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Dust emission during cutting of polyurethane-impregnated bandages

R. WYTCH, I.K. RITCHIE*, R. CLAYTON[1], D. W. GREGORY[2] and D. WARDLAW*

Department of Biomedical Physics and Bioengineering, University of Aberdeen

**Department of Orthopaedics, Aberdeen Royal Infirmary*

Abstract

The airborne dust generated when cutting splinting bandages represents a potential respiratory hazard, particularly to those who regularly remove casts with a power saw. Plaster of Paris (POP) dust is already classified by the Health and Safety Executive as a nuisance dust.

This paper reports on a study to determine the nature, size and concentration of dust produced when cutting polyurethane (PU) impregnated bandages using a power saw. It has been shown that, under severe conditions PU bandages produce lower airborne dust concentrations than POP bandage but that all of the bandages tested produced particles small enough to reach the final divisions of the lung. It is therefore recommended that a dust extraction unit be used when cutting all types of bandage.

Introduction

PU impregnated fabric bandages are becoming increasingly popular in the management of fractures owing to their high strength/weight ratio, durability and ease of application. Currently the most popular fabric is knitted continuous filament glass fibre, although cotton and polyester fabrics are also used (Wytch et al, 1987).

Plaster room personnel have expressed concern over the potential hazards resulting from the normal use of these materials (Wytch et al, 1988). These hazards include the isocyanates and other chemicals in the resin, the potential fire risk associated with polyurethanes in general (Ritchie et al, 1988), and the effects of the dust produced when casts are removed with an oscillating saw. Many plaster room staff experience irritation around the wrists, neckline and on the face during cast removal.

The high levels of POP dust generated during cutting with a power saw can be observed in every hospital casting room. There are however no published results on dust levels for POP or PU impregnated fabric bandages reported in the literature.

This paper reports on an investigation carried out to determine the airborne dust concentration, the nature and size of the particles produced during cutting of both POP and PU bandages using a power saw. The potential risk from airborne dust when cutting these materials is assessed.

Dust is defined by the Health and Safety Executive (MDHS 14, 1986) as an aerosol of solid particles, mechanically produced, with individual particle diameters 0.1um upwards. Respirable dust is that fraction of the total dust cloud capable of reaching the final lung divisions and is defined by the "Johannesburg Curve" (International Conference on Pneumoconiosis 1961), as any particle of less than 7um in diameter. For the purposes of optical counting, dust samples were classified as particles or filaments. Particles are defined as being essentially spherical in shape whilst filaments have a length to diameter ratio of greater than 3:1. The fate of any particle after entry to the human respiratory system depends on the nature and size of the particle. Occupational exposure limits have been defined for many individual dusts in Health and Safety Executive (HSE, 1987) Guidance Note

All correspondence to be addressed to Mr. R. Wytch, Department of Biomedical Physics and Bioengineering, University of Aberdeen, Forresterhill, Aberdeen AB9 2ZD, Scotland.

[1]TBA Industrial Products, Rochdale, Lancashire.

[2]Director, Electron Microscopy Unit, Department of Bacteriology, University of Aberdeen.

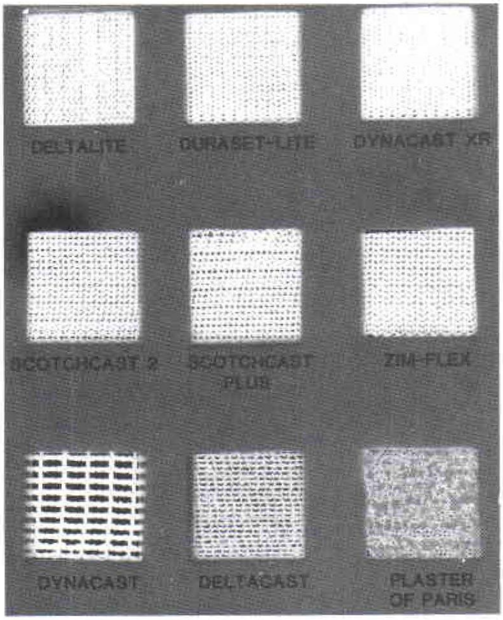

Fig. 1. Materials tested for dust production.

Table 1. Materials tested for dust production.

Type of bandage	Product name
Knitted glass fibre impregnated with polyurethane resin	Delta-lite Dynacast XR Duraset-lite Scotchcast 2 Zimflex Scotchcast Plus
Knitted polyester impregnated with polyurethane resin	Dynacast
Knitted cotton impregnated with polyurethane resin	Deltacast
Leno weave cotton impregnated with plaster of Paris	Gypsona

EH 40/88. Plaster of Paris dust has been assigned a recommended exposure limit of $10 mg.m^{-3}$.

Man-made mineral fibre (including glass fibre) has an exposure limit of $5 mg.m^{-3}$. Both these limits are in terms of an 8 hour time-weighted average exposure. No short term exposure limit has been specified for either substance but it is recommended by HSE that in such instances a value of three times the 8 hour figure be used for control purposes to apply to 10 minute periods. Thus values of 30 and $15 mg.m^{-3}$ respectively can be taken to apply.

Materials and methods

Sample preparation

Eight PU impregnated fabric bandages and POP bandage (Table 1 and Fig. 1) were compared for dust emission during cutting with an oscillating power saw. Bandages of each material 10cm (4 inch) wide were activated according to manufacturers instructions and formed into slabs 7 layers thick and 50cm long. All slabs were prepared in an identical fashion by one of the authors (RW). The slabs were cured for 72h under standard laboratory conditions, 22(+/−1) degrees Celsius, and a relative humidity of 65% (+/−2%) before testing. Each slab was mounted on a foam block covered with fresh stockinette to simulate normal cutting conditions and secured with adhesive tape at either end. Three samples of each material were tested. The results for the six glass fibre bandages have been averaged.

Test environment

Tests were carried out in a specially prepared room 4 × 3 × 3m with a filtered air inlet in one corner and a high powered suction unit (Dronsfield) in the opposite corner, capable of providing 21 complete air changes per hour. Prior to each test the room surfaces were thoroughly cleaned with an industrial vacuum cleaner and purged using the Dronsfield suction unit until the particle count measured less than 0.3 particles per metre recorded by an electronic particle counter (Royco model 218).

Test procedure

A 10 minute test period for each sample was chosen to represent intentionally severe conditions when compared to a typical time of 5 minutes for the removal of a below-knee cast. Three samples of each material were subjected to 10 minutes of continuous cutting with an oscillating saw and dust samples collected. To provide uniformity in cutting technique all samples were cut in an identical fashion with a series of parallel cuts by one of the authors (IKR). A new P.T.F.E.-coated chrome steel saw blade (Desoutter 16882) was fitted to the power saw (Desoutter C.C.1) prior to cutting the first sample of each material.

Dust sampling

Three types of dust sample were taken during each test;

(a) personal sampling for total dust.
(b) fixed position sampling for total dust and
(c) fixed position sampling for subsequent particle identification and size distribution using light and scanning electron microscopy (SEM).

The personal dust sampling head was attached to the lapel of the operator, and the fixed position dust sampling head was positioned directly in front of the operator 1m away at head height. In each case an open 25mm dia. sampling head was employed with air being drawn through a glass fibre filter at a rate of 40 l. per. min. using mains-powered rotary vane pumps to give a smooth airflow.

The fixed position sampling was in accordance with the HSE recommended method (MDHS 14) but the personal sampling was non-standard in that the airflow was 20 times the 2 l. per. min. recommended. This was necessary to enable a significant weight of dust to be collected on the sample filter in the 10 minute period. Also open faced filter holders were used instead of the modified U.K.A.E.A. sampling head specified by MDHS 14. Consequently the concentration values obtained from the personal sampling relate to total dust and not total inhalable dust (the latter being used normally for reference to occupational exposure limits). However, it is considered that the results obtained give a good indication of the relative dust emissions of the various materials.

Two further samples were taken to the right of the operator also 1m away at head height, one for particle size distribution using light microscopy and the other for particle identification using SEM. One sample head was fitted with a cellulose membrane filter with a pore size of 0.8um through which air was drawn at a rate of 10 l. per. min. for all materials except POP for which the rate was reduced to 2 l. per. min. to allow for the greater volume of dust produced. The second sample head utilized a polycarbonate membrane filter with a pore size of 0.8um and a flow rate of 3 l. per. min. for all materials except POP when a reduced rate of 2 l. per. min. was used to allow for the greater volume of dust produced by POP.

Both samples were taken throughout the total test period of 30 minutes for each type of material.

Evaluation techniques

a) Gravimetric — Personal and fixed position dust samples were evaluated using simple gravimetric techniques conforming to those given in MDHS 14. Airborne dust concentrations are determined by passing a known volume of contaminated air through a filter of predetermined weight. By re-weighing the filter at the end of the sampling period, the quantity of material is determined by the difference in weight. The concentration of total dust was found by dividing the weight gain by the volume of air passed through the filter and is quoted in mg. m^{-3} of air.

b) Particle size distribution — Standard light microscopy techniques were used to determine the size distribution of 200 particles collected on cellulose membrane filters. The cellulose membrane filter was rendered transparent by exposure to a stream of acetone vapour and the deposit sealed by the addition of a cover glass secured by Glycerol Triacetate. These were examined under bright field conditions at an overall magnification of 400x. Scanning electron microscopy (SEM) was used at magnifications of up to 9,900x to determine the nature and shape of a random selection of particles collected on a polycarbonate membrane filter. Filament length determination was carried out separately from the 200 particles. Fifty filaments with a diameter of 6–8um were sized.

SEM methods

Samples of resinated and un-resinated knitted glass fibre fabric bandage, or segments of polycarbonate filter with attached dust particles were mounted on stubs with colloidal silver adhesive, sputter-coated with platinum (20nm for bandage samples, 15nm for filter samples) and examined in a Jeol JSM — 35CF scanning electron microscope (at 5kV for material samples, 10 kV for filter samples)

Results and discussion

Figure 2 shows scanning electron micrographs of a typical knitted glass fibre fabric un-resinated and resinated.

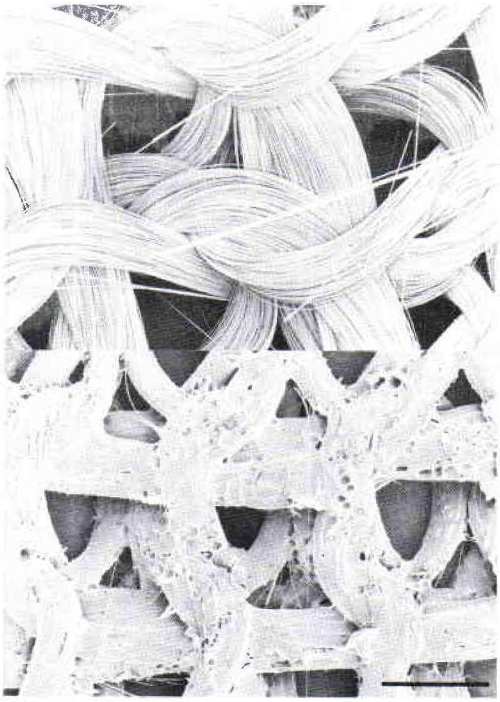

Fig. 2. Top, scanning electron micrograph showing the knitted pattern of the glass fibre bandage. Bottom, the same bandage impregnated with polyurethane resin (Bar line for both figures = 1mm).

The results for personal and fixed postition dust sampling are shown in Table 2. This shows that in this case the personal sample was always higher than the fixed position sample and serves to illustrate that the personal sampling is a more critical measure of the airborne dust level to which a person is exposed.

Both personal and fixed position dust levels for the PU impregnated materials were significantly lower than for POP. It is interesting to note that no significant level of dust was recorded for the Cotton fabric (Deltacast) and the Polyester fabric (Dynacast). However, there were significant levels of dust produced for all of the glass fibre bandages with the exception of Scotchcast Plus.

Table 3. Ratio of personal dust concentration/length of cut and ratio to POP

Material	Personal total dust concentration / length of cut	Ratio to POP
Plaster of Paris	0.026	1.00
Glass fibre bandage	0.005	0.19
Polyester	‹0.002	‹0.08
Cotton	‹0.002	‹0.04

When the results from the personal dust concentrations (Table 2) for the different types of fabric are compared with the dust produced for each centimetre (cm) of bandage cut (Table 3), it can be seen that the same rank order is obtained.

The determination of particle size distribution for plaster of Paris was not possible since the dust samples collected were too dense. This was in spite of reducing the air flow rate through the sampling head to 2 1. min−1. However from previous (unpublished) work by the authors it was established that the particles from POP dust showed a similar size distribution to the synthetic bandages.

The electron micrograph in Figure 3, shows an example of the quantity and types of dust collected on the polycarbonate filters. These were either glass fibre filaments or particles of resin, or aggregates of resin and glass fibre.

From the particle size distribution shown in Figure 4 it can be seen that 90 per cent of the glass fibre particles to 98 per cent of the cotton and polyester fabric bandage particles were respirable if the upper limit for respirability is taken as 7um (Orenstein, 1960).

The upper limit for respirability of filaments has been taken as 3um diameter (W.H.O. 1985). All the filament diameters were found to be 6um or greater. The average filament length

Table 2. Airborne dust concentrations and length of material cut

Material	Airborne dust concentration (mg. m^{-3}) Personal	S.D.	Fixed position	S.D.	Average length of cut (cm)
Plaster of Paris	35.5	1.5	17.1	2.9	823
Glass fibre bandage	3.9	1.2	1.3	0.8	774
Polyester bandage	n/s	—	n/s	—	532
Cotton bandage	n/s	—	n/s	—	1103

n/s — not significant
S.D. Standard Deviation

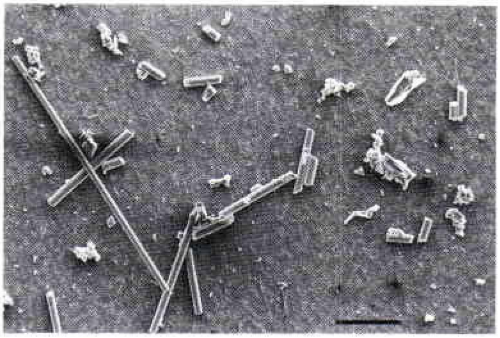

Fig. 3. Scanning electron micrograph showing a typical sample of dust collected during cutting of PU-impregnated glass fibre bandage. A combination of glass fibre filaments and particles of resin or glass fibre and resin can be seen (Bar line = 50um).

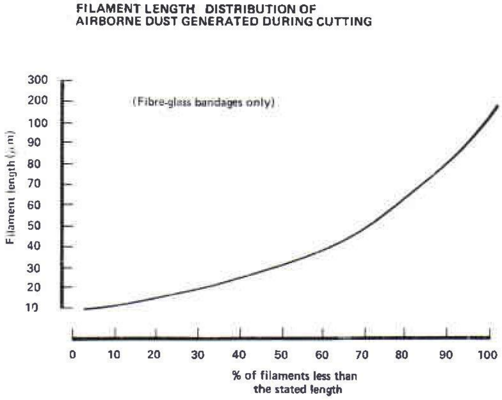

Fig. 5. Filament length distribution of airborne dust generated during cutting of glass fibre bandages.

for the glass fibre bandages is shown in Figure 5 and was found to vary form 8um to over 100um. The maximum recorded length for any filament was 300um.

Conclusions and comments

The effects of inspired dust on the lungs may be categorized as toxic, allergic, fibrogenic, carcinogenic or inert. This study has determined the concentration, the nature and the size of the dust generated during cutting of PU bandages with a plaster saw to establish whether a potential hazard exists which could lead to fibrogenesis of the lungs. The toxic, allergic and carcinogenic effects of dust produced by these materials has not been assessed.

Although cured PU resin is a stable compound and glass fibre is an inert material the potential fibrogenic effects from these substances will depend on whether dust is able to reach the alveoli. This study has shown that during removal of orthopaedic casts with a power saw, the PU impregnated bandages produce much lower concentrations of dust than POP, less than one third in the worst case.

The filaments produced by the synthetic materials are too large to reach the final divisions of the lungs and are unlikely to produce a respiratory hazard. These filaments are thought to be the cause of skin irritation experienced by some plaster room staff.

It has also been shown that at least 90% of the particles in the dust cloud are respirable and that these contain fragments of PU resin. There are no Occupational Exposure Limits for polyurethane dust, but the absence of a limit does not imply that the material is inert. It is therefore recommended that a dust extraction unit be used when cutting all types of splinting bandages with a power saw.

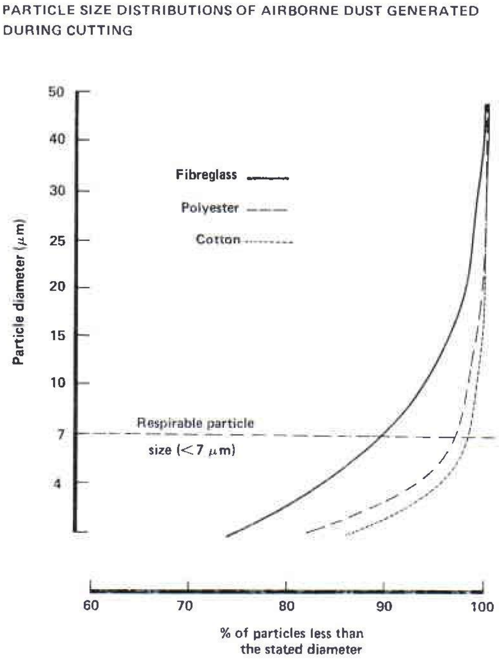

Fig. 4. Particle size distribution of airborne dust generated during cutting of bandages.

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