EVIDENCE BASED PUBLIC HEALTH POLICY AND PRACTICE

Epidemic soybean asthma and public health: new control systems and initial evaluation in Barcelona, 1996–98

J R Villalbí, A Plasencia, R Manzanera, R Armengol, J M Antó, the Collaborative and Technical Support Groups for the study of soybean asthma in Barcelona*

J Epidemiol Community Health 2004;**58**:461–465. doi: 10.1136/jech.2003.009001

See end of article for authors' affiliations

Correspondence to: Dr J R Villalbí Agència de Salut Pública de Barcelona, Pl Lesseps 1, 08023 Barcelona, Spain; jrvillal@aspb.es

Accepted for publication 9 September 2003

Objective: To evaluate the new measures adopted to control the risks from soybean unloading operations in the Port of Barcelona, after an episode of epidemic asthma in June 1996.
Methods: After an initial cautionary suspension of all soybean unloading operations, they were subsequently resumed under restrictive criteria for time, flux, simultaneity, and meteorological conditions. Emission filtration systems based on either micro pore size filters or polytetrafluoroethylene membranes on tetratex filters showed promising results.
Results: Allergen emission underwent a very important decrease to levels 95% to 98% lower. Emissions from the two plants with unloading operations are in the same order of magnitude as the processing plant that does not unload soybean. Allergen concentration levels presented fluctuations initially, but the new filters decreased mean values; despite increased unloading, allergen levels did not increase—mean allergen levels on unloading days (67 U/m^3) and on days without unloading operations (63 U/m^3) are similar. A panel of patients detected a cluster of increased symptoms during unloading operations on a day with suboptimal meteorological conditions and comparatively low allergen levels (225–415 U/m^3). Since the June 1996 episode, no further asthma outbreak has been detected.
Conclusions: The evaluation shows the effectiveness of the new filters in the control of soybean dust emission. With a systematic control programme, industrial soybean operations may function near urban centres without public health risks. These data may be useful in the development of future standards for allergenic agents.

Analysis of the circumstances giving rise to repeated outbreaks of asphytic asthma episodes in the city of Barcelona led in 1987,[1] to the identification of soybean dust generated during the unloading of ships in the port as their aetiological agent.[2 3] Subsequent corrective measures adopted in the unloading facilities involved sleeve filters, periodic follow up of dust levels during soybean unloading operations, and the timely notification by port authorities of the arrival of soybean carrying ships. Despite their initial effectiveness in achieving the suppression of asthma outbreaks and reducing allergen levels for several years,[4] in the mid-term these measure did not control risks comprehensively: although no asthma epidemic outbreaks were detected, specific IgE persisted in affected patients, along with a certain level of symptoms.[5] In 1996 a new outbreak of cases of soybean asthma was detected in hospital emergency services,[6] some being "repeaters" who had been affected by the outbreaks in the 1980s.[7] This episode has been reported elsewhere: its magnitude and clinical and epidemiological characteristics were reminiscent of those that had occurred before the adoption of corrective measures, and they were related with important, although temporary, increases of airborne levels of the allergen.[6]

Efforts were made to improve control of the problem, including an improved understanding of the emission and dispersion of the allergen, the identification of allergen concentration levels compatible with health, the reduction of allergen emission levels, and the definition of complementary safety measures. This made compatible an economic activity in the port, with social implications, with the strict requirements the city maintains for public health. This paper reports the indicators used to monitor the problem, and their evolution over time, as well as the risk reduction measures adopted. The history of the problem and the steps that led to its control, summarised chronologically in table 1, have been published elsewhere.[8] Our aim here is to present an evaluation of the measures adopted and their implications. We expect to provide useful information for those professionals who may be involved in their application in other contexts, and for clinicians involved in the treatment of the resulting problems.

METHODS

There were different phases during this process. The plants operated without restrictions until the June 1996 outbreak, when unloading operations were suspended as a cautionary measure, a review was carried out of the structural aspects of the plants, their maintenance, and the routine of unloading operations. Subsequently, unloading was authorised on a boat to boat basis and under special restrictions covering the unloading flux and its timetable; simultaneous unloading in the two docks was not permitted, and there were restrictions linked to weather conditions. These restrictions were reviewed as data on allergen concentrations suggested variations linked to their operation. The identification of dry filtration technology as a promising option for reducing emissions led to its adoption in the unloading installations in November 1997, replacing the previous standard polyester sleeves by new micro pore size (MPS) filter sleeves, or by tetratex filters in series with polytetrafluroethylene (PTFE) membrane filter cartridges. These modifications were implemented while under the special regimen of boat to boat

Abbreviations: MPS, micro pore size; PTFE, polytetrafluoethylene; RAST, radioallergoabsorbence test

Table 1 Chronology of the control of risk of soybean asthma outbreaks in Barcelona, 1982–98

1982–83	Identification of epidemic asthma outbreaks in the ICU of the Hospital Clinic, Barcelona.
1983	Municipal public health services rule out the possibility that the outbreaks are an artefact, or caused by common atmospheric pollution.
1987	Identification of soybean dust as the allergenic vehicle causing the outbreaks of asthma. Adoption of control measures based on installation of sleeve filters.
1987–89	Absence of epidemic outbreaks and improvement in allergen inmision levels. Sensitisation in patients persists, with decreases in the average IgE levels.
1994	Cluster of asthma cases. Plants are checked and a station installed in the port to permit monitoring of allergen levels near their source.
1996	Asthma outbreak (11–12 June). Suspension of soybean unloading. Checks carried out of the plants and diffuse emission control measures, as well as intensive monitoring of allergen concentrations. Post-outbreak phase: crude control of emissions, by restricting activity on each boat unloading.
1997	Study of emissions, identification of new filters to achieve greater reductions in allergen emission. Tentative implementation of new filters to control channelled emissions (November 1997).
1998	New operating licences to the three firms (June 1998), specifying a pilot phase for evaluation, eliminating all restrictions in unloading (except under extremely unfavourable meteorological conditions). Follow up of the pilot phase passed without incidents.

unloading authorisation, as the firms tested it and subsequently requested new licences for plant operation. These licences were approved in the summer of 1998 by the city government, which maintained as a cautionary measure some operation restrictions under adverse weather conditions, and required the monitorisation of soybean allergen emission and inmision levels by the firms in a pilot phase.

On the basis of this evolution, the study period may be subdivided into four phases: phase 1 covers eight days around the time of the June 1996 episode; phase 2 involves crude control methods based on the restriction of activity until the installation of new filters in November 1997; phase 3 covers the tentative use of the new filters until the pilot phase in summer 1998; and finally phase 4 involves the pilot phase evaluation until December 1998. During this period four indicators were analysed: allergen levels in the city, allergen emissions by the three firms involved, aggregated numbers of asthma cases in city emergency services, and the health status of a panel of patients. Not all the indicators were active during the entire period: emissions data could not be collected until 1997, and the panel of patients was set up towards the end of 1997. Table 2 shows the four phases and the indicators available in each phase, along with other relevant variables.

Aggregation of asthma patients attending emergency services

The emergency departments of the four university hospitals in the city monitored the daily volume of patients. As defined in the initial study of the epidemics, any day on which more than 12 asthma patients were seen was considered an abnormal or potential asthma outbreak day.[2] The names of asthma patients on such days were checked against a list of people who had been repeatedly involved in episodes of epidemic asthma. The simultaneous detection of three such patients in emergency services was considered to be a marker of an episode of epidemic asthma.[7]

Health status of a panel of patients

After a clinical epidemiological study of soybean asthmatic patients, a sentinel surveillance system was set up based on the continuous follow up of symptoms in a small group of patients. Such a system ought to facilitate early detection of episodes of allergy. A group of high risk patients was selected for this purpose. It involved 10 asthmatic ''repeaters'' resident in the areas closest to the port, and four patients not sensitised to soybean dust. To follow symptoms daily the patients were trained to measure their peak flow (a measure of respiratory function) in the morning and at night, and to fill in daily a questionnaire on symptoms. This information was complemented through periodic follow up telephone interviews. In the case of any sudden increase in acuteness of symptoms, they were required to immediately call a contact telephone number set up for this purpose. Concurrently, a plan was established to follow variations in the patients' symptoms, with successive levels of assessment and decision, including the alarm signal, investigation, notification, and

Table 2 Phases and indicators available during the study period. Barcelona, 1996–98

	Phase 1 June 1996	Phase 2 Up to November 1997	Phase 3 Up to June 1998	Phase 4 Up to December 1998
Operational situation of the plants				
Simultaneous unloading	X			X
Restrictions on timetable and flux		X	X	
Meteorological restrictions		X	X	X
Installation of new filters			X	X
Indicators available				
Epidemic asthma outbreaks	X	X	X	X
Panel of patients				X
Allergen concentration	X	X	X	X
Allergen emission levels			X	X

Table 3 Soybean allergen concentrations (RAST units per m^3) measured in the sampler situated in the port authority customs building by study period phase. Barcelona, 1996–98

	Phase 1 June 1996	Phase 2 Up to November 1997	Phase 3 Up to June 1998	Phase 4 Up to December 1998
Days studied	8	278	174	182
Measures of central tendency				
Mean	1089	184	74	59
Median	731	91	36	35
Measures of dispersion				
Range	143–3000	3–2095	8–415	8–636
Standard deviation	955	216	81	76

verification. Follow up of this panel took place during the period from February to May 1998.

Allergen concentration

This is measured by the radioallergoabsorbence test (RAST) applied to filters installed in samplers.[9 10] The measurements from sampling filters yield a 24 hour average. In this article the data presented centre on results obtained from the municipal atmospheric contamination control station situated in the port authority customs building (city district of Poble Sec) as this station was both closest to the plants and to the neighbourhoods with the greatest number of affected patients. Initally the filters were analysed in the Mayo Clinic (Rochester, USA) but the technique used was implemented in the laboratory of the Vall d'Hebron Hospital (Barcelona) from the autumn of 1997, and after an excellent correlation between the results obtained by the two laboratories had been reached, analysis of the filters was performed only in Barcleona.

Allergen emission

The facilities for unloading, manipulation, storage, and grinding of soybean in the port of Barcelona use pneumatic transportation circuits. In 1996, all foci of channelled emissions were identified. In these foci air is expelled to maintain the low pressure in the pipes; as this air is filtered before reaching the atmosphere, the emissions thus produced are channelled emissions. The steps undertaken to measure allergen emission led to the identification of almost 40 foci of channelled emissions in the three plants. The level of emission at each point and the global value for each plant were measured.[11] The RAST inhibition analytical technique provided a measurement of emissions in terms of allergen units per volume of air; thus, with the known air volume flow rate at each point, emissions can be estimated in allergen units per unit of time. Sampling was carried out in accordance with the German VDI methods, which are reference methods in several European Union countries (isokinetic procedure VDI 2066 adapted to the analytical technique using PTFE coated filters).

RESULTS

Epidemic outbreaks

After the June 1996 episode, no further epidemic asthma outbreaks have been detected in the city. The epidemiological surveillance system continues to monitor emergency services and has actively checked the situation on several occasions when events, or evolution of indicators, seemed to suggest that it was necessary, but without detecting either an epidemic asthma outbreak or clustering of ''repeater'' patients.

Panel of patients

Symptoms referred by the panel may be characterised by their instability over the study period, and by an intensity from low to moderate. There were several false alarms, caused by worsening of symptoms in a single panel member. However, a single cluster of symptoms was detected: five patients presented a sudden worsening in their symptoms (out of eight sensitised patients contacted) on a given day. During this episode, none of the controls manifested the slightest modification in their symptoms, no changes were detected in the number of asthma cases seen in emergency departments, but an increase in symptoms was confirmed in other known asthma patients not members of the panel who were contacted by telephone. On this day there was soybean unloading under ''non-optimal'' weather conditions. Levels of soybean allergen measured were comparatively low (225–415 U/m^3), although they were the highest recorded during the panel follow up period.

Allergen concentrations

Table 3 presents allergen levels data in RAST units per m^3 for the four phases analysed. Even though the measurements were in general low, some important fluctuations are visible towards the end of November 1996, when values are higher for some days. These results led necessarily to a review of unloading conditions. After the installation of the new filters there is a fall in both the measured values and their variation. In the final pilot phase for normalisation, as unloading activities increased, allergen concentrations do not rise: they are only above 300 U/m^3 on two days, and there was no unloading on either of them. In this final phase, mean allergen levels in unloading days (67 U/m^3) and in days without unloading (63 U/m^3) are similar; they are even lower on days with simultaneous unloading (45 U/m^3).

Key points

- Allergenic dust generated in the unloading of ships containing soybeans in harbours located near urban settings poses a significant public health risk, for which there are no criteria for risk management.
- Filtration systems based on either micro pore size (MPS) filters or polytetrafluoroethylene membranes on tetratex filters are effective for the reduction of soybean asthma allergen emission.
- Before this was established, risk reduction was initially possible by limiting the volume and timetable of operations, coupled with meteorological criteria.

Table 4 Allergen emission levels (allergen units $\times 10^9$/24 h) for the three plants manipulating soybean before and after new filters were fitted in November 1997

Plant	Operations	During phase 2, with traditional filter system (end of 1997)	During phase 3, with new filters (first observations in 1998)	Phase 4, with new filters (average of various observations, summer 1998)	% Change (summer 1998/1997)
A	Total for plant A	18987	87*	18	−99.9
B	Soybean unloading	1663	25	41	−97.5
	Silos	26	13	27	3.8
	Total for plant B	1689	38	68	−96.0
C	Transport and manufacture	53807	50	61	−99.9
	Flour drying	NA	NA	29	NA
	Total for plant C	NA	NA	90	NA
Total	Total emission measured	76172	175 *	176	−99.8

*The actual value was lower, as it was below the threshold of detection established previously in trials (this threshold is the value shown in the table). NA: not applicable.

Allergen emission

Table 4 shows emission data for the three plants. Very significant decreases were achieved in channelled emissions of allergen, between 95% and 99% lower than two years before. The emissions by plants A and B (those involved in unloading operations) are now of the same order of magnitude as those of plant C (which does no unloading).

DISCUSSION

A controlled trial is the most solid design for research in the fields of human health, but it would not be possible for this particular problem. We believe that these data show the effectiveness of the new filters in controlling allergen emissions: after November 1997 emissions are reduced, and allergen levels in the city also fall. They also show that during the period of restricted unloading (before normalisation) it was possible to obtain reductions in risk by limiting the flux and timetable of unloading operations, complemented by weather conditions. The Barcelona experience shows that industrial soybean plants may be located near urban settings if strict control criteria are applied. The identification of similar problems in port cities with soybean harbour facilities in Spain,[12–14] and in other countries,[15 16] points to the external relevance of this process. To date, no country has developed legislation to regulate this environmental risk.

Meteorologically, epidemic days were anticyclonic with atmospheric stability, a low altitude mixing layer, and light winds, with long calm spells. Soybean allergen levels in the city depend closely on weather conditions facilitating dust dispersion: wind speed and direction, altitude, and vertical turbulence of the air mixing layer. Thus, allergen concentration in the city may be seen as a problem of gas dispersion: with stable emission, they will be a function of weather conditions, in accordance with a probabilistic model. This model was used to define a preventive tool, which was important in the initial stage of restricted unloading, as it defined the weather associated with higher levels of allergen, and under certain weather conditions unloading was suspended. The solution to the problem is in the reduction of the allergenic particles emitted by the plants, but weather related controls play an additional safety part.

Allergen concentrations during the pilot phase showed a small increase on two days during which no unloading took place; on one of these days grain was unloaded from a train in a railway yard adjacent to one of the plants, while on the other day the conveyor belt linking the two plants was in operation. This shows that operations other than ship unloading may give rise to a certain amount of allergen emission. Railway and conveyor belt operations in the plants are now subject to the same meteorological restrictions described for the unloading of soybean carrying ships.

Policy implications

- This experience shows that industrial soybean operations may function near urban centres without public health risks under a systematic control programme.
- This experience provides data that may be useful to develop future standards for environmental agents of an allergenic nature.

The process described indicates the feasibility of using a panel of asthmatic patients allergic to soybean as part of the surveillance system. It is worth noting, however, that the delay in symptom reporting by patients requires a very active follow up. This follow up provided useful elements for the evaluation of the effectiveness of risk control. Although the control measures drastically reduced both emissions and the concentration of soybean allergen in the city air, active surveillance through the panel showed that in given circumstances small increases in comparatively low allergen concentrations may be sufficient to produce symptoms (although not severe) in a subgroup of the population allergic to soybean.

A general principle in our public health law is that industrial activities must be compatible with the health of the population. This legislation provided the grounds for the involvement of municipal authorities in dealing with this problem and controlling it. However, the only specific legislation applicable to this type of industry refers to general dust, clearly inappropriate for soybean dust, which may cause allergy. In fact, there is no environmental regulation in any country for soybean dust or any other type of allergenic products, beyond occupational standards. Our contacts with the World Health Organisation and the European Union confirm that there is no legislation based on the applicable scientific knowledge, nor any group of experts working in this area. The international nature of the problem and its economic implications may justify the involvement of the International Chemical Safety Program promoted by the International Labor Office, the WHO, and the United Nations Environment Program, to provide a global frame of reference.

The process followed in Barcelona combines research and action. It provides an example of public health applied to risk control under incomplete knowledge conditions. In such a process many uncertainties arise, which require a pragmatic response. The key to progress was intersectoral work, in interaction with applied epidemiology, clinical practice, laboratory and environmental sciences, industrial engineering, and physics of meteorology, but also with the legal,

management, and public administration fields, and a prudential use of trial and error.

There is need for further research. Key questions to be answered are the evolution of soybean sensitisation in patients after the reduction achieved in the allergen levels to which they are currently exposed. There is also a need for the development of analytical techniques for improved monitoring of emissions, where promising advances are underway.[17 18]

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution of Mark C Swanson (Mayo Clinic, Rochester Minnesota) and Maria J Rodrigo (Hospital Vall d'Hebron, Barcelona) to the measurement of soybean allergen levels.

Authors' affiliations

J R Villalbí, A Plasencia, R Manzanera, R Armengol, Agència de Salut Pública de Barcelona (formerly Institut Municipal de Salut Pública, Ajuntament de Barcelona), Spain
J M Antó, Institut Municipal d'Investigacions Mèdiques, Barcelona, Spain

Funding: none.

Conflicts of interest: none declared.

*Members of the Technical Support Group: Ricard Alsina (Direcció d'Iniciatives i Vigilància Ambiental, Ajuntament de Barcelona), Josep M Antó (Institut Municipal d'Investigacions Mèdiques), Ricard Armengol (Institut Municipal de Salut Pública, currently in SCUB 061), Dolors Carrascal (Autoritat Portuària de Barcelona), Jordi Cisteró (Autoritat Portuària de Barcelona), José I Gorostiaga (UO d'Activitats i Seguretat en l'Edificació, Ajuntament de Barcelona), José Gracia (Direcció d'Iniciatives i Vigilància Ambiental, Ajuntament de Barcelona), Rafael Manzanera (Institut Municipal de Salut Pública, currently in Institut Municipal d'Assistència Sanitària), Joan Moya (UO d'Activitats i Seguretat en l'Edificació, Ajuntament de Barcelona), Antoni Plasencia (Agència de Salut Pública), Pau Rodríguez (Direcció d'Iniciatives i Vigilància Ambiental, Ajuntament de Barcelona), Xavier Solé (Autoritat Portuària), Joan B Soriano (Institut Municipal d'Investigacions Mèdiques), Jordi Sunyer (Institut Municipal d'Investigacions Mèdiques), Jordi Vila (Autoritat Portuària), and Joan R Villalbí (Agència de Salut Pública). Members of the Collaborative Group: Joan Broquetes (Hospital de Mar), Joan A Caylà (Agència de Salut Pública), Ferràn Morell (Hospitals de la Vall d'Hebron), Josep Roca (Hospital Clínic), Maria J Rodrigo (Hospitals de la Vall d'Hebron), Robert Rodríguez-Roisín (Hospital Clínic), and Joaquim Sanchís (Hospital de Sant Pau). Josep M Pintó and Jordi Solé (ENVIROTEC) contributed to the study of emissions.

REFERENCES

1 **Ussetti P**, Roca J, Agustí AGN, *et al*. Asthma outbreaks in Barcelona. *Lancet* 1983;ii:280–1.
2 **Antó JM**, Sunyer J, Rodríguez-Roisín R, *et al*. Community outbreaks of asthma associated with inhalation of soybean dust. *N Engl J Med* 1989;**320**:1097–102.
3 **Rodrigo MJ**. Identification and partial characterization of the soybean dust allergens involved in the Barcelona asthma epidemic. *J Allergy Clin Immunol* 1990;**85**:778–84.
4 **Antó JM**, Sunyer J, Reed CE, *et al*. Preventing asthma epidemics due to soybeans by dust control measures. *N Engl J Med* 1993;**329**:1760–3.
5 **Sunyer J**, Antó JM, Rodrigo MJ, *et al*. Case-control study of serum immunoglobulin-E antibodies reactive with soybean in epidemic asthma. *Lancet* 1989;i:179–82.
6 **Plasència A**, Villalbí JR, Manzanera R, *et al*. El asma epidémico por soja y la salud pública: reaparición del problema en Barcelona. *Arch Bronconeumol* (in press).
7 **Soriano JB**, Antó JM, Plasencia A, *et al*. Repeaters count: a sentinel method for asthma outbreaks. *Thorax* 1995;**50**:1101–3.
8 **Manzanera R**, Armengol R, Villalbí JR, *et al*. *La salut pública i l'asma per soja a Barcelona*. Barcelona: Publicacions de l'Ajuntament, 1999.
9 **Swanson MC**, Li JT, Wentz-Murtha PE, *et al*. Source of the aeroallergen of soybean dust: a low molecular mass glycopeptide from the soybean tela. *J Allergy Clin Immunol* 1991;**87**:783–8.
10 **Aceves M**, Grimalt JO, Sunyer J, *et al*. Identification of soybean dust as an epidemic asthma agent in urban areas by molecular marker and rast analysis of aerosols. *J Allergy Clin Immunol* 1991;**88**:124–34.
11 **Pintó-Garriga JM**. *Informes Cargill, Ergransa and Moyresa*. Castellbell: Envirotec SCCL, 1999.
12 **Garcia-Ortega P**, Rovira E, Bartolome B, *et al*. Epidemia de asma alérgica a polvo de soja. Estudio clínico e inmunológico de los pacientes afectados. *Med Clin (Barc)* 1998;**110**:731–5.
13 **Ballester F**, Soriano JB, Otero I, *et al*. Asthma visits to emergency departments and soybean unloadings in the harbors of Valencia and A Coruña, Spain. *Am J Epidemiol* 1999;**149**:315–22.
14 **Navarro C**, Márquez M, Hernando L, *et al*. Epidemic asthma in Cartagena, Spain, and its association with soybean sensitivity. *Epidemiology* 1993;**4**:76–9.
15 **Codina R**, Ardusso L, Lockey RF, *et al*. Sensitization to soybean hull allergens in subjects exposed to different levels of soybean dust inhalation in Argentina. *J Allergy Clin Immunol* 2000;**105**:570–6.
16 **White MC**, Etzel RA, Olson DR, *et al*. Reexamination of epidemic asthma in New Orleans, Louisiana, in relation to the presence of soy at the harbor. *Am J Epidemiol* 1997;**145**:432–8.
17 **Cruz MJ**, Rodrigo MJ, Anto JM, *et al*. An amplified ELISA inhibition method for the measurement of airborne soybean allergens. *Int Arch Allergy Immunol* 2000;**122**:42–8.
18 **Gonzalez R**, Duffort O, Calabozo B, *et al*. Monoclonal antibody-based method to quantify Glym 1. Its application to assess environmental exposure to soybean dust. *Allergy* 2000;**55**:59–64.