AMERICAN JOURNAL OF INDUSTRIAL MEDICINE 50:127–135 (2007)

A Multi-Faceted Approach to Risk Assessment of Laboratory Animal Allergens at Two Facilities

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Background *Risk assessment of exposure to allergens is difficult because the relationship between exposure, sensitization, and symptoms has not been fully established. Laboratory animal allergens (LAA) are an important occupational health risk factor; 10–32% of workers exposed to these allergens develop allergic diseases. This article introduces a versatile approach to assessing the risks posed by LAA at two laboratory animal facilities.*
Methods *The risk assessment approach that was used at the laboratory animal facilities included questionnaires for management and employees, a hazard identification visit and measurements in the workplaces, as well as the creation of a list of generally recommended procedures to reduce allergen exposure.*
Results *The prevalence of work-related allergic symptoms was 17%. Suggested countermeasures at the sites included changes in ventilation and work practices, reduction of unnecessary exposure, recommendations for more comprehensive use of personal protective equipment, and wider communication about LAA risks.*
Conclusions *The approach managed to identify critical points and potential means for controlling LAA exposure.* Am. J. Ind. Med. 50:127–135, 2007. *© 2006 Wiley-Liss, Inc.*

KEY WORDS: hazard identification; occupational allergens; questionnaires; risk communication; risk management

INTRODUCTION

As many as 10–32% of persons working with laboratory animals develop allergic diseases due to exposure to laboratory animal allergens (LAA) [Bush et al., 1998]. The EU regulations on health and safety at work require every employer to make an assessment of the occupational health and safety risks. However, risk assessment of allergen exposure is complicated, as the relationship between exposure, sensitization, and symptoms has not been fully established, and new tools for risk assessment and management are needed. In this article we present the results from a multi-faceted approach to assessing LAA risks at two laboratory animal facilities.

MATERIALS AND METHODS

Risk assessment in the two laboratory animal facilities was planned to involve all parties responsible for safety at work: workers, management, and occupational health and safety personnel. The approach involved three questionnaires, a hazard identification visit and measurements in the workplaces, a summary of the generally recommended procedures to reduce allergen exposure, summaries of the questionnaires, summaries of the hazard identification visit and measurements, and finally, risk management in the form of suggested control actions.

The Management Questionnaire

The aim of this questionnaire was to collect general information about the laboratory animal facilities for the

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The work was performed at the Department of Environmental Sciences, University of Kuopio.
Contract grant sponsor: The Finish Work Environment Fund; Contract grant number: 103103.

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Accepted 14 November 2006
DOI 10.1002/ajim.20424. Published online in Wiley InterScience (www.interscience.wiley.com)

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risk assessment team. Questions covered the following topics:

- work and cleaning routines,
- ventilation systems (type, location, function, and maintenance),
- training and orientation of new employees,
- previous hazard identifications performed, and whether allergen risks were included,
- presumed prevalence of allergic symptoms among employees.

The Employee Questionnaire

All employees who continuously, intermittently, or sporadically worked in or visited the animal facilities were asked to fill in this questionnaire, which contained the following items:

- brief description of duties,
- personal evaluation of exposure to animal allergens (tasks, animal species, and exposure duration per week),
- measures used to control exposure (e.g., special caging systems, biosafety cabinets, fume hoods, isolators, and ventilated necropsy tables, respiratory protection, protective clothing),
- sources and adequacy of training and education related to allergen hazards,
- reports of any exceptional situations leading to the spread of allergens (e.g., breakdown of ventilation).

The Health Questionnaire

The health questionnaire was designed to be completed by each person who might be in contact with LAA, including students, researchers, maintenance technicians, and laundry workers. It was organized by the occupational health service at each workplace. The questionnaire contained questions about age, sex, personal and family history of allergies, smoking, pets, and past occupational history including animal care. Information about nasal symptoms (runny or stuffy nose, sneezing spells), ocular symptoms (watery, itchy or red eyes or swelling of eyes), respiratory symptoms (sputum production, wheezing, shortness of breath, persistent cough, sore throat, throat irritation, hoarseness), skin symptoms, and swelling of lips were documented. The symptoms were graded ''not at all or occasionally,'' ''a few times a year,'' ''monthly,'' or ''weekly/daily.'' Respondents were specifically asked whether these symptoms were present while working with laboratory animals. Information about changes in the respiratory or skin symptoms during the past 12 months was also elicited and graded as ''unchanged,'' ''increased,'' or ''decreased'' for those workers who had experienced these symptoms. Questions were asked about the frequency of contact with laboratory animals (''not at all,'' ''less than 10 times/days per year,'' ''monthly,'' ''weekly,'' ''daily,'' ''weekly periodically,'' or ''daily periodically'') and use of personal protection (gloves, respiratory protection, eye protectors, protective clothing, special footwear, and other equipment).

Hazard Identification Visits

Visits to the laboratory animal facilities were performed by three experienced occupational hygienists (1 day per facility). A total of 38 rooms/premises were inspected at the animal facilities. Suitable representative premises were chosen in advance including corridors, dressing rooms, social premises, file rooms, animal housing rooms, laboratories for animal operation, and cage cleaning/waste rooms. During the hazard identification visits, the workers present were interviewed, and the number of animals, types of activities in the room, and protective methods used were recorded. In addition, specific environmental parameters were measured, as described below. During the hazard identification visit, the existing procedures were checked against the generally recommended procedures (see below).

Evaluation of Air Quality

Special attention was given to the use and function of ventilation and its role in allergen transport. Pressure differences between adjacent premises were recorded (DP-CALC model 8705, TSI). Air current tubes (Dräger, Germany) were used to visualize the airflows in the animal facilities.

The temperature, relative humidity (RH) of air, and carbon dioxide (CO_2) concentrations were measured with specific sensors: an infrared sensor for CO_2, a thermistor for temperature, and a thin-film capacity sensor for RH (Q-Trak 8550/8551-EC-FI, TSI). In addition, the indoor air particulate matter ($\mu g/m^3$) (PM10) was measured in two animal rooms and two cage cleaning premises with an optical particle counter (DustTrak, TSI). The duration of monitoring was 17–127 min. PM10 represents the fraction of particles capable of reaching the tracheobronchiolar regions in the airways.

Air Sampling and Analysis of Rodent Allergens

Air samples were collected on 25 mm Teflon filters (FALP 02500, 1.0 μm pore size; Millipore, Inc., Bedford, MA) with IOM Inhalable Dust Samplers (SKC, Inc., Eighty Four, PA) or 25 mm Millipore filter holders (closed-face C25

cassette) (Millipore Inc.) using portable pumps with a flow rate of 2 L/min. Most of the samples were collected using the Millipore cassettes, as their air flow was easier to adjust. Because rodent allergens appear mostly in particles less than 10–20 μm in diameter [Bush et al., 1998; Harrison, 2001], the higher collection efficiency of IOM samplers for large (>30 μm) particles [Li et al., 2000; Harper et al., 2004] is not of vital importance. Thus, the rodent allergen results obtained with the two samplers can be regarded as comparable. A total of 10 personal task samples with 5- to 91-min sampling durations were collected. During these tasks, the personnel carried the pumps on belts with the sampler head fastened onto their collars. In addition, 21 stationary samples with 25- to 407-min sampling durations were collected. The samplers were fixed at a height of 1–1.6 m depending on whether the worker was sitting or standing during the task. The distance of the sampling stand from walls was 50 cm at minimum, and the samplers faced the room center. The filters were stored at −20°C until extraction.

The filters were allowed to thaw slowly before elution in 3-ml Minisorp tubes (Nunc A/S) in 1 ml PBS with 0.5% Tween-20 under gentle rotation for 2 hr. The filter was then discarded, and BSA (Fraction V; Sigma Chemical Co, St. Louis, MO) was added to 1% (w/v) for protein stabilization. The eluates were stored at −20°C until analysis for the level of Mus m 1 and Rat n 1 using the ELISA assays described in Korpi et al. [2004].

Generally Recommended Procedures to Reduce Allergen Exposure

Procedures and methods to control allergen exposure can be classified into four categories: (1) substitution, (2) engineering controls, (3) administrative controls including work practices, and (4) personal protective equipment [Seward, 2001]. Substitution involves the use of fewer allergenic species, the introduction of in vitro techniques, and computer modeling instead of the use of animals. Engineering controls represent attempts to isolate workers from hazards, including such measures as material substitution, process substitution, isolation or enclosure, and ventilation [Harrison, 2001]. Modification of work practices is often needed to minimize exposure. Finally, personal protective equipment may be needed to provide a barrier between employees and hazards that cannot be adequately controlled by other means [Seward, 2001; Wald and Stave, 2003]. Detailed information has been published previously on controlling LAA exposure through the following means: separation, general ventilation, task ventilation, automation, cage systems, reduction in the number of exposed persons, animals (e.g., age, gender), stock density, bedding material, housekeeping, movements within the facility, work premises and visitors, environmental monitoring, personal hygiene, protective clothing, respiratory protective equipment, training and education, pre-placement assessment, risk assessment, and health surveillance [e.g., National Institute for Occupational Safety and Health (NIOSH), 1998; Reeb-Whitaker et al., 1999; Ryder, 1999; Harrison, 2001; Preece and Renström, 2002; Schweitzer et al., 2003; Wald and Stave, 2003]. In summary, the controls should reduce both the intensity and the duration of exposure.

RESULTS

Both laboratory animal facilities showed similar results; therefore, the combined results are discussed. The description of the animal facilities that follows was obtained from the questionnaire given to management.

Both the facilities were established in the 1980s, and consisted of animal housing rooms, laboratories for animal operations and metabolism studies, necropsy rooms, cage cleaning/waste rooms, social premises, storerooms, office rooms, and dressing rooms. The facilities were organized along two or three corridors. The ventilation systems were maintained regularly, and no recirculation air was used. Maintenance comprised the measurement and adjustment of air flows once a year, regular cleaning of the air ducts, and changing of the exhaust filters. The air exchange rates were adjusted to 10–30 hr^{-1} for animal rooms and 4–5 hr^{-1} for laboratories. In the animal housing rooms, supply air was blown from the ceiling and the exhaust air vents (perforated screens) were located on the walls, behind the animal cages, in order to direct air flow away from the workers. The rodents were housed in open, solid-bottom cages. The bedding (aspen chip) was changed 2–3 times a week for rats and guinea pigs and once a week for mice by transferring animals from soiled to clean cages. For rabbits, non-contact absorbent pads beneath the perforated cage floors were used to collect excretion. Local exhaust ventilators and safety hoods were located chiefly in laboratories and/or autopsy rooms. In the cage cleaning/waste room, the soiled litter was dumped into a ventilated funnel. The animal cages were transferred from animal rooms to laboratories covered and along rarely traveled routes. The orientation of new employees included instruction in occupational safety and health issues, personal protection, and general principles of work in the animal facilities. Employees were trained and schooled regularly, and the admission of visitors was strictly controlled. With respect to cleaning routines, floors and other surfaces were swept daily and wiped 1–3 times a week with damp cloths, and no vacuum cleaning was performed. Previous risk assessments in the facilities were related to ergonomics and biological hazards. The general impression of the management in both facilities was that the prevalence of allergic symptoms among employees was negligible.

Health Status, Exposure, and Use of Personal Protection

The health questionnaire was completed by 47 participants with very different exposure profiles. The results are summarized in Table I. A total of 13 persons had doctor-diagnosed allergies, and 6 of them were sensitized to rodents or rabbits. Nine persons suffered from allergic symptoms weekly or more often. Six workers without doctor-diagnosed allergies and two workers having a doctor-diagnosed allergy reported work-related allergic symptoms. The most commonly reported symptoms affected the nose and eyes, and included sneezing, nasal congestion and discharge, redness of the conjunctiva, and itching or watery eyes. Asthma symptoms, such as wheezing and shortness of breath, and skin symptoms were also reported.

Over 50% of the workers were exposed daily or weekly to rats and/or mice, and to a lesser extent to guinea pigs and rabbits. Special clothing including coats and footwear was routinely used. However, the use of respiratory protection was not frequent, nor were eye protectors and head covers always used.

The majority of respondents felt that they had received enough information related to allergen hazards. A few workers, however, claimed not to know about hazards related to LAA. These persons were mainly involved in maintenance or cleaning duties and head not directly handling animals.

Air Quality in Animal Facilities

In the laboratory animal premises, the RH, temperature and CO_2 concentration ranged between 17 and 50%, 20–24°C, and 350–490 ppm, respectively (Table II). In one animal room, the RH was only 16%. In the archives, the air temperature and RH were within the above-mentioned range, whereas the carbon dioxide concentration was higher, at 750 ppm. Mean particle concentrations ranged from 1 to 87 $\mu g/m^3$, and total variation in PM10 particles was from <1 to 184 $\mu g/m^3$.

Concentrations of the predominant rat and mouse allergens in the air are shown in Table III. In one office sample, the mouse and rat allergen levels remained below detection limit. The lowest Mus m 1 and Rat n 1 levels, up to 0.03 and 0.2 ng/m^3, respectively, were measured in areas without animals, such as social premises, dressing rooms, corridors, and archives. Airborne allergens were present in all animal room samples. During the laboratory procedures, the allergen levels remained below 2 ng/m^3, and mostly below 1 ng/m^3. The highest rodent allergen concentrations, a few nanograms per cubic meter, were measured during animal handling/cage change in animal rooms, during cage cleaning, and when exhaust air filters were changed.

TABLE I. Summary of Allergic Symptoms, Exposure, and Protective Methods For All Persons Having Regular or Irregular Stays or Visits at the Laboratory Animal Premises

Summary of the questionnaire concerning health	Sites A and B (n = 47)
General characteristics of the workers	
Sex, M/F (n)	10/37
Age, year, mean (SD)	38.0 (8.8)
Allergy (physician-based diagnosis), n (%)	13 (28%)
Allergy to rodents and/or rabbit	6 (13%)
Smokers, M/F	3 (30%)/4 (11%)
Pets	44 (94%)
Weekly exposure to rats/mice	14 (30%)/12 (26%)
Daily exposure to rats/mice	17 (36%)/12 (26%)
Exposure to laboratory animals 10 occasions a year or less	10 (21%)
Allergic symptoms weekly or daily	9 (19%)
Nasal symptoms	8 (17%)
Ocular symptoms	4 (9%)
Lower respiratory tract symptoms	4 (9%)
Skin symptoms	3 (6%)
Allergic symptoms related to work with laboratory animals	8 (17%)
Nasal symptoms	7 (15%)
Ocular symptoms	6 (13%)
Lower respiratory tract symptoms	1 (2%)
Skin symptoms	2 (4%)
Increase in the frequency of symptoms during the past 12 months[a]	
Respiratory tract symptoms	2 (4%)
Skin symptoms	0
Use of respiratory protection	
Continuously when in laboratory animal premises	4 (9%)
In some work situations	19 (40%)
Use of protective clothing	
Special clothing, gown, overall, coverall, etc.	46 (98%)
Head covering	33 (70%)
Special footwear	45 (96%)
Eye protectors	13 (28%)
Gloves always/during some tasks	30 (64%)/6 (13%)

[a]Only 6 of those 15 who reported having symptoms monthly or more often answered the question on change in the frequency of symptoms.

Critical Points With Respect to Allergen Exposure

The critical points needing special attention were very much the same at both sites. During the hazard identification

TABLE II. Air Quality in Animal Facilities

Area (number of premises inspected)	Number of premises with positive (P)/negative (N) pressure	Temp, °C	RH, %	CO_2, ppm	PM_{10}[c], mean and (range), μg/m³
Dressing rooms (2)	P 1; N 1	—	—	—	—
Social premises (1)	N 1	—	—	—	—
Archives (1)[b]	—	23	33	750	—
Animal operation rooms (11)	P 3; N 8	21–24	17–50	350–480	—
Animal housing rooms (9)	N 5; P 4	20–23	39–49[a]	350–490	2 (<1–153); 4 (1–35)
Waste disposal rooms (2)	N 1; P 1	21–22	22–37	400–430	—
Cage cleaning premises (2)	P 1; N 1	22–23	31–39	370–390	1 (<1–26); 87 (1–184)

[a]In one animal room engaged for temporary (max 5 days) housing of animals prior to experiments the RH was 16%.
[b]Room was located apart from animal premises.
[c]A total of four samples were taken with duration ranging from 17 to 127 min.
"—" = Not measured.

visits, the major issue turned out to be ventilation malfunction. This appeared as negligible exhaust air flows in many animal rooms. Consequently, animal rooms were under overpressure. The cage cleaning/waste rooms also had positive pressure compared to the neighboring premises. The overpressure observed in areas with allergen sources contributed to spreading of allergen emissions to the adjacent premises. This was verified with allergen measurements (Table III).

A second critical point was unnecessary exposure occurring during animal dosing performed in animal rooms. In addition, one laboratory was used both for

TABLE III. Rat and Mouse Allergen Concentrations During Different Tasks and in Various Areas

Task/area; stationary (S) or personal (P) sampling	Number of samples	Sampling time, min	Number of animals	Concentration (ng/m³) or range	
				Rat n 1	Mus m 1
Corridor (S)	4	318–380	0	<0.07–0.2	<0.02–0.02
Office (S)	1	407	0	<0.1	<0.01
Dressing room (S)	3	374–402	0	<0.06–<0.1	0.02–0.03
Archives[a] (S)	1	265	0	0.2	<0.02
Social premises (S)	1	355	0	0.2	0.02
Background level in a laboratory with long-term housing of rats (S)	2	112	26 rats	0.5–0.7	—
Handling rats in a laboratory on an open bench (P)	2	10–91	2–37 rats	0.6–<2	—
Laboratory, when rats were handled on an unventilated bench/in a hood (S)	2	74–167	2–6 rats	<0.1–0.4	—
Background level in an animal room (S)	4	33–123	8–90 rats	<0.2–2.9	—
	1	345	15 mice	—	0.2
Handling animals or changing animal cages in an animal room (P)	1	67	49 mice	—	2
	1	33	90 rats	4	—
Manual emptying of cages in a ventilated funnel (P)	4	13–38	[b]	<0.6-7.5	<0.2–0.2
Cage emptying and washing (S)	2	25	[b]	2	<0.2–0.3
Change of exhaust air filter (P)	2	5	0	<4.7	1.9–3.5

[a]Room was located apart from animal premises.
[b]Cage number not specified.
"—" = Not measured.
Note, the detection limits vary due to differences in sampling times.

animal work and full-time office work. Unintentional exposure could also occur due to allergen leakage or transport with clothing and filed documents exported from animal premises. Shortcomings related to hair removal, hair waste handling, and storage procedures were also recorded.

Third, laboratory hoods were inadequate in number, and even those that were present were not used as extensively as possible, mainly due to lack of user-friendly adjustments regarding legroom and lighting. On the other hand, the use of protective clothing in the form of special gowns, shoes and gloves was generally excellent. The utilization of head cover and eye protectors was, however, overlooked at times, and respiratory protection in particular was often neglected. Regardless of the reported defects in their receipt of information on allergen hazards, the maintenance workers were properly protected when they changed the exhaust air filters. If workers are unprotected, this task causes high exposure to allergens. In Table IV, suggestions for control measures to reduce allergen exposure at these sites are presented.

DISCUSSION

In this study, risk assessment of LAA was performed following a multi-faceted approach including use of questionnaires, hazard identification visits, and a list of generally recommended practices to be followed in laboratory animal work. The risk assessment procedure involved all personnel. Thus, it required a lot of time and resources, but, on the other hand, this design ensured the best possible coverage. The personnel were well informed on the allergy issues, and the approach offered continuous assistance and feedback to workers and occupational health and safety personnel. It also served as a means of education on reducing exposure since proper techniques for working with animals or their waste were discussed throughout the process. As in any risk assessment, systematic, repeated collection and analysis of the data will give a reliable basis for the prevention of exposure to animal-derived allergens in the future.

Collecting background information through management and employee questionnaires gives the assessment team an overall impression of safety management and of employees'

TABLE IV. Suggestions for Controls to Reduce Laboratory Animal Allergen Exposure at the Laboratory Animal Facilities Under Study, Based on NIOSH, 1998; Ryder, 1999; Harrison, 2001; Preece and Renström, 2002; Wald and Stave, 2003; Sargent and Gallo, 2003; and the Research Group's Own Observations

Critical point[a]	Suggestions for control measures
General ventilation	Adjust to create positive pressure (compared to adjacent premises) in dressing rooms, social premises, and offices, and negative pressure in animal housing rooms, waste rooms, and cage washing areas. A pressure difference of at least 2.5 Pa is considered adequate
Local exhaust ventilation	Check and adjust task ventilation systems even when all hoods in the same room are on. The face velocity should normally be between 0.7 and 1.0 m s^{-1}
	Increase the utilization rate of ventilated hoods, local exhaust ventilation and ventilated cupboards when performing animal manipulations whenever possible
Work premises/practices	Do not use the same premises both for animal and office work
	Instead of animal rooms, perform animal dosing in other premises where background allergen levels are lower
	Perform hair removal in fume hoods, and seal the refuse bag to prevent exposure of cleaning workers
	Since animals are more active at night time, sweep the floors in the animal rooms early in the morning to prevent the resuspension of aeroallergens
	When changing cages, do not put dirty cages inside each other, since this may raise a cloud of allergens in the air
Paper documents	Minimize the need for documents in animal holding and handling areas. Paperless animal premises are a good alternative and possible with modern technology
	Adopt ways to minimize contamination of paper documents. Protect indispensable paper documents in the animal rooms with plastic pockets. Make copies or fax the documents
Personal protection	Encourage employees to change protective clothing with adequate frequency and to store it properly. Change work clothes daily. Personal clothes should not be stored in the same locker as dirty work clothes. Laundry baskets should not be stored in social premises
	Use head covers (hair bonnet) in animal premises
	Encourage employees to use particle filter respirators. Offer the option of personal powered air-purifying respirators (air helmets) and education on respirator selection, fit testing, inspection, cleaning, maintenance, storage, change frequency, and routine use procedures
	Wear eye protection to prevent allergens, bedding material, and test chemicals from entering the eye conjunctiva
Risk communication	Inform maintenance workers and cleaning personnel of health hazards related to tasks and materials in laboratory animal facilities
	Evaluate and modify laundering of contaminated clothing to ensure the health and safety of personnel involved in the process. Offer off-site training and education to handle potential exposure of laundry workers

[a] = The list of critical points and controls is not complete, but tailored for the two laboratory animal facilities surveyed in this study.

views on their exposure and work safety, respectively. These questionnaires may even provide useful tips regarding what to focus on or observe during the hazard identification visit. For example, exceptional exposure situations may be reported that would not come to light otherwise.

The analysis of the data collected with the health questionnaire forms a central part of the risk assessment process, because it provides an opportunity for early diagnosis of allergies, and a clear indication of any needs to improve preventive measures and exposure controls in the workplace. For animal allergens, control of exposure can be considered adequate if good practice has been followed and the results of health surveillance indicate a low incidence of laboratory animal allergy [Ryder, 1999]. At the surveyed sites, the prevalence of work-related allergic symptoms (17%) indicated the need to improve controls, even though it was within the range of generally reported prevalence of laboratory animal allergic symptoms (10–32%, [Bush et al., 1998]). Several possibilities for improvement were also detected during the hazard identification visits.

The measurement of allergen levels was included in the risk assessment approach for four reasons: (1) to assess the spread of allergens; (2) to compare allergen levels at various tasks and premises; (3) to offer a reference point if and when allergen risk assessments are conducted again; and (4) to offer a reference point if work practices or ventilation systems are changed. On the other hand, the considerable variability between individuals in magnitude of response to the same levels of allergen exposure hampers the establishment of a threshold level that could be generally applied to prevent adverse health effects [Custovic et al., 2002]. An additional perplexing issue arises from the co-exposure to other agents present in animal facilities, apart from animal allergens, which may provoke similar symptoms or modify the response towards the allergens. First, it has been shown that low concentrations of irritants may enhance bronchial responsiveness to inhaled allergens in sensitized asthmatic subjects [Molfino et al., 1991; Casset et al., 2006]. In laboratory animal premises, significant irritants originate from cleaning and disinfecting agents. Second, exposure to these irritants alone can also predispose individuals to asthmatic symptoms [Medina-Ramón et al., 2005; Massin et al., 2006]. Third, respiratory symptoms following exposure to laboratory animals may be a consequence of exposure to endotoxins, rather than to animal allergens as such [Pacheco et al., 2003]. Despite these confounding factors, few research groups have attempted to address the problematic question of threshold levels of allergens. Regarding sensitization, it has been emphasized that the likelihood of sensitization increases with increasing exposure. Even the lowest exposure levels of rat urinary allergen (0–0.25 ng/m^3) were found to be sufficient to sensitize a considerable proportion of atopic subjects [Heederik et al., 1999]. Similarly, even very low levels of allergen (<5 ng/m^3) can cause symptoms in sensitized persons [Eggleston et al., 1990, 1995]. Sensitized workers were almost four times more likely to go on to develop chest symptoms compared to non-sensitized workers [Nieuwenhuijsen et al., 2003]. Consequently, there are no ''safe'' levels of exposure to animal allergens, but rather, exposure levels should be reduced as much as reasonably practicable to prevent the development of allergies [Nieuwenhuijsen et al., 2003], and any unnecessary exposure should be avoided.

The inclusion of the measurement of few basic environmental parameters in the risk assessment approach serves as a first way of judging the air quality and function of ventilation. The air quality and function of ventilation were generally good at both animal facilities, when the CO_2 level, RH, and temperature were taken into account. The airborne particle concentrations (PM10) were also very low. A problematic issue arose from the observed pressure differences. Animal facilities are regularly designed to protect animals from airborne contaminants. Unfortunately, this enhances the spread and migration of aeroallergens from areas with animals into non-animal areas. In many cases, negative pressure sinks exist in social premises, dressing rooms, and clean corridors. This is bad for aeroallergen control and therefore should be avoided.

Based on observations during the hazard identification visit and comparisons of the existing procedures with generally recommended ones, several ways to minimize exposure to LAA were identified. At the two laboratory animal facilities, these controls included changes in work practices and work premises. An effective exposure control strategy also embraces the use of respiratory protection. But from the worker's perspective, this is probably the most unpleasant type of control. In this study, only 40% of employees used respiratory protection during at least some tasks in the animal premises, and only 9% always used it. The stated reasons for the low frequency included the voluntary aspect, the lack of personal powered air helmets, and the fact that respiratory protectors are uncomfortable, prevent communication, and hamper vision in close tasks. However, respiratory protection can reduce the severity and frequency of symptoms in allergic individuals when total exposure avoidance is not possible [Seward, 2001]. Thus, the use of both respiratory and eye protection could be expected to have a significant effect on individual exposure at the surveyed sites. However, the effectiveness of implementing the suggested control actions can be assessed only by regularly following the prevalence of symptoms. Exposure can be regarded as sufficiently low when a person suffering from laboratory animal allergy is free of symptoms in the absence of medical treatment [Preece and Renström, 2002].

Even though this study was intended to merely deal with occupational risk assessment and management rather than evaluating the effects of specific risk factors on the development of laboratory animal allergies, some findings

may deserve further discussion. Besides exposure, atopic background, sensitization, and pre-existing respiratory or skin disorders, the development of occupational allergy may be promoted by a few additional factors. One such risk factor proposed in the literature is sensitization to cats and dogs [Bryant et al., 1995; Hollander et al., 1996; Heederik et al., 1999; Gautrin et al., 2001]. The possibility of the presence of cross-reactive IgE epitopes arises from the fact that most of the major mammalian allergens belong to the lipocalin family. The major dog allergens, Can f 1 and Can f 2, have been shown to be analogous to the rodent lipocalin allergens [Konieczny et al., 1997; Aalberse, 2000], and the cat allergen Fel d 4 was recently identified as a lipocalin [Smith et al., 2004]. Another proposed risk factor for animal allergy development is smoking, but a definite link has not been proven [Bush and Stave, 2003]. In this study, 94% of the subjects interviewed had pets, and 15% were smokers, which indicates that exposure during off-work hours also has potential to affect the allergy risk, and thus, needs to be assessed separately.

In conclusion, the results showed that this risk assessment approach effectively focused on the critical points where improvements should be implemented to prevent the allergen exposure. The process encompassed several techniques applicable to risk assessment of allergens generally, and it could therefore be applied more widely in risk assessments of other allergens as well.

ACKNOWLEDGMENTS

The authors thank Henri Riuttala for handling the health questionnaire data, and Marja Teikari, M.Sc. and Kirsi Hiltunen, D.V.M. for assistance during hazard identification visits.

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