



Natural Rubber Latex Aeroallergen Exposure in Rubber Plantation Workers and Glove Manufacturers in Thailand and Health Care Workers in a UK Hospital

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Objectives—To estimate personal airborne natural rubber latex (NRL) concentrations for three occupational exposure groups; rubber plantation workers and NRL glove manufacturers in Thailand and health care workers in the UK. To utilise these data to classify the populations into appropriate exposure groups for the exposure-response analysis in the epidemiological study on latex allergy.

Methods—Two rubber plantations (110 workers), three NRL glove manufacturing factories (583 workers) in Thailand and one UK hospital (490 workers) were selected for the study. A preliminary workplace survey was carried out at each workplace in order to assign job titles subjectively in to high, moderate or low exposure groups for the purpose of sample selection. Between 5 and 20% of workers from each group for the three populations were then selected randomly for personal measurement of latex airborne allergens. Personal sampling was conducted using a 25 mm PTFE filter loaded in to an IOM sampling head at 2 l. min⁻¹. NRL aeroallergens were measured by an inhibition assay with NRL-specific IgE antibodies from NRL-sensitised people.

Results—A total of twenty-two personal samples were collected from plantation workers, sixty-one samples from the glove manufacturer employees and twenty seven from health care workers. The highest geometric mean (GM) NRL aeroallergen concentration was found in the glove manufacturing factories (7.3 µg m⁻³), followed by the rubber plantations (2.4 µg m⁻³) and the UK hospital (0.46 µg m⁻³). Amongst the NRL glove factories, the NRL aeroallergen concentrations were highest for those conducting the following tasks; glove stripping, glove inspections and packing of powdered gloves. The GM NRL aeroallergen for these tasks were in the range of 12.9 to 17.8 µg m⁻³.

Conclusions—In the process from tapping and manufacture of latex gloves through to their use the highest exposure to NRL aeroallergens is likely to occur in the manufacturing factories. Exposure to aeroallergens for the plantation workers was considered to be moderate and that of health care workers to be low. © 2000 British Occupational Hygiene Society. Published by Elsevier Science Ltd. All rights reserved.

Keywords: latex allergy; aeroallergens; rubber plantation workers; glove manufacturers; health care; Thailand

INTRODUCTION

Natural rubber latex (NRL) is produced by the

Hevea brasiliensis tree. The cloudy white liquid latex is collected by tapping the tree, it then undergoes a complex coagulation and vulcanisation process involving the addition of various chemical substances which are termed compounding ingredients (Hamann, 1993). Fresh NRL contains 30–40% rubber hydrocarbons and 2–3% proteins. The

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rubber particles contain polymers of cis-1,4 polyisoprene coated with a hydrophilic layer of proteins, lipids and phospholipids (Vandenplas, 1995). Since latex is a complex mixture of chemicals there is evidence that variations in the mixture may change the allergenicity. Processing of latex has been shown to change its protein profile both quantitatively and qualitatively (Alenius *et al.*, 1991; Slater and Chhabra, 1992). Furthermore, patients with history of latex allergy have shown different responses to different glove brands (Turjanmaa *et al.*, 1988; Jaeger *et al.*, 1992). Various serum analysis techniques, including RAST, have been used to identify specific antigenic proteins in natural latex, although the antigens have not been completely characterised. Despite the variability in isolation techniques and antigen source a number of studies show that antigenic proteins with a range of molecular weights of 5–46 kDa (Alenius *et al.*, 1991; Chambeyron *et al.*, 1992; Makinen-Kiljunen *et al.*, 1992). The two major allergens for health care workers are the 4.7 kDa Hev b 6.02 and 14.6 kDa Hev b 1 (Posch *et al.*, 1998).

IgE-mediated sensitisation to latex has recently emerged as an important occupational allergy especially among health care workers. Several reports have documented latex gloves as inducing rhinitis and asthma (Carrillo *et al.*, 1986; Tarlo *et al.*, 1990; Jaeger *et al.*, 1992). More recently Vandenplas and co-workers (1995) reported prevalence of latex-induced occupational asthma to be 2.5% amongst hospital personnel. It is well known that glove-powder particles can act as carriers of NRL allergens which may cause occupational asthma and rhinitis. However, a very limited number of studies of latex allergy have included the evaluation of workplace exposures to latex aeroallergens. Exposure measurements, especially personal samples for latex aeroallergens are essential in ensuring the exposure estimate is as accurate and precise for the characterisation of exposure-response relationships and in the development of Occupational Exposure Limits. Studies on latex allergy which have included exposure measurements have focused on measurements of latex glove total dust (Tarlo *et al.*, 1990), counts of starch particles (Newsom and Shaw, 1997) and more recently the measurement of latex aeroallergens (Swanson *et al.*, 1994; Tarlo *et al.*, 1994; Baur *et al.*, 1998; Liss *et al.*, 1997; Pisati *et al.*, 1998). The studies involving the measurement of latex aeroallergens are summarised below and are all based in hospital environments. No study to date has reported on the measurement of latex aeroallergens in rubber plantation or glove manufacturers.

Swanson and co-workers (1994) collected area samples from various locations in a US medical centre which were quantified using the RAST in-

hibition assay. Twelve personal samples for technicians working in areas where glove use was frequent showed exposures in the range 8–978 $\mu\text{g m}^{-3}$ indicated high variability between worker variance. Furthermore, only 20% of the particles carrying allergens were reported to be respirable. In a more recent Canadian epidemiological study (Liss *et al.*, 1997) twelve personal and 8 area samples were collected in different wards and operating rooms during “regular” use of powdered gloves, latex aeroallergens were quantified using an indirect enzyme linked immunosorbent assay (ELISA) technique. The number of pairs of powdered gloves used on the day of sampling ranged from three to 14 (median 6) and the personal exposures ranged from 5–616 $\mu\text{g m}^{-3}$. The limited exposure data showed no positive correlation between the number of pairs of powdered gloves used and personal latex exposure levels.

Tarlo and co-workers (1990) reported on the incidence of asthma caused by latex in a surgical glove manufacturing plant. Occupational asthma was diagnosed in 6% of the workers on the basis of a combination of latex positive skin prick testing associated with changes in spirometry and non-specific bronchial responsiveness related to workplace exposure. Personal and area air sampling for total dust was performed using PVC filters. The dust levels in the production area were reported to be consistently low and those for the glove inspectors were in the range 0.4 to 5.5 mg m^{-3} . The number of samples and sampling periods were not specified. Pisati and co-workers (1998) conducted a study of latex allergy in a textile factory where latex thread was braided to produce an elasticised ribbon. Measurable latex aeroallergens were found only in settled dust and not in aerolised powder. One of two subjects with latex sensitisation produced a positive bronchial response to a specific inhalation challenge. Other studies involving measurement of latex airborne allergens have concentrated on collecting only area samples to compare concentrations in different hospital laboratories or rooms (Tarlo *et al.*, 1994; Baur *et al.*, 1998).

Although the studies on latex aeroallergens described above provide a good measure of latex exposure by inhalation they are somewhat limited for a number of reasons. The sample size is generally small and different sampling strategies and techniques of measurement have been used which makes the pooling/interpretation of data difficult. In most cases, sampling has been carried out to estimate exposure in the high risk areas using static samples operated at high flow rates (3–375 l min^{-1}). As high sampling flow rates have been used to quantify low levels of latex aeroallergens the inlet characteristics of the sampling devices have not been known and therefore are unlikely to rep-

resent the total inhalable fraction of the latex powder. Finally, only a few of the studies on latex aeroallergen measurements have linked exposure to health effects. Baur and co-workers (1998) showed that symptoms and presence of latex-specific IgE antibodies in subjects (hospital workers) are significantly associated with levels of latex aeroallergens, and based on limited exposure data, a threshold value of 0.6 ng. m^{-3} latex aeroallergens was suggested.

The main objectives of the present study were to: (a) estimate and compare typical personal total inhalable airborne exposure concentration of latex aeroallergens for three exposure groups; plantation workers and glove manufacturers in Thailand, and health care workers in the UK (b) classify the populations into latex aeroallergen exposure groups in order to investigate the association between the potential risk of latex allergy and exposure this part will be reported separately.

METHODS: POPULATION AND SELECTION OF INDIVIDUALS

Rubber plantation workers

There are 10 rubber plantations (total of 475 workers) in Rayong Province employing similar latex extraction techniques. The plantation workers are involved in the tapping and collection of fresh latex. Tapping is the process in which a slice of bark is shaved off to a depth just short of the cambium layer. The fresh latex flows from the cut along a metal spout into a plastic cup. Approximately 6 or 7 h after tapping, the latex is collected from the tree and ammonia added to prevent coagulation of latex. The treated latex is then taken to a factory where it is concentrated and processed. A number of the plantation workers were involved in both the tapping and collection of fresh latex. Since the method of tapping and collection were identical in all 10 rubber plantations, the two plantations (110 workers) located closest to the Mabtaphut Occupational Health Centre (where the investigator was based) were selected for the latex exposure assessment exercise. Twenty percent of all plantation workers (tappers and collectors) were randomly selected from these two plantation sites for the exposure sampling exercise.

NRL examination glove manufacturing factories

Twenty NRL glove manufacturing factories in Rayong and Chonburi were identified from the register kept by the Ministry of Industry, Thailand. From this list 10 factories were excluded on the basis that 5 were surgical NRL glove factories and the other 5 factories had less than the prior criteria of 50 employees. From the remaining 10 examination glove factories, three factories nearest the

Mabtaphut Occupational Health Centre were selected for the exposure sampling study. Two factories were located in Rayong Province and the other in Chonburi Province, Thailand. There were eight glove production lines in factory A (273 workers), two in factory B (80 workers) and five in factory C (230 workers). The three factories manufactured powdered-NRL gloves, however, a small proportion of non powdered-NRL gloves were also manufactured in factories A and C.

The main manufacturing processes used in the three NRL examination glove factories were similar and included four sections:

(a) *Preparation of latex compound.* The ammonium treated natural latex is centrifuged (removing a large percentage of water soluble proteins) and concentrated from approximately 30–60% solids. The concentrated natural latex is then prepared for dipping by the addition of various stabilisers, dispersing agents, vulcanisation agents, accelerators, activators, antioxidants and other compounding ingredients. Approximately 5% of the weight of the finished product are chemicals added during this preparation of the NRL emulsion.

(b) *Production processes.* The prepared latex compound is pumped into a dipping machine. Gloves are formed on glove shaped porcelain moulds (formers) mounted on a continuous chain which moves through the latex dipping tank. The formers are first cleaned, using either acidic or alkaline solutions, and then heated before pre-treatment with a coagulant for example, calcium nitrate. The formers are then dipped into the latex bath and a uniform film is deposited. The coagulant converts the latex from liquid to solid. The formers then pass through warm water baths (leaching tanks) to remove water soluble proteins and excess additives. Wet cornstarch powder is then applied to the outer glove surface to reduce tackiness and friction. Finally the gloves are taken through vulcanisation ovens at approximately 80–90°C. During vulcanisation some of the compounding ingredients undergo chemical reactions and cross link the polymer chains in rubber into a network. In the stripping stage, the gloves are removed manually from the formers. The gloves are then carried by the workers to a rotating dryer (final curing) set at approximately 140°C which completes vulcanisation and powder distribution. To convert these gloves into powder free gloves a chlorination wash is included in the processing. Prior to chlorination the powdered gloves are turned inside-out using a mechanical suction machine operated by one individual. There are five suction machines in factory 1 and one in factory C.

(c) *Finishing processes.* These involve glove inspection, testing, packaging and storage and are all carried out manually. Similar methods of glove

leak testing were used in the three factories; gloves were selected randomly and tested for pinholes by either inflating the glove or filling gloves with water. Packaging of powdered and non-powdered gloves was carried out in separate rooms in factory A but in the same area in factory C.

(d) *Administration.* Workers in this section carry out general office duties including data processing.

An initial survey of the 3 glove factories was conducted in order to classify workers by job title into three exposure groups. Since no previous exposure data were available the classification was based purely on a qualitative assessment of each factory conducted using a checklist. Factors considered in the job classification included; working practices (manual/automated) potential for exposure by inhalation, exposure pattern (continuous/intermittent), use of control measures (engineering and personal protective equipment), duration of work shift, the working environment (process layout, housekeeping, visible powder dust) (Sadhra and Gardiner, 1999). Fifteen percent of workers from each of the three exposure groups in the three factories were selected randomly for personal sampling.

The UK general hospital

The hospital selected for the study was one of the biggest hospitals in Birmingham (UK), with approximately 3000 permanent employees. Data from the hospital Supplies Department were used to estimate the total number of powdered NRL gloves used by each hospital department during the previous 9 months. These data were used to estimate the mean number of glove pairs used in each hospital department per shift per person in order to categorise the departments into three exposure groups for example, high (more than 5 pairs of gloves per shift per person) medium (between 1 and 5 pairs of gloves) and low (less than 1 pair of gloves per person). Since the glove usage in low group was rare, this group was not included in the sampling exercise and hence 10% of the employees from just the high and medium exposure groups were selected randomly for personal sampling. The glove type (powder and non-powdered) and number used over the duration of the sampling period was recorded.

MEASUREMENT METHODS

Air sampling

Personal breathing zone air sampling for NRL aeroallergens was carried out using an IOM sampling head attached to a medium flow AFC 123 (Cassella London Limited, UK) sampling pump. A 25 mm polytetrafluoroethylene (PTFE) filter (pore size of 1.0 μm) supplied by Millipore Limited (Milton Keynes, UK) was used as the sampling media. Based on the inlet characteristics of the sam-

pler and the filter pressure drop a sample flow rate of $2.0 \pm 0.1 \text{ l. min}^{-1}$ was adopted for personal samples which enabled the collection of the total inhalable latex aeroallergen fraction. The sample flow rate was checked using a SKC rotameter (SKC Limited, Dorset, UK) before and at the end of the sampling period. Personal samplers were worn by individuals for approximately 3 h during a work shift. An information sheet was completed for each sample collected detailing the department, task(s) performed and controls used during the sampling period, sampling duration, abnormal activities/conditions and pump flow rates. After sampling, the sample and control filters were labelled and transported to the laboratory at the Occupational and Environmental Medicine Department, National Heart and Lung Institute, The Royal Brompton Hospital, UK for analysis of NRL aeroallergens.

Measurement of airborne latex allergen

Latex allergens were eluted from PTFE filters in 2 ml 0.1 M ammonium hydrogen carbonate buffer containing 0.5% v/v Tween 20 for 2 h. The concentration of latex allergen eluted from the filters was determined using a competitive inhibition radioimmunoassay. A pool of sera from three UK latex sensitised individuals was used to bind to latex coupled on to Sepharose 4B (Pharmacia UK). The serum pool was diluted 1:15 to obtain 10% binding in the RAST assay. The RAST inhibition assay has been found to be a sensitive technique capable of providing reliable result for a range of latex aeroallergen concentrations (Swanson *et al.*, 1994; Pisati *et al.*, 1988). A standard inhibition curve was constructed using a laboratory preparation of a latex allergen, extracted from ammoniated NRL, and ranging in concentration from 0.05 to 100 $\mu\text{g ml}^{-1}$. The 100 μl filter eluate or latex standard was incubated overnight at room temperature with 100 μl latex sensitised serum pool. On the second day 100 μl of 12.5% latex coupled Sepharose was added and left to incubate overnight at room temperature agitating on a shaker. Following washing of the solid phase 50 μl ^{125}I anti-human IgE was added to the tubes and left to incubate overnight at room temperature agitating on a shaker. Following washing the bound ^{125}I anti-human IgE was counted on a Packard model 5005 gamma counter (Packard Ltd, Hampshire, UK). The concentration of the latex aeroallergen in the filter eluates was read from the standard curve. The lower analytical limit of detection for this assay was 0.1 $\mu\text{g/filter}$ (CV = 22%).

RESULTS

Subjective exposure categorisation

Job titles in the factories were categorised as

Table 1. Study population and exposure ranking for NRL examination glove manufacturing factories and rubber plantation workers in Thailand

Workplace	Total no. of workers	Exposure groups ^a	Number in each exposure group
Factory 1	273	High	161
		Moderate	82
		Low	30
Factory 2	80	High	67
		Moderate	7
		Low	6
Factory 3	230	High	138
		Moderate	55
		Low	37
Plantation workers	110	Low	110
Total	693		

^a**High:** Stripping of NRL gloves (132), packaging of powdered latex gloves (114), inspection of powdered NRL gloves (64), oven operation (9), turning gloves inside out (4). **Moderate:** Packaging of non-powdered NRL gloves (27), machine operation and maintenance (45), NRL compound mixing (6), chlorination (19), glove weighing (4) and quality control laboratory work (13). **Low:** Mould cleaning (14), administration (21), warehouse assistants (19), drivers and office cleaners (9).

high, moderate or low exposure using a checklist of factors which may contribute to airborne latex exposure. Table 1 shows the number of workers and categorisation of job titles for the three glove manufacturing factories. The largest proportion of workers in all three factories were ranked in the high exposure group (63%) which included the following job titles: NRL glove strippers, glove packers (powdered gloves), glove inspectors (powdered gloves), turning of gloves “inside out” and oven operators. Job titles classified as involving moderate latex exposure (20%) included production line operators, maintenance workers, glove packers (non-powdered gloves), chlorination operators, glove weighing and laboratory quality control technicians. Mould cleaners, administration staff, drivers and office cleaners were classified in to the low exposure group. The 80 plantation workers (tappers and collectors) were grouped together and classified as the low exposure group, based on the assumption that their

exposure to latex aeroallergens by inhalation was likely to be lower than those of factory production workers.

The UK hospital workers were ranked by department based on number of gloves used per shift (Table 2). The high exposure group was defined as departments where on average more than 5 pairs of gloves were used per person shift per shift. Departments ranked as the high exposure group (48%) included the Accident and Emergency Department, Intensive Care Unit (ITU), Oral Surgery and Operating Theatres. The moderate exposure group (46%) was defined as departments where on average between 1–5 pairs of gloves per person and included Medical and surgical admission wards and The Outpatients department. The Medical records department was included in the low exposure group where latex gloves were used by staff during the occasional reorganisation of filing in a basement store as a means of preventing mechanical injuries.

Table 2. Subjective ranking of exposure for health care workers in a UK hospital

Exposure groups	Department (number of workers)	Total number in exposure group
High	Accident & Emergency Department (52), Intensive Care Unit (51), Oral Surgery Department (17), 10 Operating Theatres (87)	207
Moderate	8 Medical & Surgical admission wards (148), Out Patients Department (45)	193
Low	Medical Records (90)	90
Total		490

Table 3. Summary—natural rubber latex aeroallergen concentrations for the three workplaces

	N ^a	AM	NRL aeroallergens ($\mu\text{g m}^{-3}$)			Min	Max
			SD	GM	GSD		
Glove factories	61	14.98	17.68	7.32	4.27	0.20	98.80
Rubber plantation	21	3.01	2.32	2.36	2.02	0.80	9.11
UK Hospital	27	0.73	0.82	0.46	2.82	0.10	2.74

^aN=Number of personal samples; AM=Arithmetic mean; SD=Standard deviation; GM=Geometric mean; GSD=Geometric standard deviation; Min=Minimum concentration measured; Max=Maximum concentration measured.

Personal sample number

Twenty-one personal air samples (19% of the workforce) were collected from the two rubber plantations in with a mean sampling time of 3.5 h. The majority of the samples (85.7%) were collected during the tapping of latex, with the remainder taken during tapping and collection of latex.

For the NRL examination glove factories, 61 personal samples were collected. Forty samples (10.9%) were collected from the high exposure group, 15 samples (10.4%) from the moderate exposure group and 6 samples (8.2%) from the low exposure group.

A total of 27 personal samples were collected from the UK hospital studied. Twelve personal samples (5.8%) were collected from ITU (high exposure group) and 15 samples (7.8%) from the Medical and surgical wards (moderate exposure group). The mean sampling times for factory workers and hospital staff were 3.1 and 3.6 h respectively. Along with the 109 personal samples collected for the three populations a total of 16 control filters were analysed for latex aeroallergens using the RAST inhibition technique. The latex aeroallergens on control filters were below the level of detection.

Overall NRL aeroallergen concentrations for the three populations

All personal air samples collected from the three workplaces produced NRL aeroallergen concentrations with a non-normal distribution. Therefore

all exposure data were log-transformed with the measures of central tendency and spread given by the geometric mean (GM) and standard deviation (GSD). The highest GM NRL aeroallergen concentrations was found in the NRL glove factories ($7.3 \mu\text{g m}^{-3}$), followed by the rubber plantations ($2.4 \mu\text{g m}^{-3}$) and the UK hospital ($0.5 \mu\text{g m}^{-3}$) respectively (Table 3).

Plantation workers sampled during latex tapping produced GM NRL concentrations of $2.4 \mu\text{g m}^{-3}$ ($n = 18$). The personal samples collected from factory 2 ($\text{GM} = 9.9 \mu\text{g m}^{-3}$, $n = 11$) produced similar NRL aeroallergen concentrations to samples collected from factory 3 ($\text{GM} = 8.6 \mu\text{g m}^{-3}$, $n = 24$), however, personal samples collected from factory 1 were on average 60% ($p = 0.50$) lower than found in factory 2 and 69% ($p = 0.40$) lower than those found in factory 3. The highest GM NRL concentration was obtained for glove stripping ($17.8 \mu\text{g m}^{-3}$, $n = 17$) followed by glove inspection ($15.1 \mu\text{g m}^{-3}$, $n = 10$) and packaging of gloves ($12.9 \mu\text{g m}^{-3}$, $n = 13$).

NRL aeroallergen concentrations by subjective group classification

Table 4 shows the average NRL aeroallergen concentrations for different subjective exposure groups. For the factory processes, the job titles classified as the high exposure group had the highest GM NRL concentration ($15.4 \mu\text{g m}^{-3}$). In contrast, the personal air samples collected for the moderate exposure group had a lower GM NRL

Table 4. NRL aeroallergen concentrations by the degree of exposure based on a prior categorisation

Workplaces	Exposure group	N ^a	AM	NRL aeroallergens ($\mu\text{g m}^{-3}$)			Min	Max
				SD	GM	GSD		
NRL glove factories	High	40	21.03	19.07	15.35	2.46	0.39	98.80
	Moderate	15	3.88	4.07	2.30	3.09	0.24	15.00
	Low	6	2.46	4.13	1.00	4.18	0.20	10.80
Rubber plantations	Low	21	3.01	2.32	2.36	2.02	0.80	9.11
UK hospital	High	12	0.82	0.27	0.44	3.30	0.10	2.74
	Moderate	15	0.74	0.19	0.48	2.60	0.12	2.72

^aN=Number of personal samples; AM=Arithmetic mean; SD=Standard deviation; GM=Geometric mean; GSD=Geometric standard deviation; Min=Minimum concentration measured; Max=Maximum concentration measured.

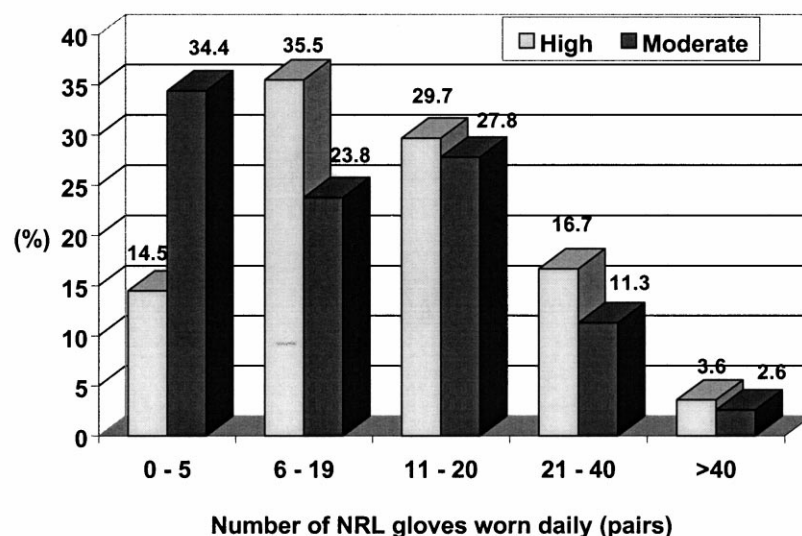


Fig. 1. Number of NRL gloves worn daily for the high and moderate hospital exposure group ($N = 289$).

concentration of $2.3 \mu\text{g m}^{-3}$. The GM NRL aeroallergen concentrations for the rubber plantations workers involved in tapping and collection of latex produced GM exposure levels of $2.4 \mu\text{g m}^{-3}$.

Latex glove usage in the hospital exposure groups

Figure 1 shows the number of NRL gloves worn daily by the 289 health care workers in the high and medium exposure groups. The majority of the workers (35.5%) in high exposure group used between 6–10 gloves per day whereas the majority of workers (34.4%) in the medium exposure group used between 0–5 pairs of gloves each day. The percentage of workers using more than 40 gloves per day for the high and medium exposure groups was

3.6 and 2.6% respectively. The percentage of health care workers wearing latex gloves for more than 2 h per day was similar for both the high and medium exposure groups (approximately 28%). However, 18.1% of workers in the high exposure group and 4.6% of workers in the medium exposure group wore gloves for up to 6 h a day. During personal sampling some of the workers in high exposure group wore non-powdered gloves, however, powdered NRL gloves were worn by all workers sampled in the medium exposure group.

Classification of exposure categories based on the exposure measurements

Using the exposure data shown in Tables 3 and 4

Table 5. Re-classification of job titles using measured NRL aeroallergen concentrations

Concentration categories	Job titles/Departments	N ^a	AM	NRL aeroallergens ($\mu\text{g m}^{-3}$)			Min	Max
				SD	GM	GSD		
High GM $> 5 \mu\text{g m}^{-3}$	Glove strippers	17	25.25	26.84	17.77	2.23	5.49	98.80
	Glove packers (P)	13	18.07	10.03	12.85	3.28	0.39	33.51
	Glove inspectors	10	17.69	10.15	15.08	1.86	5.01	39.80
	Compound mixers	1	15.0	—	—	—	—	—
Moderate GM $1-5 \mu\text{g m}^{-3}$	Glove packaging (NP)	5	3.96	4.07	2.01	4.46	0.24	9.14
	Maintenance	6	2.75	2.30	1.89	2.72	0.57	6.08
	Office workers	6	2.46	4.13	1.00	4.18	0.20	10.80
	Chemists (Q.C)	3	2.28	0.22	2.28	1.10	2.11	2.53
	Latex tappers	18	3.18	2.46	2.44	2.12	0.80	9.11
	Latex tappers & collectors	3	2.00	0.52	1.96	1.28	1.70	2.60
Low GM $< 1.0 \mu\text{g m}^{-3}$	Nurses-ITU (P)	4						
	Nurses ITU (NP)	8	0.71	0.82	0.39	0.50	0.10	2.46
	Nurses—Medical & surgical admission wards	15						

^aN = Number of samples; AM = Arithmetic mean; SD = Standard deviation; GM = Geometric mean; GSD = Geometric standard deviation; Min = Minimum concentration measured; Max = Maximum concentration measured; P = Powdered; NP = Non-powdered.

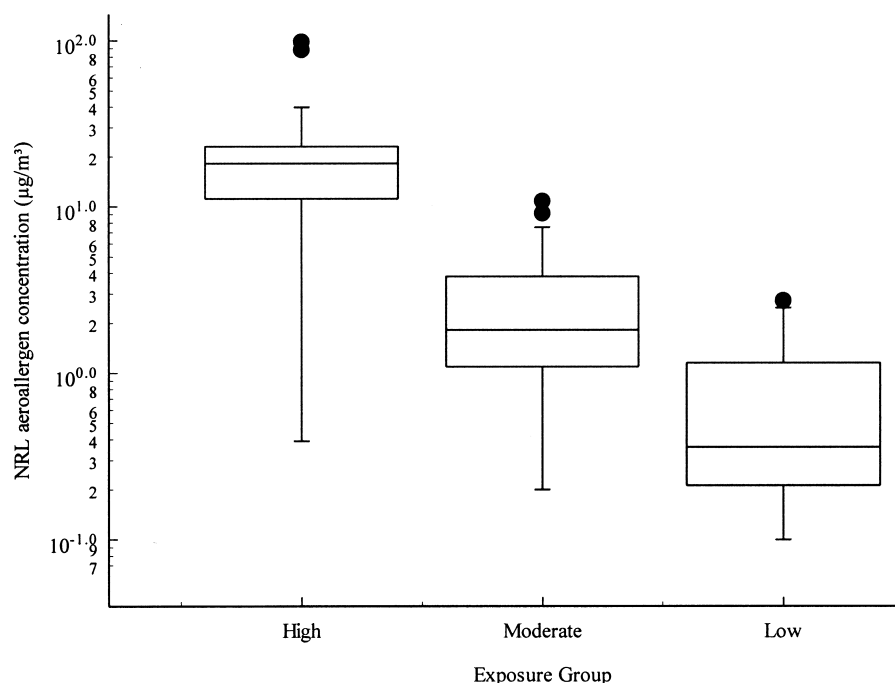


Fig. 2. Box-whisker plots of NRL aeroallergen concentration for the reclassified exposure groups. Comparison of NRL aeroallergen concentrations of samples taken from the exposure groups. The Y-axis (log scale) represents the NRL aeroallergen concentrations. Results are displayed as box-whisker plots where the upper and lower limits of the boxes represents the 25th and 75th percentiles, the whiskers extends to 1.5 times the interquartile ranges. Observation outside this range are marked as dots. The median values are indicated by the lines in the boxes.

the three populations were reclassified in to three exposure groups (Table 5). The GM NRL concentrations for each job title were used and groups were defined as those with a GM of less than $1.0 \mu\text{g m}^{-3}$ (low exposure), 1.0 to $5.0 \mu\text{g m}^{-3}$ (moderate exposure) and greater than $5.0 \mu\text{g m}^{-3}$ (high exposure). The distribution of NRL aeroallergen concentrations for the exposure based classification is shown in Fig. 2.

DISCUSSION

The prevalence of latex allergy has increased in the last 10 years and has become an important occupational health hazard especially amongst health-care workers. Despite latex aeroallergens being linked with the development of allergic diseases, only in a limited number of studies has the measurement of latex aeroallergens been included. Furthermore, different techniques for the sampling and analysis of latex aeroallergens have been used as no standard method is currently available.

To date there have been no studies on the evaluation of NRL aeroallergens in NRL glove manufacturing factories or rubber plantations, but cases of occupational asthma in a latex glove manufacturing factory have been reported (Tarlo *et al.*, 1990). In this study, an initial workplace survey of two rubber plantations (110 workers), three NRL glove

manufacturing factories (583 workers) in Thailand and UK health care workers (490 workers) was conducted in order to assign job titles subjectively as high, moderate or low exposure. The subjective classification of exposure groups was found to be in good agreement with the measured latex aeroallergens levels.

A total of 109 personal samples for latex aeroallergens were collected for the three populations. The NRL aeroallergen levels were found to be higher in the glove manufacturing factories and rubber plantations than those measured in the UK hospital. However, it is important to note that the serum used for the RAST inhibition assay was obtained from latex sensitised health care workers based at the UK hospital. Thus, the pooled NRL-allergic sera may have missed allergens unique to the Thai latex workers, resulting in underestimation of NRL aeroallergens for this population.

The GM aeroallergen concentration determined in the three gloves manufacturing factories was $7.3 \mu\text{g m}^{-3}$ with little inter-factory variance. For all three factories, the highest NRL aeroallergens concentrations were obtained for workers involved in handling powdered gloves, for example, stripping gloves of moulds, inspecting gloves for pin-holes by inflating them and packing of gloves. This finding is not surprising since powder dust was visible on work surfaces, the floor and on workers clothing.

On average, four-thousand pairs of gloves were inspected per shift per person accounting for the high levels measured for the glove inspectors. Ventilation in the factories was provided by ceiling and wall mounted fans with no local exhaust ventilation. Approximately 28% of workers in the three glove production factories used half-face disposable dust masks.

Packaging of non-powdered gloves produced low levels of NRL aeroallergens. It is likely that other powdering agents such as the calcium carbonate used in the coagulating process remain deposited on the gloves and that this agent can also act as an NRL allergen carrier, similar to cornstarch. Measurable amounts of NRL aeroallergens were also detected in offices located in a separate building away from the main glove manufacturing plants. Thus, workers not involved directly in the production work may also be exposed to NRL aeroallergens. Trace levels of NRL aeroallergens may be transported to the offices on clothing, equipment and footwear of workers moving between the production plant and offices.

The average level of NRL aeroallergens in the rubber plantations was $2.36 \mu\text{g m}^{-3}$. This level is comparable with NRL aeroallergen levels measured for non-powdered packaging stations, laboratories and offices in the glove factories. Latex aeroallergens in the rubber plantations may be generated by volatilisation of the fresh latex. NRL is a cytoplasmic system consisting of particles of rubber dispersed in an aqueous serum phase and it is often unstable without a preservative. Once it has become unstable, volatile fatty acids may be given off as a vapour enabling NRL allergens to become airborne. Another explanation for this may be that the process of removing the bark could produce some rubber dust which may act as a carrier for the NRL allergens.

For the UK hospital, the mean level of NRL aeroallergens ($0.46 \mu\text{g m}^{-3}$) was similar to levels reported in other studies of health care workers (Baur et al., 1993 and Swanson et al., 1994) but significantly lower than the levels measured in the glove production factories. This may be explained by the fact that a much larger number of gloves are handled by the factory workers, especially those involved in the stripping, inspection and packaging of gloves. The maximum number of NRL gloves used by the nurses, even in the high exposure departments, was 40 pairs per person per shift. Although the majority of workers in the high exposure group used more gloves per shift than those in the moderate exposure group, aeroallergens levels for both groups were similar. This may be explained by the fact that different glove types and brands were used by the nurses in the two exposure groups during the sampling period. A number of nurses in the high exposure group had experienced symptoms

related to the use of powdered NRL gloves and used non-powdered gloves during the sampling period. The number of pairs of powdered gloves reported as used during the sampling period ranged from one to 16. The correlation (Pearsons) between the number of pairs of powdered gloves used during the sampling period and personal latex exposure was found to be positive ($r = 0.79$, $n = 19$). In previous studies, this correlation has been examined for smaller sample sizes and found not to be positive.

The large exposure variation within the defined groups and job titles underlines the complexity of exposure assessment in the three populations studied. Airborne exposure levels in the latex glove manufacturing factories appear to be dependent mainly on glove type being manufactured, processing conditions, individual work practises, the local environment, the effectiveness of respiratory protective equipment used and production rates. Amongst the health care workers the level of airborne exposure appears to be dependent largely on number of latex gloves used by the individual. Other factors which need to be investigated further include glove type (brand), frequency and duration of glove use, number of gloves used by colleagues working in the same environment and the effectiveness of control systems.

The size of particles which carried the allergens in the samples taken from the glove factories, the rubber plantation and the UK hospital was not measured. Swanson et al. (1994) found that the majority of particles (more than 80%) carrying allergens were $7 \mu\text{m}$ or larger and, therefore, less likely to reach the lower respiratory tract. Nevertheless, lower respiratory symptoms such as asthma were reported. Cornstarch used by the manufacturers of NRL products as a donning powder is a heavily cross-linked carbohydrate, with particle sizes ranging from 1 to $3 \mu\text{m}$ in diameter. There is only a slight increase in the mean diameter of the cornstarch particles when they are exposed to moisture, and cornstarch powder with this range of diameters can transport NRL aeroallergens into an individual's respiratory tract (Tomazic et al., 1994).

The exposure data and the categorisation of exposure groups presented in this paper for the three populations studied is being used currently to investigate whether there is an association between exposure and the prevalence of NRL sensitisation amongst the three study groups. Information on the prevalence of latex sensitisation for the three populations has been collected using questionnaires, skin prick tests and the measurement of NRL-specific IgE antibodies. The findings will be presented in a separate publication.

Although different studies on the measurement of latex aeroallergens have used different assays, the NRL aeroallergen levels measured in the UK hospi-

tal were found to be similar those reported in other studies. The levels were similar in different clinical areas. This group has been designed as "low" exposure. The NRL aeroallergen levels in the NRL glove manufacturing factories were the highest ever reported. The high exposure tasks included the stripping and inspection of NRL gloves, powdered glove packaging and latex compounding mixing. Other tasks in the glove manufacturing factories and tappers and collectors had relatively more modest an exposure.

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