in the united States: results from wave 2 of the National epidemiologic survey on alcohol and related conditions. Am J Geriatr Psychiatry. 2012;20(5):380–90.
- 44. Binet E, et al. A portrait of mental health services utilization and perceived barriers to care in men and women evacuated during the 2016 fort McMurray wildfires. Adm Policy Ment Health. 2021;48(6):1006–18.
- 45. El-Hage W, et al. Improving the mental health system for trauma victims in France. Eur J Psychotraumatol. 2019;10(1):1617610.
- Crompton D, et al. Mental health response to disasters: is there a role for a primary Care-Based clinician?? Prehosp Disaster Med. 2022;37(5):706–11.
- 47. Groves RM. Nonresponse rates and nonresponse bias in household surveys. Int J Public Opin Q. 2006;70(5):646–75.
- Schlenger WE, Silver RC. Web-based methods in terrorism and disaster research. J Trauma Stress. 2006;19(2):185–93.
- 49. Grimm A, et al. Behavioural, emotional, and cognitive responses in European disasters: results of survivor interviews. Disasters. 2014;38(1):62–83.

# **Publisher's note**

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.