Burning behaviour of bedding : comparison of different standards

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Burning behaviour of bedding: Comparison of different standards

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Introduction

Bedding is used to protect duvets, pillows and mattresses from soiling and, of course, to give the bedroom an individual touch. In 2003 Switzerland imported 6523 tons of bedding items. 305 tons of them were exported in the same period (1). Therefore, 6205 tons of bedding items were sold in Switzerland.

Unfortunately, cigarette ash or a lit candle coming in contact with bedding can cause a fire and therefore injure people.

A survey was launched in the United Kingdom to determine the number of related incidents and injuries in 1998. In total, 1758 accidental dwelling fires caused by candle light were registered (2). Candle related incidents accounted for 3 % of all dwelling fires. In 196 accidental dwelling fires (11 %) bedding was the first material ignited by a candle with 1 fire causing casualties and 98 fires causing non-fatal injuries (2). Figure 1 shows the materials first ignited by a candle.

The survey concludes that in the U.K. candle related fires most often start in bedrooms and living rooms (2).

Another study made in the U.K. reports that in 31 % of 17584 fires bedding was the first textile material ignited (3).

An older survey done in the USA covering 3087 case histories of fire victims showed the frequency of involvement of the 25 highest-ranking flammable fabrics identified as the first items ignited. Mattresses (347 incidents) ranked 5, sheets (224 incidents) ranked 11 and blankets (208 incidents) ranked 12 (3). The proportional distribution of the 17 highest-ranking fabrics is displayed in figure 2.

In Switzerland, data available are not so detailed. The best data source covering burning injuries is the "Unfallstatistik" (statistic on accidents). In 2002 about 13000 people were injured in fire accidents, which corresponds to 1.8 % of all accidents recorded by the SUVA (Schweizerische Unfallversicherungsanstalt). About 5500 of these were non-occupational accidents (4). Thus, estimation done on the

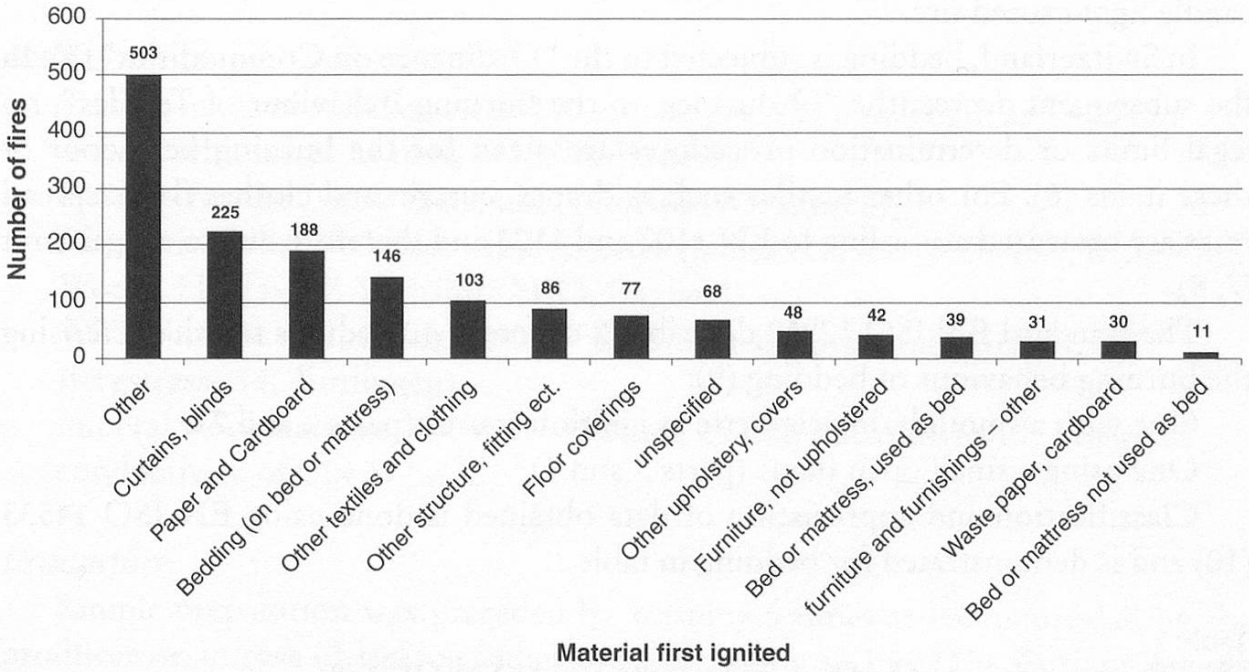


Figure 1 **Material first ignited by a candle from 1758 dwelling fires in the United Kingdom (1998) (2); not all materials are shown**

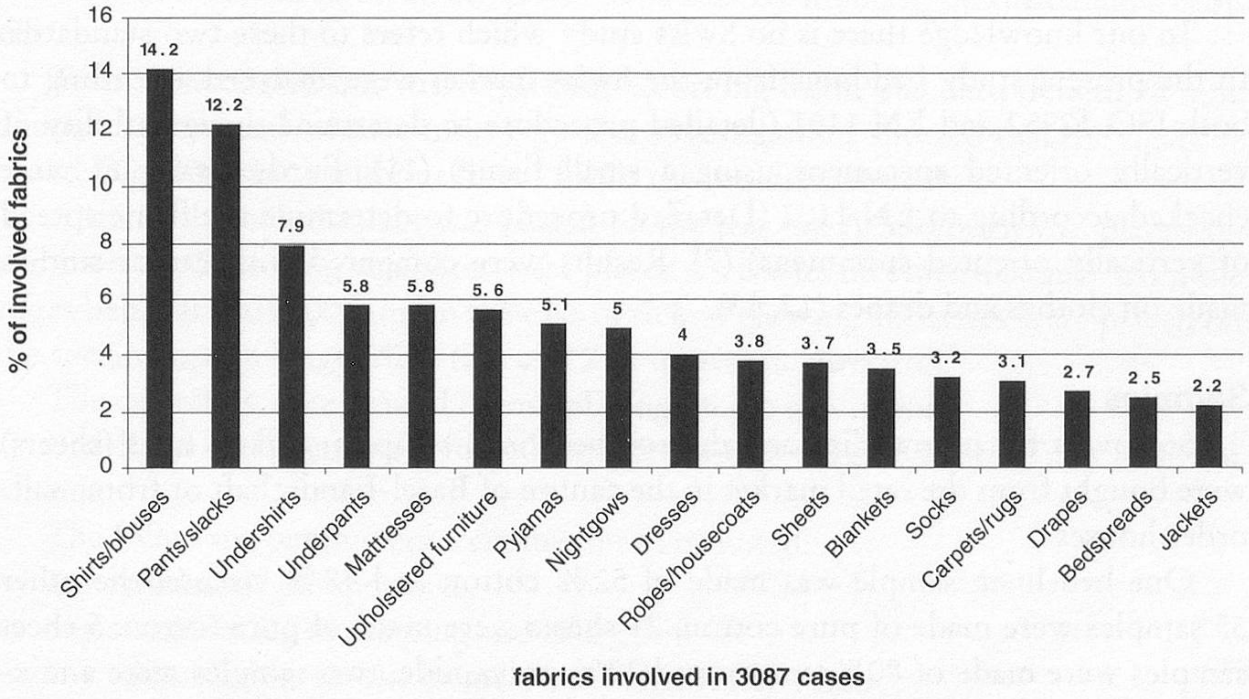


Figure 2 **Frequency of the 17 highest-ranking flammable fabrics to be the first item ignited in 3087 case histories (1976) (3)**

basis of the 1998-U.K. study would reveal 30 people as injured in the bedroom by candle light caused fire.

In Switzerland, bedding is subjected to the "Ordinance on Commodities" (5). In the subsequent decree, the "Ordinance on the Burning Behaviour of Textiles", no legal limits or determination procedures are given for the burning behaviour of these items (6). For other textiles such as drapes, curtain and clothes flame spread rates are measured according to EN 1102 and 1103 and therefore due to a legal limit (7, 8).

The standard EN ISO 12952 describes 2 different procedures for characterising the burning behaviour of bedding (9):

One with a smouldering cigarette as ignition source (parts 1 and 2)

One using a small open flame (parts 3 and 4).

Classification and appreciation of data obtained is done using EN ISO 14533 (10) and is demonstrated for bedding in table 1.

Table 1
Classification scheme of bedding items according to EN 14533 (8)

Class	*Class definition*
A	PASSES test of ignition with a smouldering cigarette PASSES test of ignition with a small open flame
B	PASSES test of ignition with a smouldering cigarette
C	DOES NOT PASS test of ignition with a smouldering cigarette DOES NOT PASS test of ignition with a small open flame

To our knowledge there is no Swiss study which refers to these two standards. In the present study beddings from the Swiss market were analysed according to both ISO 12952 and EN 1101 (detailed procedure to determine the ignitability of vertically oriented specimens using a small flame) (11). Further samples were checked according to EN 1102 (Detailed procedure to determine the flame spread of vertically oriented specimens) (7). Results were compared with earlier studies made on clothes and drapes (12, 13).

Samples

56 covers for pillow slips and duvets (bed-linen samples) and 31 ticks (sheets) were bought from the retail market in the canton of Basel-Landschaft or from mail-order houses.

One bed-linen sample was made of 52 % cotton and 48 % viscose; the other 55 samples were made of pure cotton. 24 sheets were made of pure cotton, 5 sheet samples were made of 80 % cotton and 20 % polyamide, two samples were a mixture of 52 % cotton and 48 % viscose respectively 95 % cotton and 5 % elastan.

Procedures

Instruments

- Test rig made of stainless steel: 400 mm height, 400 mm length and 400 mm width (Schlosserei Arxhof, 4435 Niederdorf)
- Burners for the "small flame test" (Culatti AG, Zürich)
- Rhoburn Modell 480 flammability tester (James H. Heal & Co Ltd, Richmond Works, Halifax, W. Yorkshire HX3, England)
- WTB climatic cabinet KBF 240 (WTB Binder Labortechnik GmbH, Bergstrasse 14, Tuttlingen)
- mineral wool mattress (450 mm×450 mm, 25 mm thickness) with a thermal conductivity of 0.04 W/m K

Procedure

Sample preparation was preceded by washing 5 times as recommended by the producer or, in case of lacking indications, according to EN 1101. Surface density was determined by weighing and calculation and the fabric composition was noted for each sample.

The procedures of the standards used in present study are briefly described in the following parts.

EN 12952 Part 1 and 2: smouldering cigarette (9)

Three specimens of 450 mm by 450 mm were cut out of each sample and conditioned for at least 24 hours at 20 °C and 65 % relative humidity in the climatic cabinet.

Tests were carried out with cigarettes according to the standard (length 70 mm, diameter 8 mm and tobacco mass 1 g). Our investigations showed that the cigarette brand "Gauloise blue without filter" fulfils the requirements.

A mineral wool mattress was placed on the test rig. A Specimen was placed on the mattress. 2 glowing cigarettes were placed on the textile; their distance from the edges being at least 100 mm. In the case of ticks 4 glowing cigarettes were placed on the specimen, 2 in length direction and 2 in transverse direction.

The cigarettes were ignited before placing on the specimens.

Bed-linen specimens were folded covering one glowing cigarette. Ticks were not folded.

The following parameters were measured or noted:

- any ignition of the specimen
- any smouldering or glowing and extinction
- any smouldering, smoke or measurable heat after 1 hour
- any discolouring and its dimension at cigarette locations
- any destruction of the textile and its dimension

EN 12952 Part 3 and 4: small open flame (9)

The same sample preparation as for part 1 and 2 was used for this test. However, burning behaviour was investigated with small flames (flame height 35 mm) using burners made according to the standard. For ticks and duvets only one burner was used whereas 2 burners were applied for pillow specimens. Pillow slips were folded covering one burner. The second burner laid sidewise on the tightest spot of the textile surface.

The burners were ignited before covering and touching the specimen

During the experiment, the following parameters were observed and noted:

- any ignition of the specimen
- any smouldering or glowing
- any smouldering, glowing or measurable heat after 15 minutes
- any discolouring and its dimension at burner locations
- any destruction of the textile and its dimension

EN 1101 Ignitability (11)

- 3 specimens measuring 80×80 mm were cut out
- 14 specimens of 80 mm width and 200 mm length were cut out
- specimens were conditioned at least for 24 hours at 20 °C and 65 % relative humidity in the climatic cabinet

The ignitability was measured with the rhoburn apparatus according to EN ISO 6940 and the mean ignition time was calculated as given in annex B in the standard (14). Surface ignition was applied.

EN 1102 flame spread rate (7)

- specimens were 560 mm long and 150 mm wide
- from each sample, 3 specimens were cut out lengthwise and 3 specimens in transverse direction.
- specimens were conditioned at least for 24 hours at 20 °C and 65 % relative humidity in the climatic cabinet
- ignition time was 10 seconds

The flame spread rates of these six specimens were measured with the rhoburn apparatus and averaged as described in EN ISO 6941 (15).

"Second marker" according to the prEN 1103: 2004

EN ISO 1103 is valid for clothes and determines the flame spread rate according to EN ISO 6941. In EN ISO 6941 two threads are used, the 1st at 220 mm and the 2nd at 520 mm distance from the burner. The flame spread rate is calculated using the distance between the two threads (300 mm) divided by the time elapsed for severing both of them (15).

In the draft prEN 1103 only the second thread at 520 mm will be used (16). Two burning processes are measured: a) the ignition of the textile and b) the propagation of the flames.

Measurement of the flame spread rate yields the time at which the third thread was severed.

Quality assurance

International standards are considered as validated. No reference material was available for in house validation of these standards. Furthermore no validation data are mentioned in the standards. We therefore determined the reproducibility of the ignition time (ignitability) and the flame spread rates of a sample as a substitute.

The reproducibility of the mean ignition time was calculated from 7 measurements of a bedding cover made of 100 % cotton. Its average was 2.4 seconds with a standard deviation of 0.1 s (rsd=4 %).

6 specimens of the same cotton duvet were used to determine the reproducibility of the flame spread rate. The average flame spread rate was 38.3 mm/s with a standard deviation of 1.8 mm/s (rsd= 4.7%).

Results

Test with a smouldering cigarette (EN 12952 part 1 and 2)

None of the tested samples was ignited by a smouldering cigarette.

7 bed-linen samples and 5 ticks did not show any smouldering. The other samples smouldered without flames. Discolouration of all samples occurred in less than 50 mm distance from the cigarette location. Differences could be observed in the destruction of the textile. In some samples the fabric structure of the textile was still recognizable. The results of this test and the number of textiles with preserved fabric structure are shown in table 2.

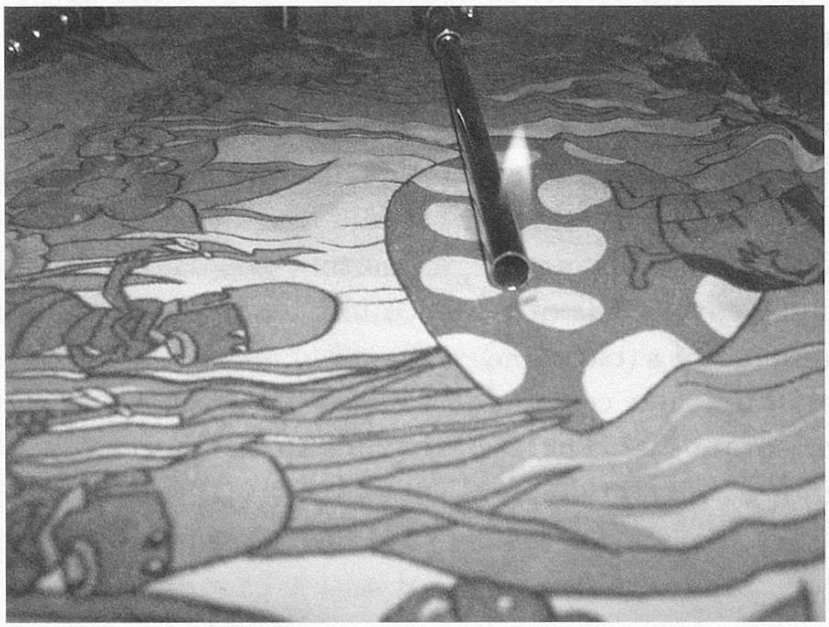
Table 2
Results of the smouldering test of bedding items with a smouldering cigarette (EN 12952) (7)

	Number of samples	*Ignition observed*	*Smouldering observed*	*Fabric structure preserved*
Bed-linen, covers for duvets and pillow slips	56	0 (0 %)	49 (88 %)	7 (12 %)
Sheets, ticks	31	0 (0 %)	26 (84 %)	5 (16 %)

Interestingly, paper from a local newspaper did not smoulder any further or ignite with a smouldering cigarette, but paper used for copying smouldered progressively over a 50 mm horizontal distance to the cigarette.

Test with a small open flame (EN 12952 part 3 and 4)

The test procedure using a small open flame is shown in picture 1. These burners simulate lighters and matches.



Picture 1 **Duvet cover being tested with a small open flame according to EN 12952 parts 3 & 4**

All samples were ignited under these conditions and would have burnt totally without extinguishing. Again, the fabric structure was still recognizable in some textile samples. Table 3 shows the results of this test.

Table 3
Test of bedding items with a small open flame (EN 12952) (7)

	Number of samples	*Ignition observed*	*Fabric structure preserved*
Bed-linen, covers for duvets and pillow slips	56	56 (100 %)	10 (18 %)
Sheets, ticks	31	31 (100 %)	10 (32 %)

EN 1101 Ignitability

Mean ignition times for the bed-linen samples were between 1.1 and 3.5 s. Sheets and ticks showed a wider distribution (0.5 to 3.7 s). None of the bed-linen samples but seven sheets (23 %) showed ignition times lower than 1.5 s. Three sheets had the same ignition time as a newspaper (0.6 s).

On one hand some sheets had a towelling surface made of thin cotton threads which render them better ignitable. On the other hand the average surface density of sheets was higher (177 g/m² versus 141 g/m²) which meant lower flame spread rates. In Figure 3 the bedding items are plotted against the corresponding ignition time. The distribution of the surface density is shown in figure 4.

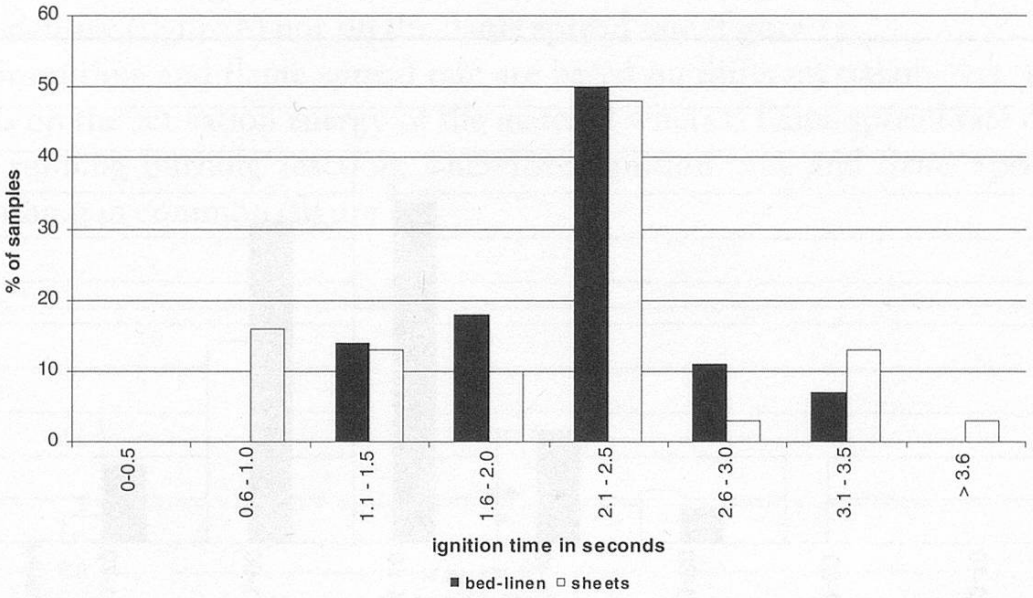


Figure 3 **Ignition time according to ISO 6940** (bed-linen n=56, sheets n=31)

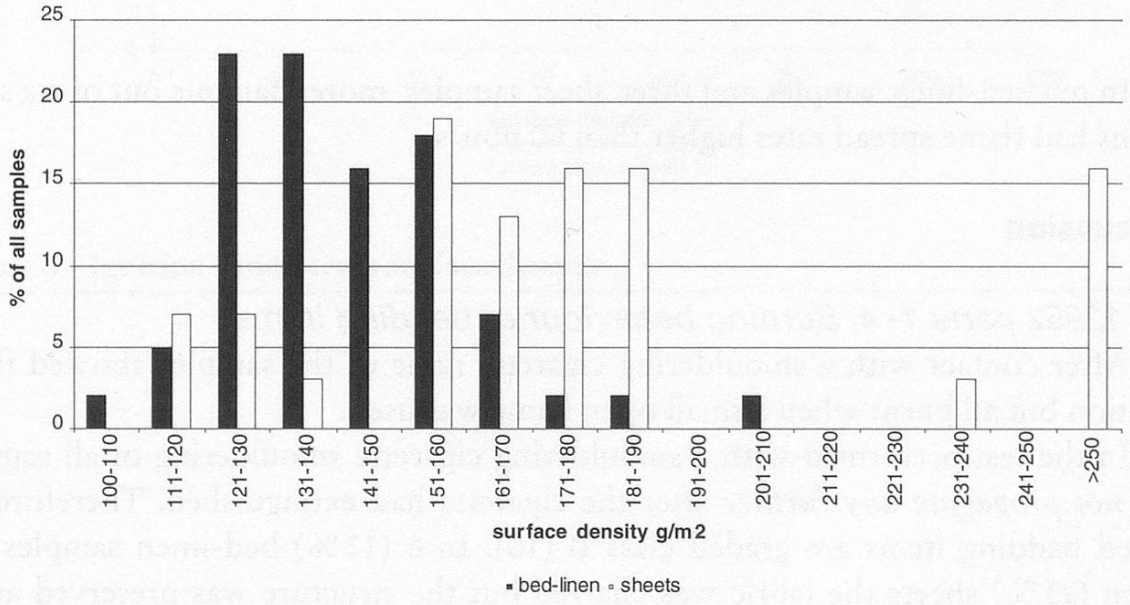


Figure 4 **Distribution of the surface density of bedding**

EN 1102 Flame spread rate

The average flame spread rates calculated on the basis of 6 specimens per sample ranged between 15.1 mm/s and 66.6 mm/s. The lowest belonged to a sheet and the highest to a bed-linen sample.

6 samples had flame spread rates higher than 60 mm/s (averages of 6 specimens: 60.9; 60.9; 62.8; 64.3; 66.6 mm/s for bed-linen samples 64.7 mm/s for a sheet) (Figure 5).

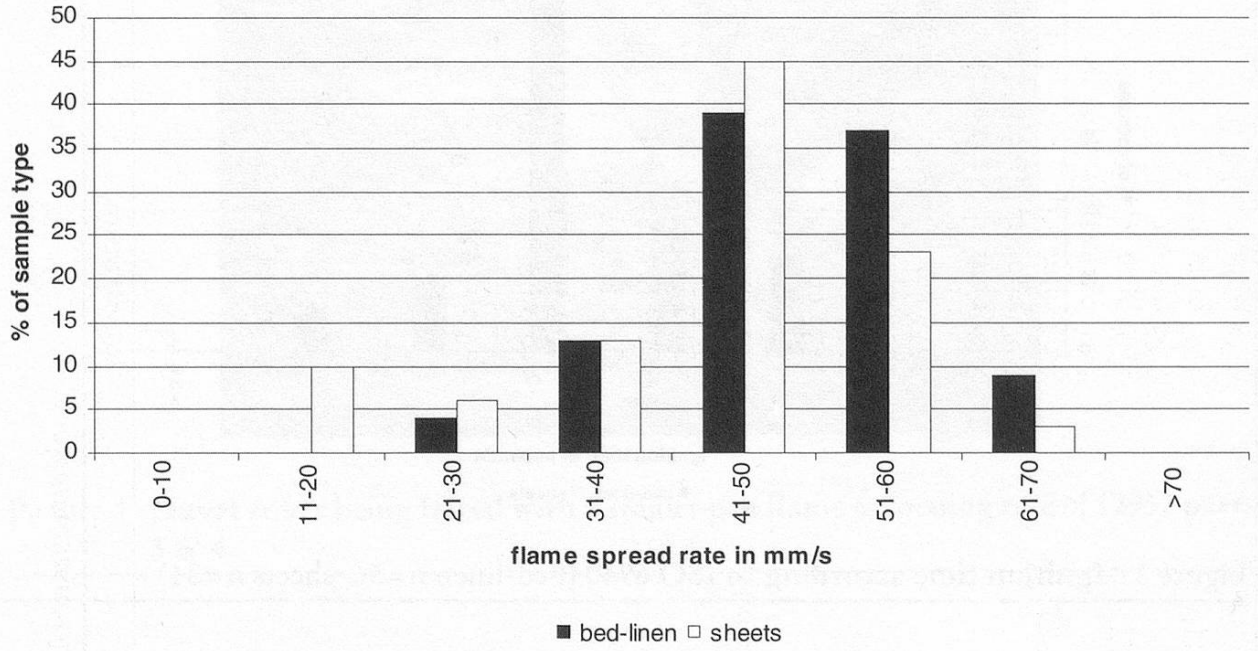


Figure 5 **Distribution of the flame spread rates of bed-linen and sheets**

In ten bed-linen samples and three sheet samples, more than one out of six specimens had flame spread rates higher than 60 mm/s.

Discussion

EN 12952 parts 1–4, Burning behaviour of bedding items

After contact with a smouldering cigarette none of the samples showed flame ignition but all burnt when a small open flame was used.

In the test performed with a smouldering cigarette smouldering of all samples *did not propagate any further* after the cigarette had extinguished. Therefore the tested bedding items are graded class B (10). In 6 (11 %) bed-linen samples and seven (23 %) sheets the fabric was charred but the structure was preserved at the contact spot with the cigarette (table 2). The other samples had a hole in the textile. This is the only differentiation in the investigated textiles which these tests give.

Paper form a newspaper is also graded in class B. But this thin paper has high flame spread rates.

Although the test procedures of the EN 12952 can be regarded as realistic even though a burner is used as a candle substitute, they are not suitable to distinguish the investigated bedding items and to distinguish the bedding items from a paper.

EN 1101 Flammability

One of the findings of this study was that flammability depended neither on the surface density (figure 6) nor on the flame spread rate (figure 7).

Ignition time and flame spread rate are based on different parameters. Ignition depends on the activation energy of the material whereas flame spread rate depends on the running burning reaction. Therefore, ignition time and flame spread rate have nothing in common (figure 7).

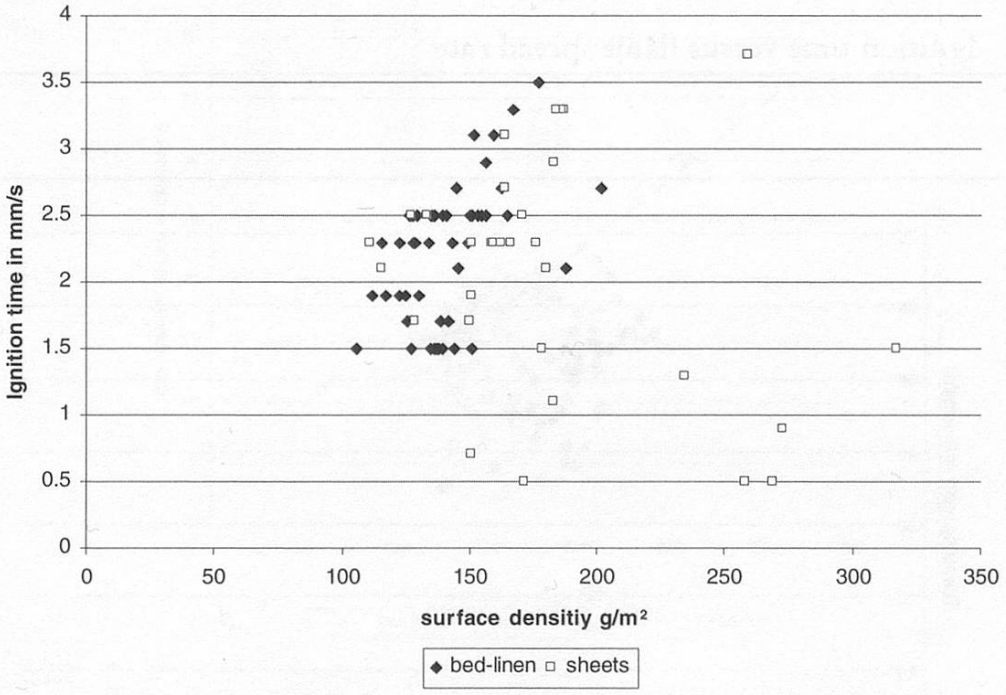


Figure 6 **Ignition time versus surface density**

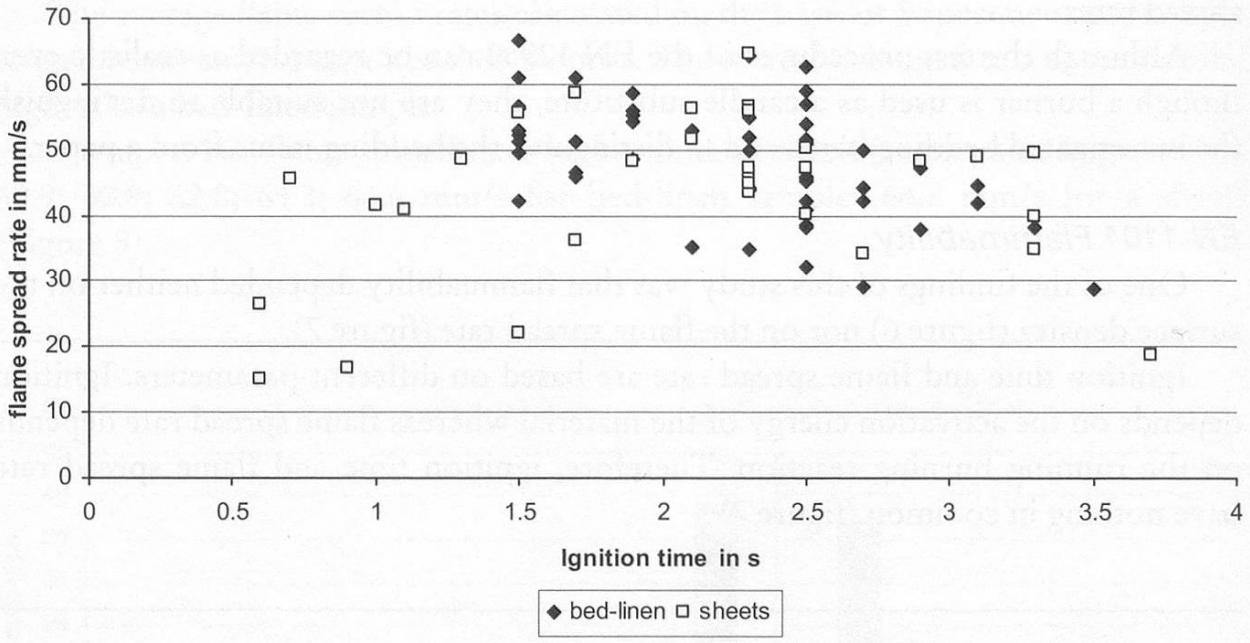


Figure 7 **Ignition time versus flame spread rate**

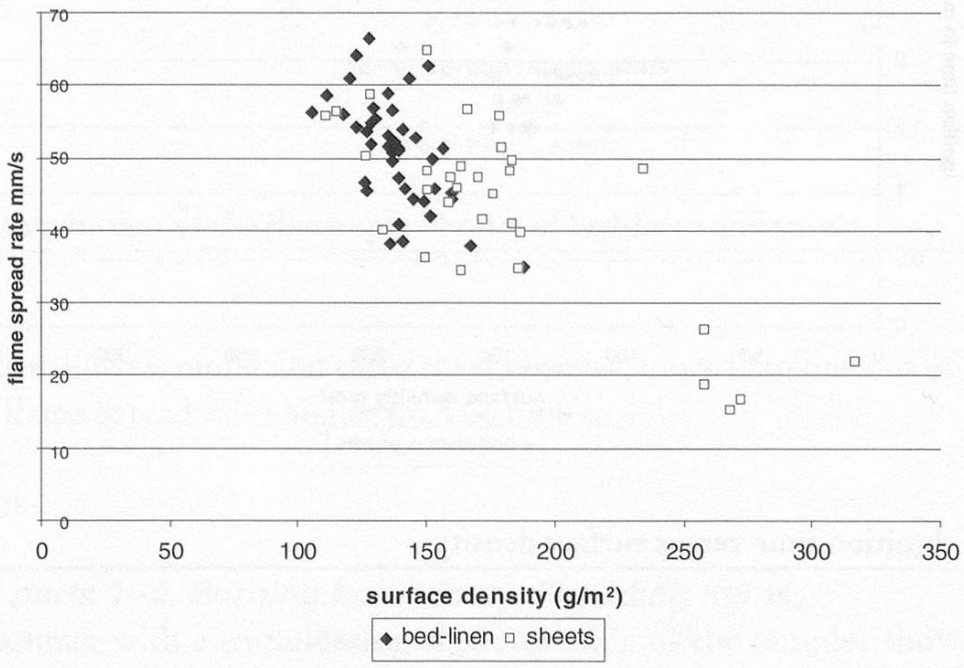


Figure 8 **Flame spread rate versus surface density, EN 1102 (ISO 6941)**

EN 1102 Flame spread rate

Whereas former studies on clothes made of cotton showed that there is a negative correlation between flame spread rate and surface density (12, 13, 17) the case

was not that obvious for bedding. However, higher surface density still meant lower flame spread rate (figure 8). Sheets with surface densities of about 250 g/m² have flame spread rates lower than 30 mm/s. Most samples had surface densities between 100 and 200 g/m² with flame spread rates ranging from 40 to 70 mm/s. In comparison, a paper from a newspaper had a surface density of 49 g/m² and an average flame spread rate of 116.7 mm/s (lengthwise=114 mm/s and crosswise=119.3 mm/s).

"Second marker" according to the draft prEN 1103: 2004

In figure 9 the time for burning the 2nd thread is plotted versus the specific surface density. Bed-linen did not show any correlation between these two parameters whereas a trend could be observed for sheets. Linear regression gave a low correlation coefficient of about r=0.87.

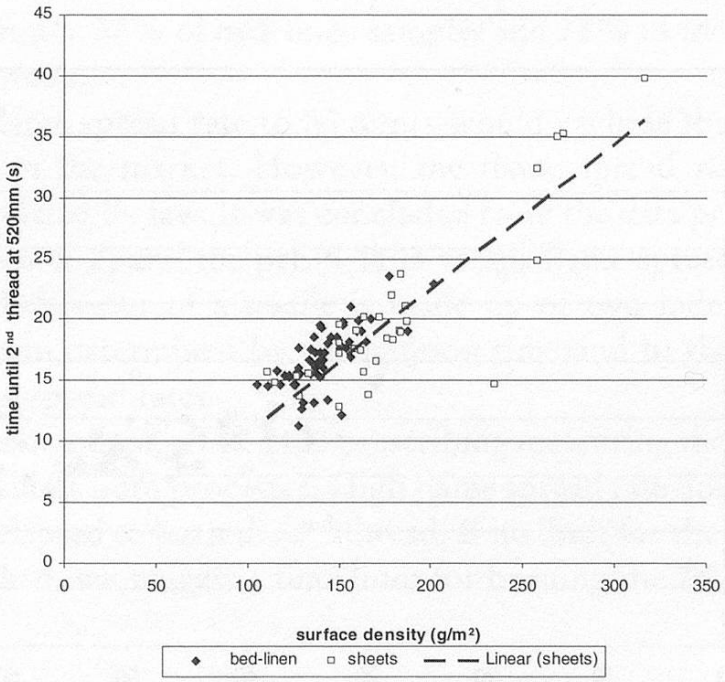


Figure 9 **Time elapsed to burn 2nd thread versus surface density**

In table 4 13 samples are listed which would not comply with the legal limit for curtains and drapes in the "Ordinance on the Burning Behaviour of Textiles", which is 60 mm/s for 5 out of 6 specimens. The time needed to severe the 2nd thread is neither dependent on the surface density nor on the flame spread rate (figure 10).

Table 4
Characteristics of bedding which would not comply with Swiss legal restrictions (6)

Sample	*Surface density*	*Average flame spread rate*	*Average needed to burn 2nd thread*
A (sheet)	180 g/m²	51.5 mm/s	18.4 s
B (bed-linen)	146 g/m²	52.8 mm/s	18.5 s
C (bed-linen)	106 g/m²	56.2 mm/s	14.7 s
D (bed-linen)	129 g/m²	56.9 mm/s	12.7 s
E (sheet)	128 g/m²	58.6 mm/s	15.4 s
F (bed-linen)	112 g/m²	58.7 mm/s	14.6 s
G (bed-linen)	135 g/m²	58.9 mm/s	17.6 s
H (bed-linen)	120 g/m²	60.9 mm/s	15.4 s
I (bed-linen)	144 g/m²	60.9 mm/s	13.4 s
J (bed-linen)	151 g/m²	62.8 mm/s	12.1 s
K (bed-linen)	123 g/m²	64.2 mm/s	15.4 s
L (sheet)	151 g/m²	64.7 mm/s	12.8 s
M (bed-linen)	129 g/m²	66.6 mm/s	11.3 s

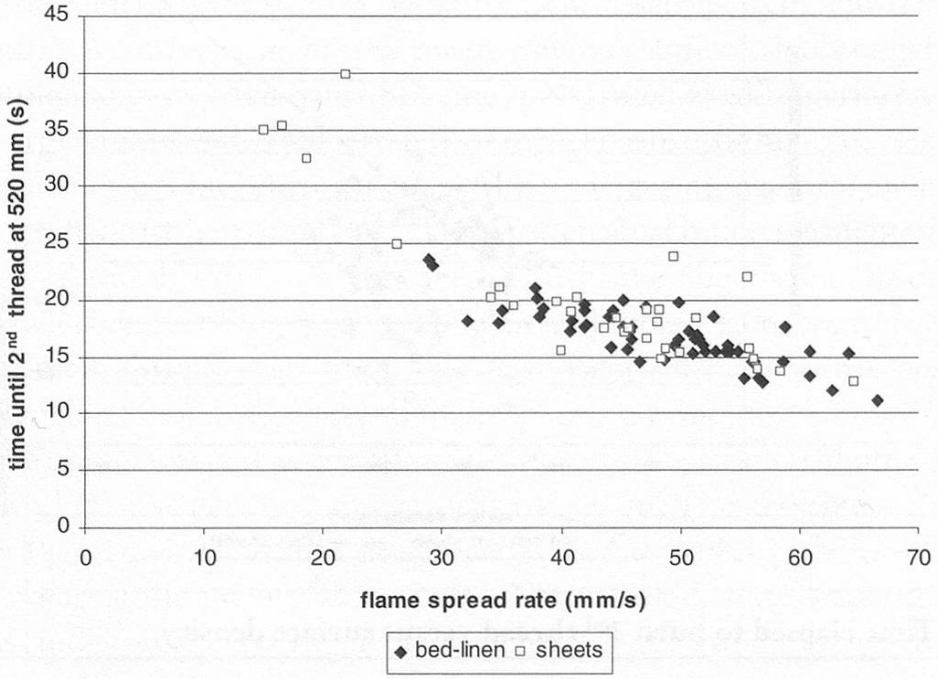


Figure 10 **Time elapsed to burn 2nd thread versus flame spread rate**

Conclusions

Although the tests of EN 12 952 mirror realistic conditions they are not suitable for determining the burning behaviour of bedding items because no difference between samples were apparent.

Flammability tests (EN 1101) and flame spread rate tests (EN 1102) revealed big discrepancies in the burning behaviour of bed-linen and sheets. Therefore, both tests are suitable to characterise the burning behaviour of bedding items.

Obviously there is no relation between the ignition time and the surface density or the flame spread rate. The mean ignition time (ignitability) is an important parameter for characterising the burning behaviour of a textile, because ignition is a precondition for burning. The shorter the ignition time the easier the textile catches fire. Ignition times as short as those of newspaper implicate a potential health hazard for humans. More attention should be given to this feature. Nevertheless, further studies should be performed to give conclusive answer in this respect.

In the "Ordinance on the Burning Behaviour of Textiles" (6) the flame spread rate is limited for curtains to 60 mm/s and for clothes to 90 mm/s. 5 out of 6 specimens of a sample have to fulfil this limit. Taking into account the limit for drapes and curtains 13 (14.9 %) tested bedding items would not fulfil this norm.

39 % of the bed-linen and 45 % of the sheet samples had flame spread rates in the range of 41 to 50 mm/s. 37 % of bed-linen samples and 23 % of the sheets laid in the range of 51 to 60 mm/s.

Limiting the flame spread rate to 60 mm/s would exclude the most dangerous bedding items from the market. However, the flame spread rate (flammability) should also be regulated by law. It was concluded from the data presented, from the ignitability (figure 6 & 7) and the prEN 1103 versus flame spread rate (figure 10), that the burning behaviour of a textile is made up of two independent physical processes: a) ignition determined by the ignition time and b) flame spread determined by the flame spread rates.

The draft of the standard prEN 1103 prescribing measuring the time for burning the 2nd thread considers both processes. High flame spread rate does not correspond with a short time elapsed to burn the 2nd thread. If no limit for the flame spread rate should be established, we suggest a time limit for burning the 2nd thread of 15 seconds.

Acknowledgements

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Summary

The burning behaviour of 81 bedding samples was investigated. Samples consisted of 56 bed-linen samples such as covers for duvets and pillow slips and of 31 sheets or mattress covers. All samples were investigated according to the tests descirbed in the standards EN 12952, ISO 6940 and ISO 6941.

EN 12952, which contains specific tests using a smouldering cigarette and a small open flame, is not suitable for the determination of the burning behaviour of

bedding items because it does not reveal differences in burning behaviour of the bedding samples.

EN 6940 and EN 6941, however, are better fit for this purpose because they highlight differences in ignition time and flame spread.

A legal limit for the flame spread rate value of 60 mm/s is proposed. This limit is already valid for curtains and drapes in Switzerland. Ten bed-linen and three sheets would not fulfil this specification. Seven sheets respectively ticks had ignition times of less than 1.5 seconds.

No relation was found between ignition time and flame spread rate or surface density. For sheets flame spread rates tended to depend on surface density.

Zusammenfassung

81 Bettwäsche-Proben wurden auf ihr Brennverhalten untersucht. Es handelte sich um 56 Bettwäschebezüge wie Duvetbezüge und Kissenbezüge und 36 Leintücher und Fixleintücher. Alle Proben wurden nach EN 12952, ISO 6940 und ISO 6941 untersucht.

Die EN-Norm 12952, die Tests mit einer brennenden Zigarette und einer kleinen Flamme vorschreibt, eignet sich nicht zur Bestimmung des Brennverhaltens von Bettwäsche. Diese Tests liefern keine Unterschiede im Brennverhalten der Bettwäsche.

Dagegen sind ISO 6940 und ISO 6941, die die Entzündungszeit und die Flammenausbreitungsgeschwindigkeit bestimmen, zur Beschreibung des Brennbarkeitsverhaltens der untersuchten Bettwäsche-Proben geeignet.

Ein Grenzwert von 60 mm/s wird für die Flammenausbreitungsgeschwindigkeit vorgeschlagen, er gilt auch für Vorhänge und grossflächige Textilien in der Schweiz. Wird dieser Wert herangezogen, würden zehn Bettbezüge-Proben und drei 3 Leintücher-Proben die Norm nicht erfüllen. Sieben Leintücher-Proben wiesen eine Entzündungszeit von weniger als 1,5 Sekunden auf.

Es wurde keine Beziehung zwischen der Entzündungszeit und der Flammenausbreitungsgeschwindigkeit oder der spezifischen Flächenmasse gefunden. Ein linearer Trend konnte zwischen der Flammenausbreitungsgeschwindigkeit und der spezifischen Flächenmasse für Leintücher ermittelt werden.

Résumé

Les 81 échantillons de linges ont été éxaminé pour leur inflammabilité.

Il s'agit de 56 fouzzes de duvet et de cousin ainsi que de 36 draps et draps fix.

La norme EN 12952 qui contient les tests spécifiques avec une cigarette allumée et une petite flamme n'est pas approprieé à determiner l'inflammabilité. Ces tests ne donnent aucune différence du campartement d'inflammabilité.

Par contre les normes ISO 6940 et ISO 6941 sont valables pour déterminer le temps d'inflammation et la vitesse de propagation des flammes. Ces tests ont donné

des resultats probants du temps d'inflammation ainsi que de la vitesse de propagation des flammes.

Ume limite Suisse de 60 mm/s de la vitesse de propagation des flammes est proposeé aussi bien pour les rideaux et que pour les textiles grande surface. Cette valeur accepteé, dix fouzzes de duvet et trois drapes ne rempliraient pas la norm. Pour sept draps le temps d'inflammation a été inferieur à 1,5 sec. Il n'y a eu aucune relation entre le temps d'inflammation, vitesse de propagation des flammes et les surfaces spécifiques. Une tendance lineaire a été constatée pour les draps entre la vitesse de propagation des flammes et les surfaces spécifique.

Key words

Bedding, burning behaviour, international standard 12952, ignitability, flame spread rates

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