EVIDENCE BASED PUBLIC HEALTH POLICY AND PRACTICE

Assessing post-disaster consequences for health at the population level: experience from the AZF factory explosion in Toulouse

Thierry Lang, Valérie Schwoebel, Eloi Diène, Eric Bauvin, Eric Garrigue, Karine Lapierre-Duval, Anne Guinard, Sylvie Cassadou, for the Scientific and Operational Committees

J Epidemiol Community Health 2007;**61**:103–107. doi: 10.1136/jech.2005.043331

See end of article for authors' affiliations

Correspondence to: Professor T Lang, Département d'Epidémiologie et IFR 126, Faculté de Médecine, 37 allées Jules Guesde, 31073 Toulouse, France; lang@cict.fr

Accepted 10 June 2006

Background: A major explosion occurred in the AZF chemical factory in Toulouse in September 2001. A comprehensive programme of epidemiological surveillance was set up.
Objectives: To present an overview of the programme and discuss the methods and potential utility of post-disaster epidemiology. The programme had three objectives: (1) to analyse comprehensively the short-term and long-term effects of air, water and secondary soil pollution on health; (2) to identify health problems needing special attention; and (3) to investigate the long-term direct and indirect effects on the population's health.
Methods: The programme was organised through three committees: (1) a scientific committee, (2) an executive programme committee and (3) an institutional committee which aimed to facilitate exchanges between the epidemiologists, the regional authorities, the population and the media. As the catastrophe was an industrial disaster that had a major effect on workers and companies, and also caused severe damage to many schools and buildings all over the city, routine and ad hoc surveillance systems were used and three specific ad hoc questionnaire surveys in workers, schoolchildren and the general population were planned.
Results and Conclusions: Although the routine surveillance systems had limitations, several sources provided useful information for public health decisions and were found to be concordant with ad hoc epidemiological studies. Defining a victim was central to the choice of a programme design based on an approach either to victims of the disaster or to the entire population in the surrounding region. Anticipation and preparation for such disasters are thus required.

Despite increasing concern about the consequences of catastrophes, much has still to be learnt in this respect from the epidemiological and public health point of view.[1] With regard to the severe consequences, epidemiological programmes should be able to provide information for appropriate decisions relating to environmental issues, health-care delivery and secondary prevention in the population. However, the effects of a catastrophe have been shown to have profound effects on the lives of the population in the medium and long term.[2]

After the major catastrophe which took place in Toulouse in 2001, a comprehensive programme of epidemiological surveillance was rapidly set up. This paper aims to present an overview of the programme and to discuss the methods and potential utility of post-disaster epidemiology, based on the preliminary results.

The catastrophe

In Toulouse, on Friday, 21 September 2001 at 10:17 h, an explosion occurred in a warehouse storing ammonium nitrate at the AZF factory, Grande Paroisse, Toulouse, France, belonging to the Total-Fina-Elf company. For several hours immediately after the explosion, an orange and presumably toxic cloud covered the city. Toxic chemicals subsequently leaked into the nearby river for some days. During the first 24 h after the explosion, 30 deaths were recorded and >3000 persons were injured. In the whole of the city, over 27 000 houses and apartment buildings were totally or partially destroyed.[3] Six chemical plants had to shut down. One thousand factories, representing 20 000 jobs, were damaged by the explosion. Damage was assessed as severe in 144 companies, representing 4300 jobs. After 6 months, 1800 workers were still unemployed as a result of the disaster.

Goals of the programme

A health-monitoring programme was set up with three goals: (1) to analyse comprehensively the health risk and health effects of air, water and secondary soil pollution in the short and long term; (2) to identify specific health problems needing special attention; and (3) to study the direct and indirect long-term effect on health of the entire population of Toulouse.

METHODS

Organisation

The programme was implemented and financed by the Institut de Veille Sanitaire, a French national epidemiological agency. It was organised through three committees: (1) a scientific committee, composed of academics and researchers from the Institut de Veille Sanitaire, defined the goals and design of the studies, supervised the analysis, made recommendations to health authorities and provided information to the population from a ''scientific'' viewpoint, independently of the authorities and the employers; (2) an executive programme committee was in charge of the programme and data analysis; (3) an institutional committee, composed of regional and local authorities, health authorities, unions, victims, experts and population representatives, aimed to facilitate the organisation of the studies and encourage exchanges between the epidemiologists in charge of the programme, the population and the media. Ongoing results of the programme were presented regularly, giving the opportunity for debate on the consequences of the catastrophe.

Short-term investigations

Health risk assessment

Data on emitted pollutants were obtained from the company owning the factory and from the fire department. Some pollutants were measured in air and water by the regular local air quality-monitoring network and by official institutions. Their possible toxic effects were assessed by searching the literature and databases on toxic products. Exposure of the population to toxic agents in the air was estimated by mathematical models which included the data collected by the meteorological experts. Regarding soils, possible exposure through direct ingestion and indirect exposure through ingestion of agricultural products such as fruit and vegetables were estimated using mathematical modelling.[4]

Detection of specific health problems

Routine surveillance systems of the area were used. Additional items were added within 1 week of the explosion to the information routinely collected by a sentinel network of 40 general practitioners and 17 paediatricians in Toulouse. These items were related to health effects known to occur after similar disasters, such as mental health[5] and effects anticipated in relation to the content of the toxic cloud, such as respiratory, eye and ear symptoms. Unexplained syndromes were also included to detect unexpected health effects. Data were available within a few days. Specialists in ear and eye diseases were requested to report the number of patients seen daily. The ''Centre Anti-Poison'' (regional centre for information on any suspected toxic effect) was used as an alert system to detect unexplained and possibly toxic cases. Information on pregnancy termination for medical reasons was also obtained from the medical regional committee in charge of examining all regional cases. The number of new prescriptions for psychotropic drugs delivered daily and the medical certificates describing injuries due to the explosion were obtained, within 3 months, from the local health insurance authorities.[6] A specific code was used in the hospital information systems throughout the whole area to record any admission for injuries or diseases related to the explosion. Specific inquiry was carried out in each hospital in the area and in hospitals within a radius of 300 km to check that no secondary death occurred among the 590 persons who had been admitted to hospital for injuries immediately after the explosion. The results of systematic screening for ear and eye diseases in schoolchildren, performed within 2 months of the explosion, were collected. The data on acute ischaemic heart disease from the regional registry were also used, although they were obtained >1 year after the catastrophe.[7 8]

Long-term ad hoc studies

To assess the direct and indirect long-term effects of the explosion, the definition of a ''victim'' needs to be discussed. A victim may in fact be a person who (1) had sought emergency care at a hospital after the disaster, (2) identified himself or herself as a victim, (3) had obtained compensation from an insurance company, (4) was registered on a list of victims eligible for allowances or (5) was physically or mentally affected by the explosion. As the catastrophe affected a large proportion of the city population, and health was not necessarily the first priority, our goal was to assess the health consequences in the whole population, independently of access to care. Specific population-based studies were conducted among three population groups: workers, schoolchildren and the general population.

Workers

The explosion had occurred in an industrial plant and deaths occurred mostly among workers. The effect on employment was considerable. A cross-sectional study and a cohort study were planned among workers. The target population was the adults working in the Toulouse metropolitan area on the day of the explosion. Every person who worked <3 km from the centre of the explosion (the ''proximal zone'') was included in the study (estimated population: 20 000 workers). A sample of workers (n = 30 000) stratified according to economic sector and size of the company was planned to be randomly selected from the rest of the Toulouse metropolitan area. Data were collected through a self-administered questionnaire administered to the workers through the worksite physicians, through their employers, or mailed to them directly with a covering letter signed by the president of the scientific committee. Post-traumatic stress syndrome was assessed using the Impact of Event Scale–Revised. Fifty thousand questionnaires were sent out 1 year after the explosion, in September 2002. A total of 9517 questionnaires were not distributed, mainly due to inaccuracies in the database of companies in the area. Finally, 13 764 completed questionnaires were received. The participation rate was estimated to be 34% among workers. To detect possible toxic health effects and mental health problems, a cohort study was planned in a subgroup of participants of the cross-sectional study. In the questionnaire, persons were asked whether they agreed to volunteer for a 5-year follow-up study. Their consent was also obtained for future linkage between data from the cross-sectional study and national mortality data in order to study very long-term effects of the disaster. A cohort of 3006 workers agreed to be followed up for 5 years at the multiphasic health screening centre of the local health insurance system.[9]

Schoolchildren

As one college student died, 100 schools were damaged, and five of them entirely destroyed, health effects on children needed to be analysed. Two cross-sectional studies were performed in schoolchildren. The first was conducted 9 months after the explosion and took advantage of the international Health Behaviour in School-aged Children study, which was organised by the World Health Organization and previously planned in the spring of 2002.[10] The sample originally planned in Toulouse was expanded to include 700 schoolchildren in the proximal zone. Specific questions relating to the catastrophe were added. A second cross-sectional study was conducted 16 months after the explosion, including all pupils in the first year of grammar school (Sixièmes des colleges) in the proximal zone and a sample from a control area in the north of Toulouse. One thousand children aged 10–13 years were included. Participation rates were 78% in the first cross-sectional study and 74% in the second study carried out at 16 months.[9]

General population

A cross-sectional study was conducted 18 months after the explosion in collaboration with the French national institute for statistics and economic studies (INSEE). This study concerned adults over 18 who were resident in Toulouse at the time of the explosion. A stratified random sample of 2206 houses and apartments (1470 in the proximal zone and 736 in the rest of the city) was first selected on the basis of data from the 1999 census. Selected apartments were visited by interviewers who then randomly included one adult per unit of housing. The questionnaire was completed during a face-to-face interview. Participation rate was 60% and a total of 1191 persons were included (811 in the proximal zone and 380 in the rest of the city).[9]

DISCUSSION

Now that it is >4 years after the catastrophe, it is time to learn lessons from the programme itself in order to anticipate future

catastrophes. This is the first experience of a programme on this scale after a disaster in France. Detailed results of the specific studies have been published elsewhere[11] or are in preparation.

Usefulness of routine health information systems for epidemiology after catastrophes

The programme enabled us to provide information to the health authorities and the population that none of the assessments of population exposure to any toxic agent in the air, water or soil indicated that potential health effects should be anticipated.[4]

During the initial weeks after the disaster, two major problems were identified from the data provided by the routine surveillance systems: a high incidence of ear injuries and mental health problems. As a result, systematic screening for hearing loss in the immediate disaster area and increase in mental health services were recommended.[12]

The information obtained from routine surveillance systems has to be treated with caution. Events are entered as codes by a variety of health personnel and this does not result in a strict definition as in a research context. The database records health problems collected through access to care, which is far from indicating the true prevalence, especially in the context of a disaster. Furthermore, health insurance data provide information on purchase of drugs, not on their consumption. Despite these limits, concordant information from several sources provided a useful basis for public health decisions, although the prevalence of the disorders could not be reliably assessed. However, months later, the three specific studies conducted among workers, schoolchildren and the general population gave concordant results. Each study showed the considerable effect and high prevalence of post-traumatic stress disorders.[9] In the future, it will be important to try to analyse how mental health reflects the direct consequences of the explosion or the indirect effects on housing, schooling and work. Each study confirmed the deep social and economic disruption caused by the disaster and showed the considerable effect and high prevalence of post-traumatic stress disorders.[9]

Was such a programme useful and effective?

The institutional committee has proved to be useful in maintaining a link with the institutions, the population and the victims' associations, which were regularly informed during the meetings. It has thus probably encouraged debate on health issues. Victims' associations were invited to participate in designing the questionnaire used in the population study. To have been able to investigate in detail any possible toxic effects of the explosion and to rule them out with confidence may have helped to avoid a post-disaster syndrome similar to that observed in The Netherlands, where an epidemic of medically unexplained symptoms occurred 5 years after a catastrophe in Amsterdam.[13] In that case, toxic exposure had not been clearly ruled out by the authorities. The Toulouse programme has also helped to stop some rumours about ''hidden consequences'' of the catastrophe. The programme was able to recommend screening of hearing loss immediately after the explosion, to draw attention to mental health problems and to help increase the delivery of health care. Indeed, during the post-emergency period, about 6 weeks after the disaster, emergency aid was no longer available, although healthcare needs were still high, particularly for mental health.

Communication relating to victims

Defining a victim was difficult in a situation where individuals demanded compensation and benefits. Different points of view were expressed and led to difficulties in communicating the results to the population and the media. As indicated above, at least five definitions of a victim could be used. Communication was further complicated by the population approach of epidemiology, which aims to assess the effect on the community rather than on the individual. An example is increased cardiovascular morbidity after a disaster, which can be described as a consequence of the accident. As these diseases are multifactorial in nature, it is not possible to state that some individuals with coronary events should be included among the victims. Taking time into account also complicated the concept of a victim as it could be assessed at different points in time, either short term, concerning direct effects, or long term, with indirect effects through job, housing or schooling problems and effects on social relationships. It also raises the question of the extent to which social and health issues are connected by society at a given time. For example, are unemployment and disruption of social ties considered to be determinants of health?

Which epidemiological design for the surveys?

The choice of the definition of a victim, of an effect, direct or indirect, is also related to the definition of the target population under study and thus the methodology used. A first approach is to include victims on the basis of records, as after the bombing in Oklahoma City.[14] In these cases, results are related to direct victims and the response rates are high, as in studies of victims of terrorist attacks,[15 16] or to a lesser extent victims of floods.[17] These inclusion protocols are however difficult to relate to a clear definition of the population under study. This is also the case when populations are recruited on the basis of access to care. A major determinant is physical injury during the event[18 19]; however, a selection process occurs due to the variability of access to care. After the Schiphol air disaster, this approach was imposed by the nature of the problem, an epidemic of medically unexplained symptoms reported by general practitioners.[20] In the Enschede project, victims were included on the basis of a broad definition of a person affected, comprising ''everyone who suffered direct loss or injury as well as those whose exposure was less direct''.[18] The voluntary basis of such recruitment makes it difficult to assess the effect on the community, as volunteers are unlikely to be representative of the population who were affected.

Another approach is to define populations by their exposure to the catastrophe. In the event of direct exposure, the population may be well defined and response rates have usually been high, as among industrial workers after the explosion at their paint factory in Norway (response rate about 97%).[21] Rescue workers are another well-defined population.[9] Particularly in disasters that affect a large community, it is thus tempting to design studies in the general population based on representative samples, to give a valid estimate of the effect irrespective of whether the population decides to access health services or not. It has been shown that health is not necessarily the first priority after a disaster, when housing, work or family difficulties come first before symptoms considered as minor, as was the case for hearing problems after the AZF explosion in Toulouse.[9] The general population option was chosen in Toulouse, as it has been in other disasters. Nevertheless, in this case, the response rate is a major obstacle in interpreting the results, as it is usually lower than expected and tends to diminish with the length of time between the disaster and the study. The response rate to telephone surveys after 11 September 2001 in New York was 73% 3–4 days after the attack, 63% 1–2 months later and 34% 6 months later, with comparable methods.[22 23] Low response rates (63%) were reported 6 months after the Newcastle earthquake.[24] The methods used to contact the population need to be considered. Mailed questionnaires have been reported to have lower response rates than telephone surveys or face-to-face

What is known on this topic

- Information for managing the health consequences of disasters and catastrophes is needed rapidly for urgent public health decisions.
- Information is also needed in the long term, as consequences of disasters are long lasting.

What this paper adds

- Routine health surveillance systems are able to provide information in a short time and give guidance for public health decisions.
- Defining a victim of a catastrophe may be a problem in communicating the results to the population and the media, as several definitions exist.
- The definition of a victim must also be considered when deciding on study design.
- Studies of representative samples of the population are theoretically the best approach to examine the prevalence of health effects; however, if the studies are performed too long after the event, the response rate may be low and the generalisability of the results may not be better than that of victim-based studies.

interviews.[9 24] Despite a design which should provide a representative sample of the community, low response rates might thus lead to a situation that appears to be not so far from the design based on volunteers, as long as the extent to which the non-response was selective is not documented.

CONCLUSIONS

A catastrophe is, by definition, unexpected and unique. Post-disaster health effect assessment and epidemiological surveillance have to be prepared before the occurrence of a catastrophe. Catastrophes have to be anticipated. Thus, both flexibility and preparation are needed.[25] Anticipating disasters and setting up a Humanity Impact Assessment programme requires a complex network to assess the needs of the various institutions and categories of people concerned and to organise a complex interdisciplinary approach with time constraints. Research is also needed on availability and validation of mental health indicators, including post-traumatic stress disorders. A lack of consensus in the literature has been noted on definition and measurement of mental health problems.[5] This is even more true when children are concerned.[26] Analysis of the global health effect of the Toulouse disaster is still in progress. We believe that it could be used in the future when deciding the health consequences of operating dangerous factories in inhabited areas.

ACKNOWLEDGEMENTS

This programme was possible thanks to the active participation and involvement of the many institutions and individuals, experts and volunteers both inside and outside the health sector. The institutions contributed through their data or by allowing their staff to be involved in the project. These institutions and the persons who participated in the working groups are numerous. Their names can be found on the website of the Institut de Veille Sanitaire: http://www.invs.sante.fr. We thank S Dasté for secretarial assistance from the start of the programme. The programme was financed by the Institut de Veille Sanitaire.

Authors' affiliations

T Lang, E Bauvin, E Garrigue, IFR126 Santé Société, F-31073 Toulouse Hospitals (CHU), F-31000 Toulouse, France
T Lang, Institut de Veille Sanitaire, Toulouse, France
V Schwoebel, A Guinard, Cellule inter-régionale d'Epidémiologie, Institut de Veille Sanitaire, Toulouse, France
E Diène, Département Santé Travail, Institut de Veille Sanitaire, Toulouse, France
K Lapierre-Duval, Comité de suivi ''AZF'', Institut de Veille Sanitaire, Toulouse, France
S Cassadou, Département Santé Environnement, Institut de Veille Sanitaire, Toulouse, France

Funding: The programme was implemented and financed by the Institut de Veille Sanitaire.

Competing interests: None.

Members of the scientific and operational committees for follow-up of the effects of the AZF factory explosion on health—*Scientific Committee*: T Lang, S Cassadou, F Cayla, G Choisnard, M Combier, JL Ducassé, M Fabre, B Fraysse, O Deguine, JP Raynaud, L Schmitt, JM Soulat, M Goldberg, C Gourier-Frery, E Imbernon, P Malfait, B Helynck, B Thélot. *Operational Committee*: V Schwoebel, E Diène, S Dasté, A Guinard, K Lapierre-Duval, C Hemery, C Ricoux, E Bauvin, E Garrigue, S Rivière.

REFERENCES

1 **Dominici F**, Levy JI, Louis TA. Methodological challenges and contributions in disaster epidemiology. *Epidemiol Rev* 2005;**27**:9–12.
2 **Noji EK**. Disasters: introduction and state of the art. *Epidemiol Rev* 2005;**27**:3–8.
3 **Mouilleau Y**, Dechy N. Premières analyses des dommages observés à Toulouse après le sinistre du 21 septembre survenu sur le site AZF de la Société Grande Paroisse. *Rapport intermédiaire. Institut National de l'Environnement Industriel et des Risques*. 24 Oct 2001; 47pp.
4 **Comité de suivi épidémiologique ''AZF''**. Conséquences sanitaires de l'explosion survenue à l'usine ''AZF'' de Toulouse le 21 septembre 2001. Conséquences des expositions environnementales. *Rapport InVS*. Saint Maurice: InVS, 2003.
5 **Galea S**, Nandi A, Vlahov D. The epidemiology of post-traumatic stress disorder after disasters. *Epidemiol Rev* 2005;**27**:78–91.
6 **Balssa G**, Panofre G, Hurstel JF, *et al*. Explosion de l'usine AZF de Toulouse: description des lesions prises en charge au titre d'accident du travail par la Caisse primaire d'assurance maladie de la Haute-Garonne. *Arch Mal Prof* 2004;**6**:463–9.
7 **Ruidavets JB**, Paterniti S, Bongard V, *et al*. Triggering of acute coronary syndromes after a chemical plant explosion. *Heart* 2006;**92**:257–8.
8 **Ogawa K**, Tsuji I, Shiono K, *et al*. Increased acute myocardial infarction mortality following the 1995 Great Hanshin-Awaji earthquake in Japan. *Int J Epidemiol* 2000;**29**:449–55.
9 **Comité de suivi épidémiologique''AZF''**. 21 Septembre 2001–21 Septembre 2004: bilan de l'explosion de l'usine ''AZF'' à Toulouse. *Bull Epidemiol Hebd* 2004;**38–39**:185–92.
10 **Currie C**, Roberts C, Morgan A, *et al*, eds. *Young people's health in context. Health Behaviour in School-aged Children (HBSC) study: international report from the 2001–2002 survey*. WHO Policy Series: HePCA no 4. Copenhagen: WHO Regional Office for Europe, 2004:63–72.
11 **Godeau E**, Vignes C, Navarro F, *et al*. Effects of a large-scale industrial disaster on rates of symptoms consistent with posttraumatic stress disorders among schoolchildren in Toulouse. *Arch Pediatr Adolesc Med* 2005;**159**:579–84.
12 **Comité de suivi épidémiologique ''AZF''**. Conséquences sanitaires de l'explosion à l'usine de Grande Paroisse le 21 Septembre 2001. *Rapport intermédiaire*. Juillet 2002. http://www.invs.sante.fr (accessed 5 Nov 2006).
13 **Donker GA**, Yzermans CJ, Spreeuwenberg P, *et al*. Symptom attribution after a plane crash: comparison between self-reported symptoms and GP records. *Br J Gen Pract* 2002;**52**:917–22.
14 **North CS**, Nixon SJ, Shariat S, *et al*. Psychiatric disorders among survivors of the Oklahoma City bombing. *JAMA* 1999;**282**:755–62.
15 **Abenhaïm L**, Dab W, Salmi LR. Study of civilian victims of terrorist attacks (France 1982–1987). *J Clin Epidemiol* 1992;**45**:103–9.
16 **Verger P**, Dab W, Lamping DL, *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**:1384–9.
17 **Verger P**, Rotily M, Baruffol E, *et al*. Evaluation des conséquences psychologiques des catastrophes environnementales: une étude de faisabilité à partir des inondations de 1992 dans le Vaucluse (France). *Santé* 1999;**9**:313–8.
18 **Roorda J**, van Stiphout WA, Huijsman-Rubingh RR. Post-disaster health effects: strategies for investigation and data collection. Experiences from the Enschede firework disaster. *J Epidemiol Community Health* 2004;**58**:982–7.
19 **Mines M**, Thach A, Mallonee S, *et al*. Ocular injuries sustained by survivors of the Oklahoma City bombing. *Ophtalmology* 2000;**107**:837–43.

20 **Yzermans J**, Gersons BPR. The chaotic aftermath of an airplane crash in Amsterdam. A second disaster. In: Havenaar JM, Cwikel JG, Bromet EJ, eds. *Toxic turmoil.* London, Kluwer Academic Publishers, 2002.
21 **Weisaeth L**. The stressors and the post-traumatic stress syndrome after an industrial disaster. *Acta Psychiatr Scand Suppl* 1989;**355**:25–37.
22 **Galea S**, Ahern J, Resnick H, *et al.* Psychological sequelae of the September 11 terrorist attacks in New York City. *N Engl J Med* 2002;**346**:982–7.
23 **Schuster MA**, Stein BD, Jaycox L, *et al.* A national survey of stress reactions after the September 11, 2001, terrorist attacks. *N Engl J Med* 2001;**345**:1507–12.
24 **Carr VJ**, Lewin TJ, Webster RA, *et al.* A synthesis of the findings from the Quake Impact Study: a two-year investigation of the psychosocial sequelae of the 1989 Newcastle earthquake. *Soc Psychiatry Psychiatr Epidemiol* 1997;**32**:123–36.
25 **Verger P**, Schwoebel V, Aulagnier M, *et al. Démarches épidémiologiques après une catastrophe.* Paris: La Documentation Française, 2005.
26 **Yule W**, Bolton D, Udwin O, *et al.* The long-term psychological effects of a disaster experienced in adolescence: I: The incidence and course of PTSD. *J Child Psychol Psychiatry* 2000;**41**:503–11.