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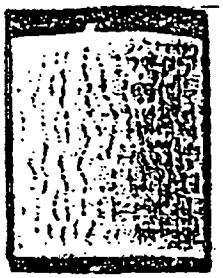

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THE DETERMINATION OF RESPIRABLE PARTICLES IN TALCUM POWDER

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Abstract—The mass concentrations of potentially respirable particles produced during routine application of talcum powder were determined. Tests were conducted both on adults exposed to talc over the whole body area and infants exposed in the napkin area. The total exposure time, the amount of powder used and the average talc concentration in the air in the region of the nares were measured. These average talc concentrations were compared with the threshold limit value (TLV) which is considered safe for industrial talc workers, and also with chronic exposure levels for experimentally exposed hamsters in which no adverse reactions were seen. The average adult exposure was 600 times less than the TLV and 500 times less than the level at which no adverse effects were seen in chronically exposed hamsters. Likewise, the average infant exposure was over 2000 times less than the TLV and over 1800 times less than the hamster no-effect level.

INTRODUCTION

When finely divided powder is dispensed from a container with a sprinkle-hole cap, airborne particles are formed in the environment of the user. Some will be 'respirable particles', but they will be at a relatively low concentration and exposure will be of short duration because of settling and dispersion. One example is the particles produced during the normal use of baby or body talcum powders.

The mass concentration of respirable particles produced during the powdering of a baby or an adult cannot be effectively measured with standard dust-sampling equipment which is used to accumulate and sample particles from more stable atmospheric areas such as mines or factories (Ayer, Sutton & Davis, 1968; Cochrane, 1972; Lippmann, 1970). The short duration and low concentration of particles produced during a single application of talcum powder poses problems and one purpose of this study was to design both the method and equipment needed to overcome these problems.

A 'respirable particle' has the potential to reach and be deposited in the lung. The probability of this occurring depends upon the aerodynamic equivalent diameter (AED) of the particle. The AED of a particle is defined as the diameter of a unit density sphere having the same aerodynamic qualities as the particle in question. In this study, a respirable particle was defined as having an AED of 10 μm or less (Ettinger, Partridge & Royer, 1970; Seltzer, Bernaski & Lynch, 1971).

A second objective of this study was to compare the average talc exposure of infants and adults to two quite different published acceptable levels of talc inhalation. Firstly, the data was compared to 3 mg/m^3, the permitted threshold limit value—time weighted average (TLV—TWA) as listed by the American Conference of Governmental Industrial Hygienists (1977). Secondly, the average talc exposures were compared to the respirable talc concentration of 8 mg/m^3 reported by Wehner *et al.* (Wehner, Zwicker & Cannon, 1977a) in an inhalation study, at which no adverse reactions were seen in chronically exposed hamsters. The TLV—TWA cited above is the weighted average concentration for a normal 8-hr working day in a 40-hr working week, to which industrial workers may be exposed safely.

EXPERIMENTAL

Equipment. Two pieces of specialized equipment were required to measure the respirable particle concentration. A prefilter to simulate the human respiratory tract by dividing the talc into respirable and non-respirable particle fractions was needed. A mass-monitoring device to remove the respirable particles from the air stream and weigh them in a very short time interval was also essential.

A 10-mm nylon cyclone was used to simulate the particle fractionation system of the human respiratory system (Caplan, Doemeny & Sorenson, 1977; Seltzer *et al.* 1971). The percentage of particles that can penetrate into the lung increases with decreasing aerodynamic equivalent diameter until other physical factors take effect and the percentage penetration reaches a plateau.

The American Conference of Governmental Industrial Hygienists and the AEC Los Alamos Scientific Laboratory have established a standard respirable dust size fractionation curve (Ettinger *et al.* 1970; Seltzer *et al.* 1971). Investigators have shown that the 10 mm nylon cyclone operating at 1·7 litres/min flow rate, has a collection efficiency for respirable particles which matches this standard (Caplan *et al.* 1977; Seltzer *et al.* 1971).

The nature of this study required mass measurement of respirable powder in quantities as low as 0·1 μg in a relatively short time span sometimes as low as 2 sec. The Thermo Systems, Inc. (TSI; St Paul, MN) quartz-crystal mass monitor Model 3210A, designed for general particle monitoring appli-

cations, was chosen for this purpose. This modular unit contains a quartz-crystal sensor nonpulsing vacuum pump to provide airflow to the 10 mm cyclone and a strip-chart recorder.

The cumulative mass of respirable particles which were fractionated by the cyclone was collected on the quartz crystal and recorded every 2 sec. Total accumulations as low as 0·1 μg could be read directly from the strip-chart-recording. Measurements were made by sampling the air immediately adjacent to the nasal openings during powdering using the 10 mm nylon cyclone.

Before initiation of the study, the collection efficiency of the TSI Mass Monitor for talc particles of a respirable size was tested using the following procedure. A low density talc airborne concentration (less than 5 mg/m³ respirable particle content) was generated in a closed chamber and sampled with the 10 mm nylon cyclone prefilter at the preferred flow rate of 1.7 litres/min. The air stream containing the respirable talc particles was then divided, with a precision splitter, and 1 litre/min passing to the mass recorder and 0·7 litres/min passing to a 13 mm membrane filter of 0·8 μm pore size. The mass recording readout on the instrument was then compared with the mass collected on the membrane filter and weighed on an electromicrobalance.

It was determined that good agreement (within 2%) could be obtained between recorder and gravimetric readings if the mass loading on the quartz-crystal sensor was kept below 15 μg talc. As the crystal mass loading increased beyond 15 μg, the talc particle deposition efficiency fell off and disparity between recorder reading and gravimetric readings increased. In this study, mass accumulations were below 15 μg for all individual tests.

Baby-powdering procedure. A group of forty-eight mothers with infants under 16 months of age, who regularly used a leading brand of talcum powder* at nappy changing time, participated in this phase of the study. Mothers were supplied with a 36 in high changing table and mat, an appropriately sized disposable napkin, and powder in its commercial 14 oz twist-top canister. All six canisters used were from the same lot.

Each mother was instructed to remove the napkin on her own infant, powder the napkin area as she normally would, and place a new napkin on the baby. When the task was completed, she was instructed to pick up her child signalling an end to the nappy-changing procedure. This procedure was repeated three times in succession for each mother–infant pair, the results being averaged. Determinations of total exposure time, amount of powder used, and average talc concentration in the air at the level of the infant's nares were made. Before running each test, the area was vacuumed to remove airborne particles left from the previous test.

To sample the airborne powder, the cyclone inlet was held next to the baby's head approximately 4 in above the surface of the changing mat (Fig. 1). Total exposure time was defined from the first shake of powder to the end of nappy changing. The investigations were carried out over two four-day time periods.

Adult powdering procedure. Twenty-three adult males and twenty-one adult females who routinely used the same leading talcum powder daily were tested in this phase of the investigation. All normally applied the powder directly to their bodies or to their hands before application to the body. Subjects were asked to shower, towel dry, enter a small (3·75 × 6·5 × 7 ft) anteroom, and apply powder from a new 14 oz twist-top canister to their bodies in their normal manner. This anteroom procedure assured a constant environment for the equipment, which is sensitive to high levels of humidity and to the temperature and humidity fluctuations that could occur with the opening and closing of the bathroom door. On entering the anteroom, each subject donned a headband with the attached cyclone which was positioned at the level of the individual's nose (Fig. 2).

Using a stopwatch, each subject was timed for the duration of the powdering procedure from the first shake of the canister to the moment body powdering was completed and the subject left the powdering anteroom. Again, the total exposure time, quantity of powder used and average talc concentration in the air at the level of the adults' nares were determined. The investigations were carried out over two four-day time periods.

*Johnson's Baby Powder®.

RESULTS

The results of the trials are summarized in Table 1. Frequency distributions of exposure concentrations for both infant and adult data are given in Tables 2 and 3. For infant exposures the time-weighted average (±SD) was 0·095 ± 0·039 mg.min/m³ and for adult exposure, the time-weighted average was 1·727 mg.min/m³.

The exposure factor is defined as the number of times by which the TLV—TWA for talc workers

Table 1. *Exposure of infants and adults to respirable talc particles*

	No. of subjects	Weight of talc used (g)	Exposure time (min)	Concentration* (mg/m³)
Infants†	48	0·88 ± 0·63	0·52 ± 0·17	0·19 ± 0·084
Adults	44	8·84 ± 8·32	1·23 ± 0·55	2·03 ± 1·49

*Average concentration, in mg/m³, was calculated by dividing the weight of respirable particles collected by the volume of air sampled for each subject, and averaging the results. The flow rate to the mass monitor was 1 litre/min; therefore, the exposure time in minutes was equal to the air volume in litres.

†Because of the very low airborne respirable concentrations during the infant powdering, it was necessary to use the mean of three consecutive tests on each infant.

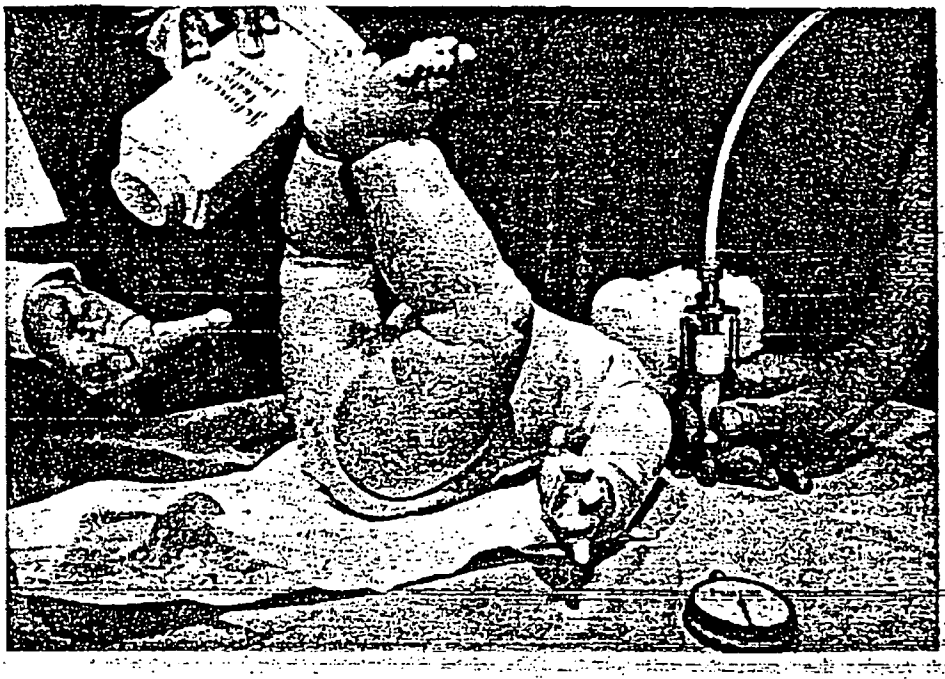

Fig. 1. Simulation of particle collecting cyclone positioned at the level of baby's nares during nappy-change powdering.

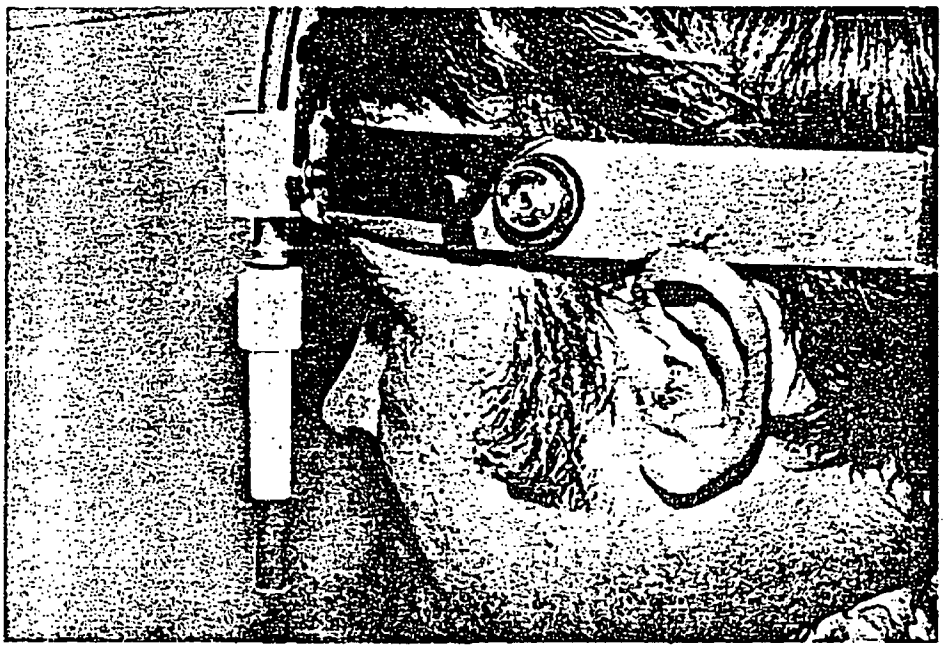

Fig. 2. Particle collecting cyclone attached to a headband and positioned at the level of the subject's nares during adult whole-body powdering.

Table 2. *Frequency distribution of infant exposure (mg.min/m³) to respirable talc particles*

Exposure levels*† (mg.min/m³)	No. of infants within exposure level	Percentage of infants within exposure level
0·10–0·19	4	8·33
0·20–0·29	15	31·25
0·30–0·39	19	39·58
0·40–0·49	6	12·50
0·50–0·59	3	6·25
0·60–0·69	0	0·00
0·70–0·79	1	2·08

*Data for the mean of three exposures.
†The time-weighted average (±SD) for three exposures was 0·285 ± 0·117 mg.min/m³; the average for one exposure was 0·095 ± 0·039 mg.min/m³. Because these results approximated a normal distribution, parametric statistical procedures were applied to the raw data.

Table 3. *Frequency distribution of adult exposure (mg.min/m³) to respirable talc particles*

Log$_e$* exposure levels (mg.min/m³)	No. of adults within exposure level	Percentage of adults within exposure level
−1·80 to −1·36	1	2·27
−1·35 to −0·91	3	6·83
−0·90 to −0·46	4	9·09
−0·45 to −0·01	3	6·82
0·00–0·44	9	20·45
0·45–0·89	9	20·45
0·90–1·34	6	13·64
1·35–1·79	5	11·36
1·80–2·24	2	4·55
2·25–2·69	2	4·55

*The adult exposure data closely approximated a log-normal distribution. Therefore, a log$_e$ transformation was made to "normalize" the data and parametric statistical procedures were applied to the transformed data. The log$_e$ of the time-weighted average exposure (±SD) was 0·5464 ± 0·9339 and antilogs allowed estimation of the original population, the time-weighted average being 1·727 mg.min/m³.

exceeds the time-weighted average concentrations determined for infants and adults in this study. Exposure factors were calculated by dividing the weekly TLV concentration for talc workers by the calculated weekly concentrations for either infants or adults. The time-weighted exposures for infants and adults were converted to weekly exposure concentrations by multiplying by the number of applications per day and by seven (days/week) and dividing by 60 (min/hr). J. N. Sivertson (unpublished data, 1976) has shown that mothers, who are regular users of baby powder, powder their infants (1 to 24 months old) an average of five times/day. One powder application each day was assumed for adults. The average values obtained were 0·055 and 0·20 mg.hr/m³ for infants and adults respectively. The corresponding 90% tolerance limits for the 95th percentiles were found to be 0·099 and 1·23 (Diem, 1962). The talc TLV of 3 mg/m³ was converted to a weekly exposure for the talc workers assuming a 40-hr working week. This figure of 120 mg.hr/m³/wk was then divided by the average infant or adult weekly time-weighted values, and the exposure factors were calculated to be 2182 for infants and 600 for adults. Exposure factors calculated from the 90% tolerance limit for the 95th percentile for each group were 1212 and 98 respectively.

The above exposure data were also compared with the data of Wehner (Wehner *et al.* 1977a) from a hamster inhalation study. In this case the no-effect level for the hamsters 100 mg.hr/m³/wk exceeded the exposure levels of the infants and adults 1818 and 500 times respectively.

DISCUSSION

The background level of respirable particles in the area of the tests was monitored and found to be less than 0·003 mg/m³. It was determined that background particles would increase the concentration by a maximum of 4% under the most severe conditions encountered, e.g., 1·5 min of exposure and 0·1 μg total respirable mass collected. Therefore, background was not considered in calculating the exposure concentrations.

It was interesting to observe the different methods of powder application; three-quarters of the mothers applied the powder directly to the baby's body and the remainder placed the powder in their hands and then on the baby. One mother applied the powder to the napkin. Analysis of data resulting from the various application methods showed no significant differences in any of the monitored parameters.

The average adult exposure concentration (2·03 mg/m³) was over ten times greater than that found for infants (0·19 mg/m³). Adults were also exposed for a longer time period, 1·23 min compared with 0·52 min for the infants. On average, men tended to powder in a shorter time than women, but to use more powder and create greater airborne respirable particle concentrations.

It is noteworthy that Wehner *et al.* (1977a) were unable to produce any talc-related toxicity in hamsters with extensive exposures to 8 mg/m³/wk of respirable talc. The same group later demonstrated that although the talc deposited in the deep lung, it was cleared with a biological half-life of 7–10 days (Wehner, Wilkerson, Cannon, Buschbom & Tanner, 1977b).

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