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Desorption Kinetics of Trichloroethylene and Perchloroethylene from Cotton Fabrics

Key Words
Cotton fabric
Trichloroethylene
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Desorption kinetic
Dry cleaning
Twisted weave
Linen weave
Surface area

Abstract
Linen and twisted weave cotton fabrics were exposed to trichloroethylene (114, 164 or 246 ppm) or perchloroethylene (130 or 282 ppm) for 6 h and then desorption kinetics were determined for 20 min in solvent-free air. Both solvents desorbed from the cotton samples with an initial rapid rate and subsequently more slowly. Clothes that had been subjected to commercial dry cleaning with perchloroethylene were shown to be a source of indoor air pollution for the organo-chloro solvent.

Introduction

Much attention has been paid in the last decade to the interaction of cellulose fibres with organic solvents, especially to the influence of the surface area of the fibres and the prevailing moisture content of the air [1], because these factors are important in predicting the behaviour of the solvents with the surrounding air. The basic characteristics of the system have been determined with values obtained from inverse gas chromatography, but for practical applications this technique is not reliable, because cellulose is a fibrous material, with a chain structure consisting of both crystalline and amorphous arrangements of glucose molecules. This results in pores with a diameter of 100–250 nm being present particularly in the amorphous region [2], and these may cause a hysteresis effect in sequential sorption-desorption events.

Trichloroethylene and perchloroethylene are organo-chloro compounds that are often used for degreasing and cleaning. Samples of exhaled breath and air taken from immediately around humans show that a higher concentration of these organo-chloro compounds is found indoors than outdoors [3]. As those in contact with the compounds can be contaminated via the air, or from skin or clothing, the adsorption of the compounds onto the fabric of cotton working clothes is important. Another source of perchloroethylene can come from the dry cleaning of clothing.

The aim of the study was to measure the adsorption/desorption kinetics of perchloroethylene and trichloroethylene on cotton fabrics derived from working clothes.

Methods

Small samples (10 × 10 cm) of white and green linen and twisted weave cotton fabric were cut from used working clothes, washed several times and dried. Samples were secured on clothes hangers in stainless-steel wire cages, and exposed to the solvents in a dynamic solvent exposure chamber. Gas chromatography was used to monitor the concentration of the solvents.

Samples were exposed to the selected concentrations of solvents for 6 h, and then ventilated in a solvent-free atmosphere for 20 min (temperature 25 °C, 50% relative humidity). Cotton samples were taken into head-space vials (6 ml) throughout this period, which were then sealed for subsequent analysis. Determination of solvent con-

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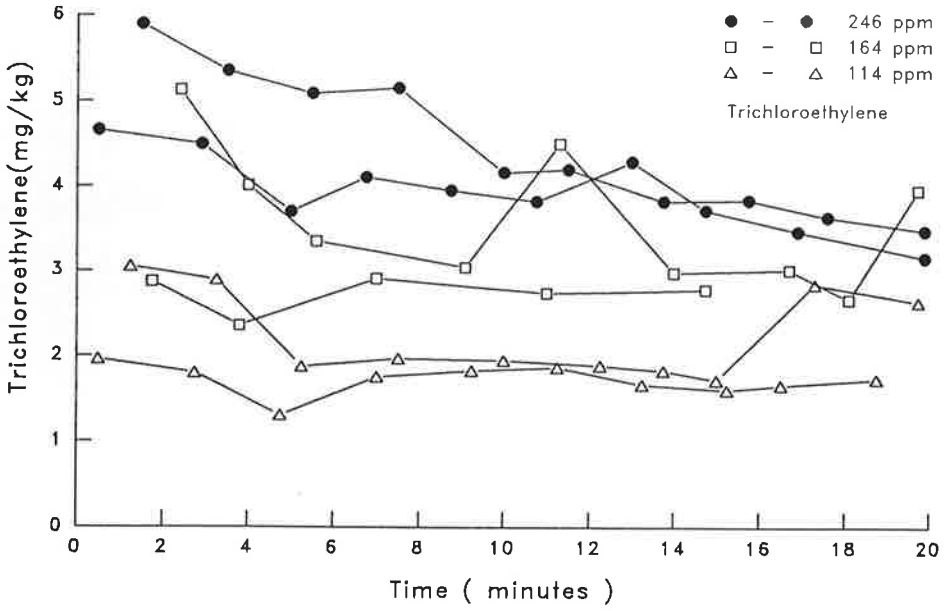


Fig. 1. Desorption kinetics of trichloroethylene from white cotton fabric (twisted weave) after 246, 164 and 114 ppm trichloroethylene exposure over 6 h.

centration was by capillary gas chromatography, after desorption and equilibration of the cotton samples with 5 ml carbon disulphide. Each sample was analysed in triplicate (1-µl aliquot). For samples that had been dry-cleaned, these were ventilated at room temperature for up to 56 h, then packed, sealed and stored at –21 °C before analysis.

Results

Laboratory Studies

Trichloroethylene was adsorbed onto the twisted weave white cotton fabric in a concentration-dependent manner (5.9 mg/kg at 246 ppm exposure for 6 h; fig. 1). With the highest concentration of trichloroethylene tested (246 ppm), the desorption was linear over 20 min, with a 50% loss after 23 min (fig. 1), whereas there was little loss of trichloroethylene over 20 min with the lowest exposure level (114 ppm).

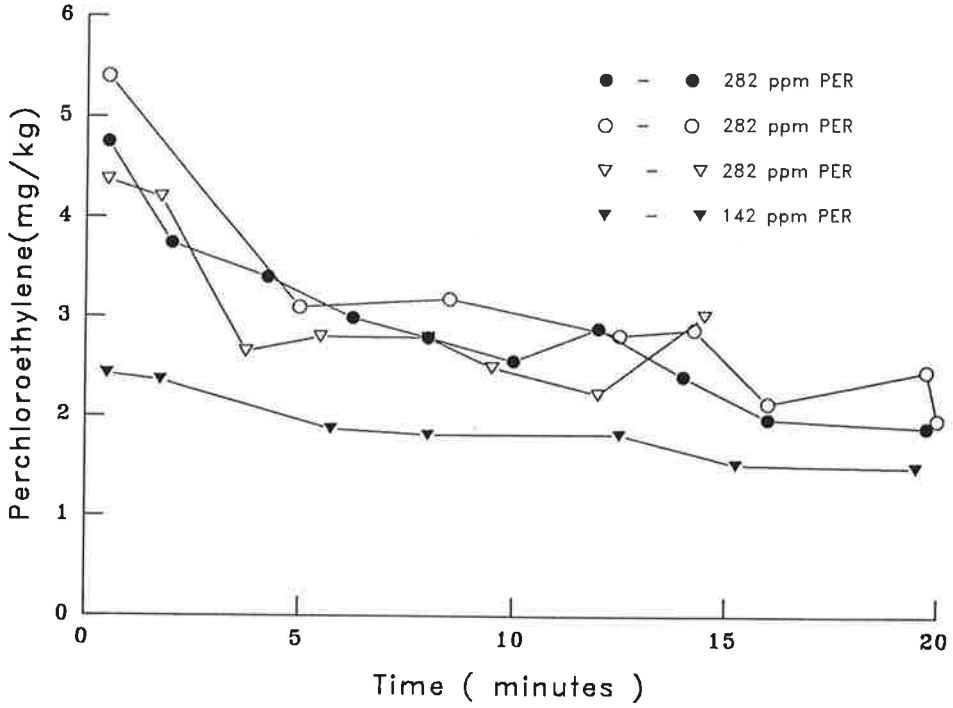
The adsorption of perchloroethylene on green linen weave cotton samples is shown in figure 2. After exposure to 282 ppm perchloroethylene for 6 h, the cellulose fibres adsorbed between 4.3 and 5.4 mg/kg. After ventilation with solvent-free air for 20 min, half the perchloroethylene was desorbed from the samples, whereas at the lower exposure level of 142 ppm only 20% of the perchloroethylene was desorbed. This desorption was linear with respect to time.

The values obtained from the samples (fig. 1–3) indicate that, especially after exposure to the higher concentrations of solvents, the desorption proceeds at two rates. Inititally, there was a rapid desorption (20 min for trichloroethylene and 10 min for perchloroethylene), and then a slower rate of decline in the concentration of solvent retained on the fabric samples.

Perchloroethylene was adsorbed onto twisted weave white cotton fabric to a much greater extent than onto green linen weave cotton fabric (compare fig. 2 and 3). Figure 3 also shows the relationship between the amount of perchloroethylene adsorbed onto the white linen weave cotton fabric and the surface area of the samples. The desorption of perchloroethylene followed first-order kinetics.

Field Samples

The white and green cotton samples were dry-cleaned in a commercial shop. Subsequently, the samples were ventilated in the laboratory for 6, 24 or 56 h. Figure 4 shows the content of perchloroethylene after these treat-



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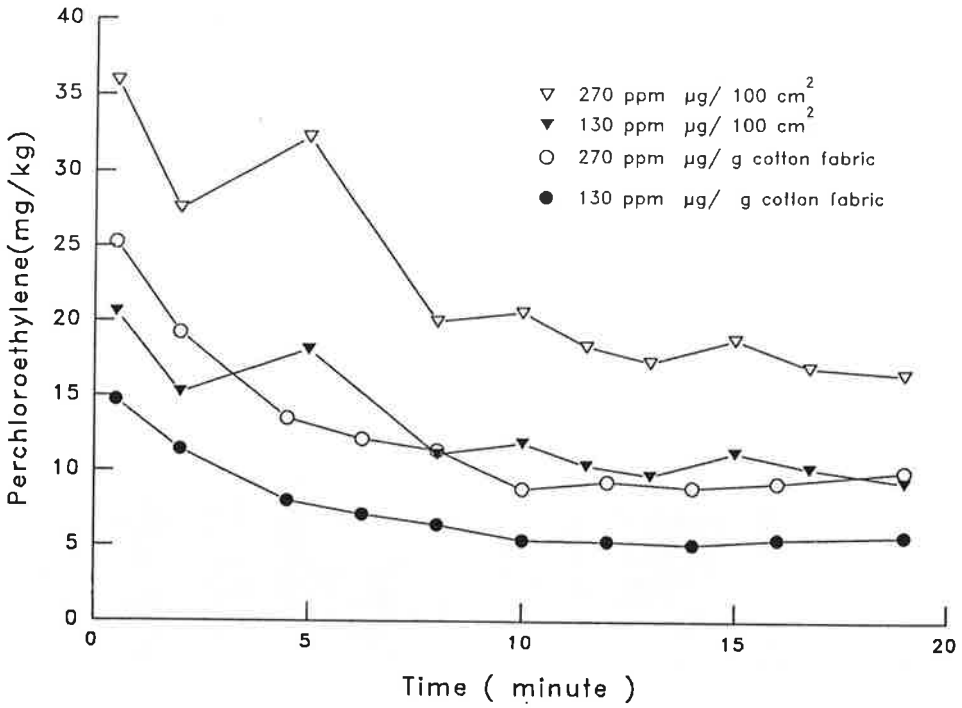

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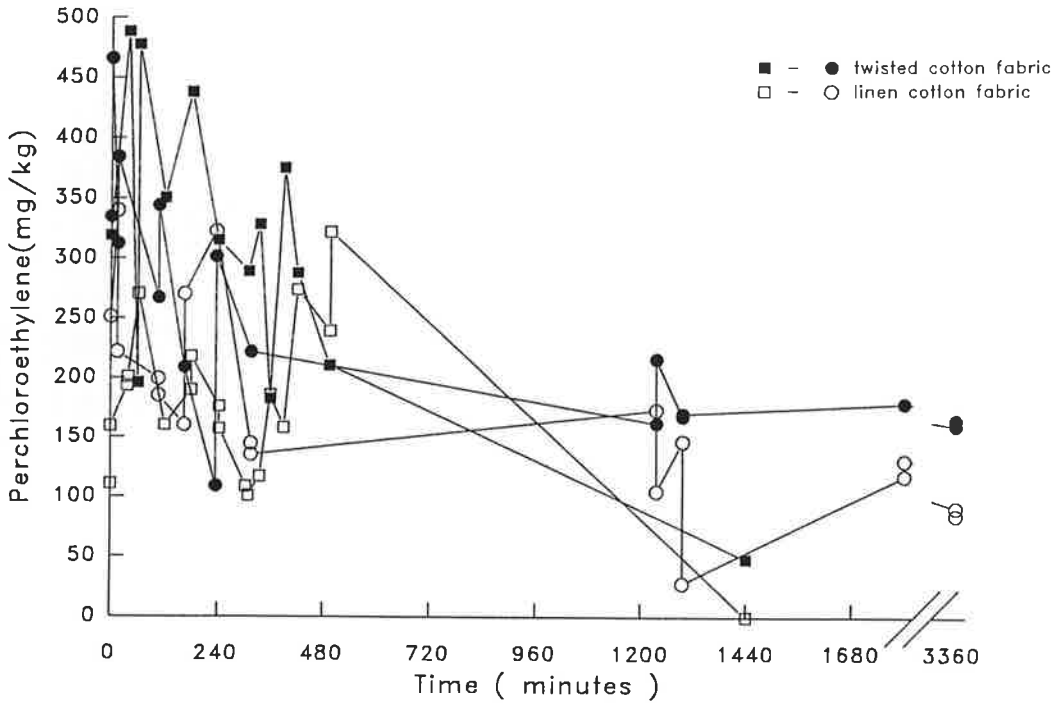
Fig. 2. Desorption kinetics of perchloroethylene from green cotton fabric (linen weave) after 282 and 142 ppm perchloroethylene (PER) exposure over 6 h.

Fig. 3. Desorption kinetics of perchloroethylene from white cotton fabric (twisted weave) after 130 and 270 ppm perchloroethylene exposure over 6 h.



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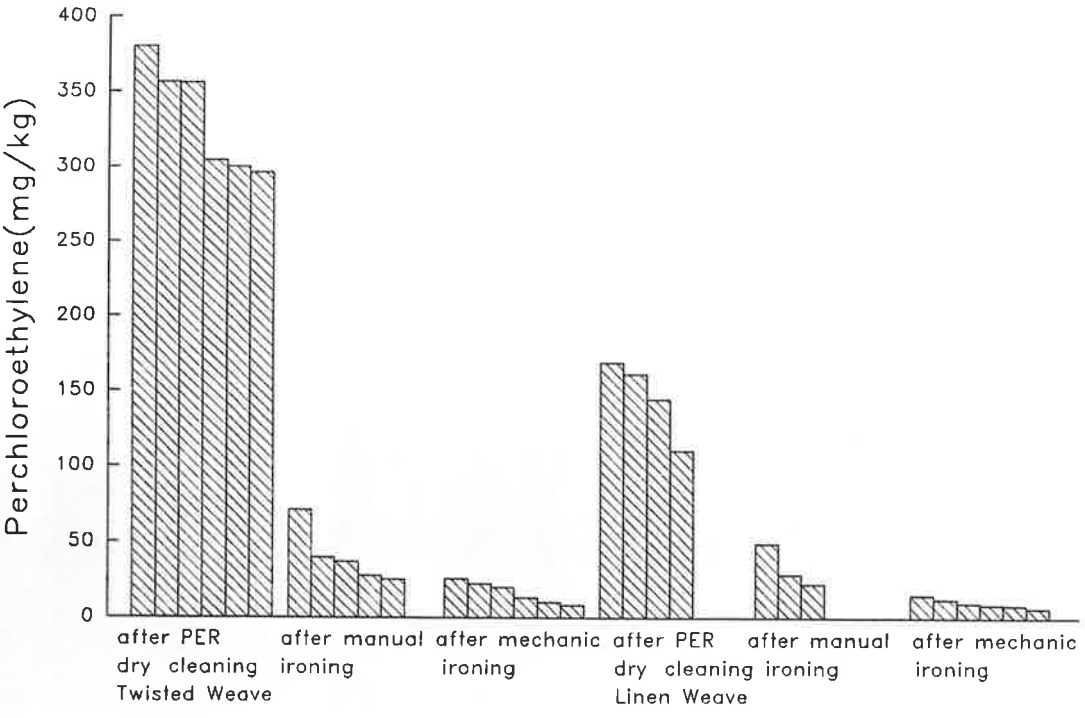

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Fig. 4. Perchloroethylene desorption of cotton fabric after dry-cleaning during hanging in ambient room air conditions.

Fig. 5. Perchloroethylene (PER) loss after dry-cleaning of cotton fabrics by use of manual steam ironing and sequential mechanical steam ironing.

ments. The amount of perchloroethylene retained on the cotton fabric ranged from 335 to 466 mg/kg for twisted weave and from 251 to 340 mg/kg for linen weave material.

Dry-cleaned clothes are normally ironed before being worn, so the effect of such treatment was investigated. Although there was a large amount of perchloroethylene retained on both twisted weave and linen weave fabrics after commercial dry cleaning, both manual ironing and subsequent mechanical ironing by a steam press reduced the amount of perchloroethylene retained on the clothes (fig. 5). Nevertheless, more than 5 mg perchloroethylene per kilogramme fabric persisted through these treatments.

Discussion

The procedures described in this paper demonstrate that it is possible to measure reproducibly microgramme amounts of solvents adsorbed to fabrics derived from working clothes. With sequential analysis of samples, it is possible to obtain the kinetic data necessary for modelling the elimination of perchloroethylene and trichloroethylene. The methodology was also shown to be of use in monitoring the loss over several days of perchloroethylene from commercially dry-cleaned clothes.

Cotton samples exposed to perchloroethylene or trichloroethylene and then removed to solvent-free air showed a fast phase of loss of adsorbed material for the first 20 min, which was followed by a slower rate of loss over a long period. When the loss of perchloroethylene from commercially dry-cleaned cloth samples was monitored, there was a decay of adsorbed perchloroethylene over several days. The perchloroethylene retained on dry-cleaned cotton fabrics was shown to be higher than in previous reports [4, 5].

Simulation of the events occurring in the dry cleaning of clothes showed that much of the perchloroethylene adsorbed on the clothes was lost after ironing and pressing, but there was a residual amount of perchloroethylene (about 5 mg/kg) that could be released into the breathing zone of the wearer, but did not reveal its presence from its odour. Thus, adsorbed organo-chloro solvents on clothes may be a source of contamination of the indoor environment [6].

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