WHO Prequalification of Vector Control Products

Phys/Chem tests for ITNs: Abrasion resistance

Factors which may affect validity of tests and results using the **abrasion resistance method**

- incorrect identification of the technical face and back of ITN fabric;
- incorrect mounting of sandpaper - no creases, flat top;
- incorrect mounting of samples to prevent slippage;
- use of incorrect sandpaper grade. The correct grade: AW-C P240;
- not replacing sandpaper with every sample;
- use of incorrect materials for backing the testing samples and abradant;
- not replacing the backing foam and standard wool when damaged;
- the abradant should impose a pressure of 9 kPa on the sample and trace a Lissajous figure;
- inspection of the samples at incorrect abrasion intervals. Correct abrasion intervals should be 10, 25, 50, 75, 100, 125, 150, 175, 200, 250, 300 rubs;
- failure of samples spread across five or more inspection intervals. If this is the case the test should be repeated to determine better accuracy.

1. Purpose of the Method

This document describes the method for assessing the abrasion resistance of open mesh textile structures such as those used in Insecticide-treated Nets (ITNs). It is an accelerated abrasion test using a light abradant (sandpaper) to evaluate the propensity for hole formation subject to a dry, flat abrasive mechanism.

2. Considerations for Use of the Method

This method is used to assess the abrasion resistance of an ITN that is subjected to a light abrasive action and is designed to reflect conditions that an ITN will be exposed to during normal use.

The abrasion resistance is measured on both fabric sides (face and back). A circular ITN test sample mounted in a holder is rubbed against an abradant (sandpaper) of predetermined specification (AW-C P240) using a Martindale abrasion tester (as described in ISO 12947-1:1998) *(1)*. The abradant imposes a pressure of 9 kPa on the sample and traces a Lissajous figure. The sample is exposed to a number of abrasion rubs, prior to an inspection interval and is inspected for failure. The initial inspection of the sample is carried out at 10 rubs and subsequently at 25 rubs. After the 25 rubs inspection, the inspection intervals are every 25 rubs, up to 200 rubs. After 200 rubs,

the inspection intervals are every 50 rubs, up to a total of 1000 rubs. The test is terminated when yarn breakage occurs in the sample.

2.1.Terminology

- **Open mesh textile**: A textile which due to its inherent structure consists of a large number of closely spaced apertures.
- **Abrasion rub**: One revolution of the two outer drives of the Martindale abrasion tester.
- **Inspection interval**: Period after a specified number of rubs at which each sample is visually examined for failure.
- **Failure**: A failure is defined as the breakage of a single filament yarn resulting in a hole of approximately 5 mm.
- **Face**: The technical face of the fabric.
- **Back**: The reverse side of the fabric.

2.2.Technical Face and Back of ITN Fabrics

In knitting, the technical face and back of the fabric are determined by the way the fabric is manufactured. Identification of the technical face and back of the fabric can be aided by optical microscopy in order to confirm the loop structure.

3. Apparatus and Materials

3.1.Apparatus

The apparatus required to conduct this test is a Martindale abrasion tester and auxiliary materials, as described in ISO 12947-1:1998 *(1)*.

3.2.Materials

- The abradant required is a AW-C P240 sandpaper on a Grade C paper.
- The test sample backing fabric is ‘standard wool’ (as described in ISO 12947-1:1998) *(1)*.
- The test sample backing foam is PU foam (as described in ISO 12947-1:1998) *(1)*.
- The abradant backing foam (PU foam).

4. Sampling and Test Samples

4.1.Sampling

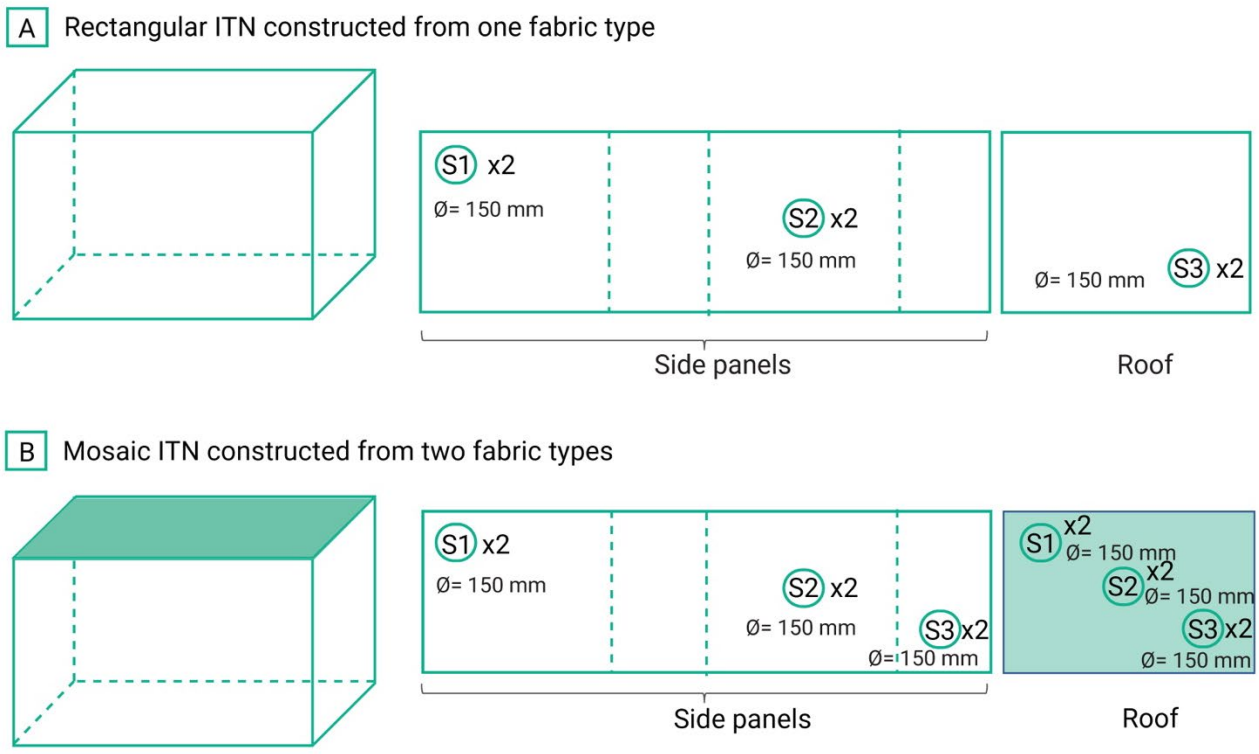
Sampling procedure for ITNs is dependent on the design and construction of the ITN, including the presence of multiple fabrics in the ITN design. The sampling procedure is declared in the Implementation guidance: Declaration of ITN construction and sampling and must ensure that any

differing fabrics in the ITN are adequately represented. The total number of samples required is dependent upon the study and the product.

For the data generation for PQ Module 3 dossier on abrasion resistance of ITNs, four ITNs per batch and six samples per fabric type per ITN are required for testing (3 samples of face side and 3 samples of back side). Figure 1 shows an example of ITN sampling schemes. The position of samples should be measured from the left hand and top seams of each panel.

Figure 1. Example ITN sampling schemes for abrasion resistance of insecticide-treated nets.

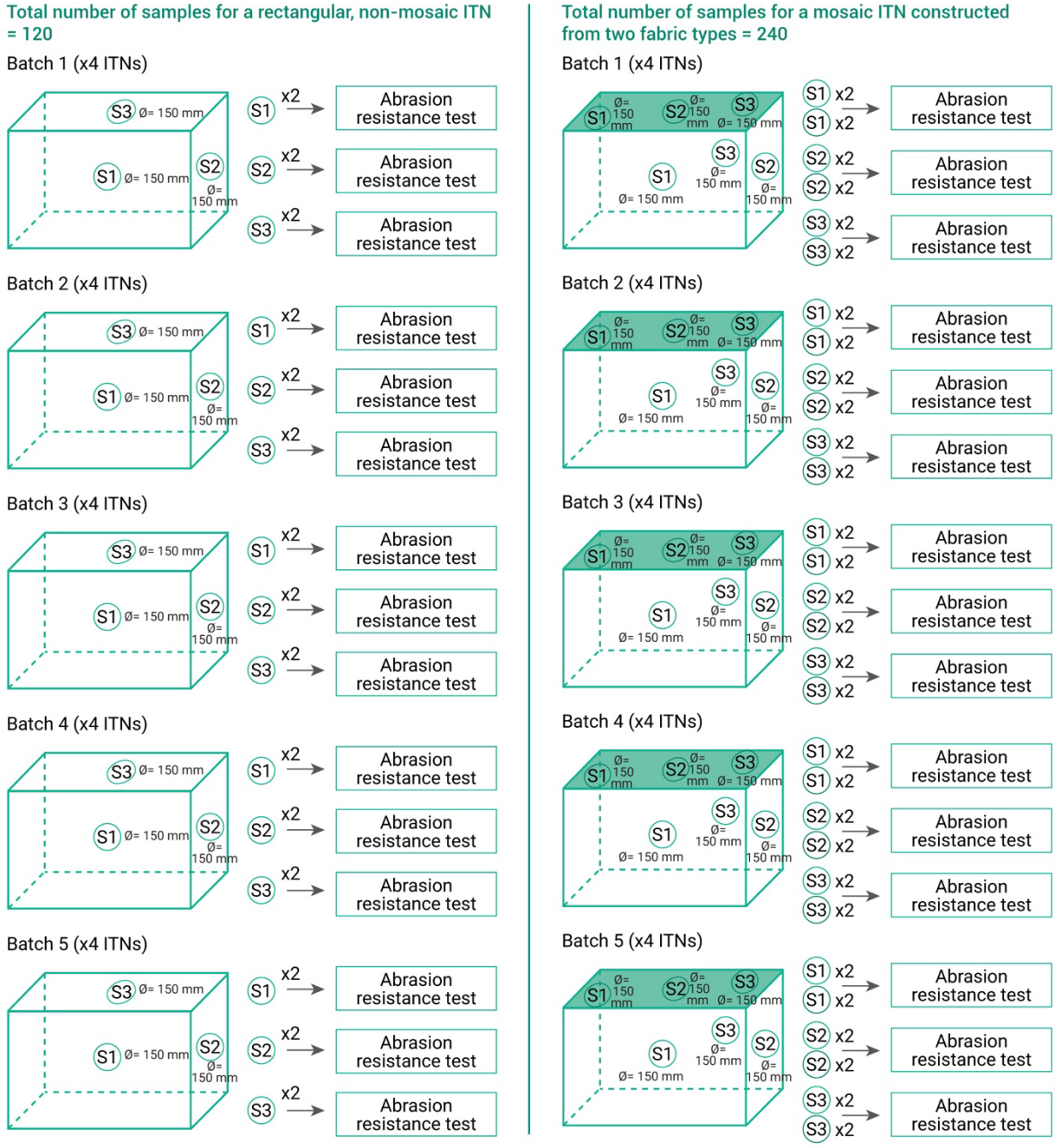
Fabric samples are cut from ITNs in defined positions to capture fabric variability. Each fabric type in the constructed ITN must be sampled and tested separately.



Therefore, a total of 120 (3 samples per ITN x 2 fabric sides x 4 ITNs per batch x 5 batches) samples are required for the measurements of homogeneous nets (60 samples should be measured on the face, (face side up), and 60 samples on the back, (back side up)), and a total of 240 (3 samples per ITN x 2 fabric sides x 4 ITNs per batch x 2 fabric types x 5 batches) samples are required for the measurements of mosaic nets (120 samples should be measured on the face, (face side up), and 120 samples on the back, (back side up)), as shown in Figure 2. Samples cut from ITNs for back side should be cut from positions directly adjacent to face sample positions shown in Figure 1. When cutting samples, cut the face side samples first and then flip the fabric and cut the back side samples - this will ensure that half of samples are face side samples and the other half are back side samples.

When taking the samples for testing it is important to ensure that they do not share wale yarns.

Figure 2. Example of total number of samples required for abrasion resistance of insecticide-treated nets for face and back of the fabric.



4.2.Test Samples

The test sample is a circle of at least 150 mm in diameter.

4.3.Sample Backing Materials

- The test sample backing fabric is 'standard wool' (as described in ISO 12947-1:1998) *(1)* with dimensions of 150 mm (+/- 0.5 mm).
- The test sample backing consists of foam (PU foam as described in ISO 12947-1:1998) *(1)* with dimensions of 150 mm (+/- 0.5 mm).

Backing foam and wool fabric should be replaced if they get damaged.

4.4.Abradant (Sandpaper)

The abradant material measures 38 mm in diameter (+/- 0.5 mm). Sandpaper should be replaced with every testing sample.

4.5.Abradant Backing Foam

The abradant backing foam (PU foam) measures 38 mm in diameter (+/- 0.5 mm).

4.6.Sample Mount

In some types of ITN sample, it may be necessary to use a sample mount, which is essentially a cut out fabric that is placed in-between the sample and the mount holder of the Martindale to increase grip and stability of the sample in the mount. This is made from the standard wool abradant fabric (as described in ISO 12947-1:1998) *(1)*. The sample mount is at least 160 mm in diameter with a 125 mm hole in the center.

5. Conditioning

The atmospheres for preconditioning, conditioning, and testing of samples are specified in ISO 139:2005 *(2)*.

6. Procedure

1. Mount the sample on the sample mount over the top of the auxiliary materials, in the following order:
    i. PU Foam.
    ii. Standard wool fabric.
    iii. Sample.
    iv. Sample mount (if required).

2. Mount fabric face up when testing the face side of the fabric. When testing back side of fabric, mount the back side up. It may be necessary to use a sample mount to prevent it from slipping. A sample mount is a circular piece of the standard wool fabric with a cut-out center so that it does not interfere with the area of the sample being tested. The procedure is illustrated in Figure 3 and Figure 4.
   An equal number of measurements should be made on both the face and back.
3. Mount the abradant in the sample holder. This should be placed over the PU foam as backing. Do not allow any creasing of the abradant. Should creasing occur, discard the abradant and use a new piece. Tips for mounting without creasing:
   i. Cut the circular abradant to size as accurately as possible, too large or too small may lead to creasing.
   ii. Cut the circular abradant around its edges approximately every 10 mm, no cut should be longer than 2 mm, as illustrated in Figure 5. Figures 6-9 illustrate acceptable and unacceptable examples.
4. Set the Martindale abrasion tester up to operate with 9 kPa pressure.
5. Set the Martindale abrasion tester so that it will stop at the relevant inspection intervals of 10 rubs, 25 rubs, then every 25 rubs up to 200 rubs. After 200 rubs, inspection should take place after every 50 rubs, up to a maximum of 1000 rubs.
6. At each inspection interval, inspect the sample for yarn failure.
7. Once a yarn break is observed, the sample fails. Remove the abradant from this sample and continue testing the other samples.
8. The test is completed when all samples have failed.

Figure 3. Order of mounting sample – Side view.

Figure 4. Mounting samples to prevent slippage– view from above.

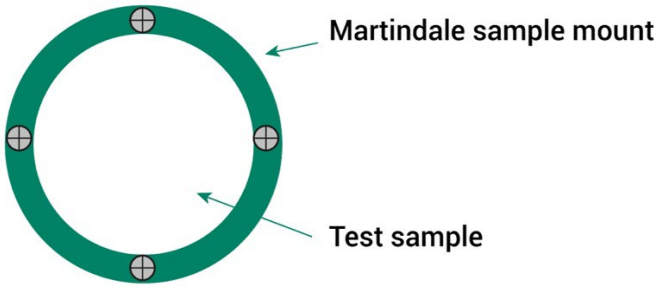


Figure 5. Cutting of the sandpaper abradant around the edges to prevent creasing of the sandpaper surface. Make small cuts towards the centre. No cut should be longer than 2 mm.

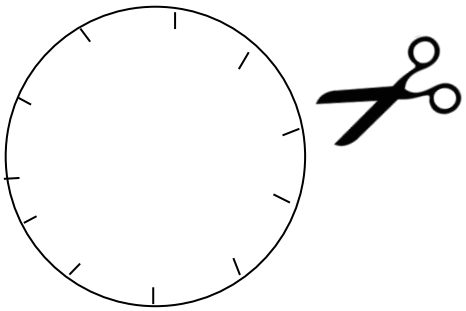


Figure 6. Correct mounting of the abradant – no creases.

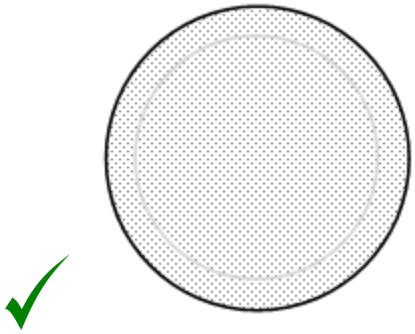


Figure 7. Incorrect mounting of the abradant. Creases are present in the abradant surface. Should this occur, discard and use a new piece of sandpaper

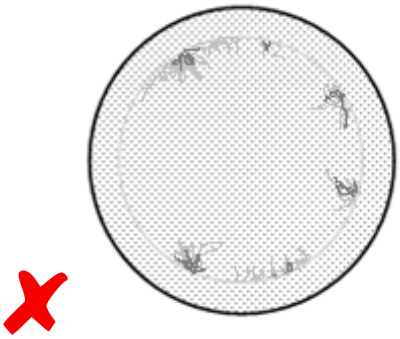
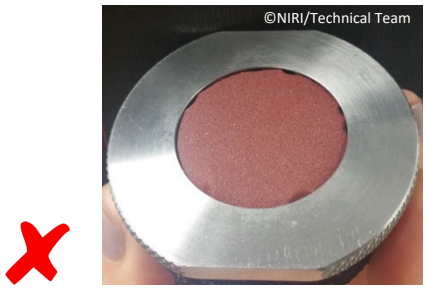


Figure 8. Example of acceptably mounted sandpaper. No creases, flat top *(3)*.

Figure 9. Example of unacceptably mounted sandpaper. Creases are visible around the edge leading to an uneven testing surface *(4)*.



7. Results

7.1. Recording and interpretation of results

At each inspection, after each rub interval:

A. Record a zero (0) when a yarn break is observed in the sample (sample has failed).
B. Record a one (1) when no yarn break is observed in the sample (sample is intact).

7.1.1. Considerations for the presentation of results

Results should be recorded in a matrix, an example of which is shown in Table 1.

Table 1. Example of test data and interpretation of results for a homogeneous ITN with a total number of 120 samples.

Sample number	Fabric side	Number of rubs										
		10	25	50	75	100	125	150	175	200	250	300
1	Face	1	1	1	1	1	1	1	1	0	0	0
2	Face	1	1	1	1	1	1	0	0	0	0	0
3	Face	1	1	1	1	1	1	1	1	0	0	0
4	Face	1	1	1	1	1	0	0	0	0	0	0
5	Face	1	1	1	1	1	1	1	1	0	0	0
6	Face	1	1	1	1	1	1	1	1	0	0	0
7	Face	1	1	1	1	1	1	1	0	0	0	0
8	Face	1	1	1	1	1	1	1	1	0	0	0
9	Face	1	1	1	1	1	0	0	0	0	0	0
10	Face	1	1	1	1	1	0	0	0	0	0	0
11	Face	1	1	1	1	1	1	1	1	0	0	0
12	Face	1	1	1	1	1	1	1	0	0	0	0
13	Face	1	1	1	1	1	1	1	0	0	0	0
14	Face	1	1	1	1	1	1	1	1	0	0	0
15	Face	1	1	1	1	1	1	1	1	0	0	0
16	Face	1	1	1	1	1	1	1	0	0	0	0
17	Face	1	1	1	1	1	1	1	0	0	0	0

Table 1. Example of test data and interpretation of results for a homogeneous ITN with a total number of 120 samples.

Sample number	Fabric side	Number of rubs										
		10	25	50	75	100	125	150	175	200	250	300
18	Face	1	1	1	1	1	1	1	0	0	0	0
19	Face	1	1	1	1	1	1	1	0	0	0	0
20	Face	1	1	1	1	1	1	1	0	0	0	0
21	Face	1	1	1	1	1	1	0	0	0	0	0
22	Face	1	1	1	1	1	1	0	0	0	0	0
23	Face	1	1	1	1	1	1	0	0	0	0	0
24	Face	1	1	1	1	1	1	0	0	0	0	0
25	Face	1	1	1	1	1	1	0	0	0	0	0
26	Face	1	1	1	1	1	1	0	0	0	0	0
27	Face	1	1	1	1	1	1	0	0	0	0	0
28	Face	1	1	1	1	1	1	0	0	0	0	0
29	Face	1	1	1	1	1	1	0	0	0	0	0
30	Face	1	1	1	1	1	1	0	0	0	0	0
31	Face	1	1	1	1	1	0	0	0	0	0	0
32	Face	1	1	1	1	1	0	0	0	0	0	0
33	Face	1	1	1	1	1	0	0	0	0	0	0
34	Face	1	1	1	1	1	1	0	0	0	0	0
35	Face	1	1	1	1	1	1	0	0	0	0	0
36	Face	1	1	1	1	1	1	0	0	0	0	0
37	Face	1	1	1	1	1	0	0	0	0	0	0
38	Face	1	1	1	1	1	0	0	0	0	0	0
39	Face	1	1	1	1	1	1	1	0	0	0	0
40	Face	1	1	1	1	1	1	0	0	0	0	0
41	Face	1	1	1	1	1	1	0	0	0	0	0
42	Face	1	1	1	1	1	1	0	0	0	0	0
43	Face	1	1	1	1	1	1	0	0	0	0	0

Table 1. Example of test data and interpretation of results for a homogeneous ITN with a total number of 120 samples.

Sample number	Fabric side	Number of rubs										
		10	25	50	75	100	125	150	175	200	250	300
44	Face	1	1	1	1	1	0	0	0	0	0	0
45	Face	1	1	1	1	1	1	1	1	0	0	0
46	Face	1	1	1	1	1	1	1	1	0	0	0
47	Face	1	1	1	1	1	1	1	0	0	0	0
48	Face	1	1	1	1	1	1	1	0	0	0	0
49	Face	1	1	1	1	1	0	0	0	0	0	0
50	Face	1	1	1	1	1	0	0	0	0	0	0
51	Face	1	1	1	1	1	0	0	0	0	0	0
52	Face	1	1	1	1	1	1	0	0	0	0	0
53	Face	1	1	1	1	1	1	0	0	0	0	0
54	Face	1	1	1	1	1	1	0	0	0	0	0
55	Face	1	1	1	1	1	1	0	0	0	0	0
56	Face	1	1	1	1	1	1	0	0	0	0	0
57	Face	1	1	1	1	1	1	0	0	0	0	0
58	Face	1	1	1	1	1	1	1	1	0	0	0
59	Face	1	1	1	1	1	1	1	0	0	0	0
60	Face	1	1	1	1	1	1	1	1	0	0	0
61	Back	1	1	1	1	1	1	1	1	0	0	0
62	Back	1	1	1	1	1	1	0	0	0	0	0
63	Back	1	1	1	1	1	1	1	1	0	0	0
64	Back	1	1	1	1	1	0	0	0	0	0	0
65	Back	1	1	1	1	1	1	1	1	0	0	0
66	Back	1	1	1	1	1	1	1	1	0	0	0
67	Back	1	1	1	1	1	1	1	0	0	0	0
68	Back	1	1	1	1	1	1	1	1	0	0	0
69	Back	1	1	1	1	1	0	0	0	0	0	0

Table 1. Example of test data and interpretation of results for a homogeneous ITN with a total number of 120 samples.

Sample number	Fabric side	Number of rubs										
		10	25	50	75	100	125	150	175	200	250	300
70	Back	1	1	1	1	1	0	0	0	0	0	0
71	Back	1	1	1	1	1	1	1	1	0	0	0
72	Back	1	1	1	1	1	1	1	0	0	0	0
73	Back	1	1	1	1	1	1	1	0	0	0	0
74	Back	1	1	1	1	1	1	1	1	0	0	0
75	Back	1	1	1	1	1	1	1	1	0	0	0
76	Back	1	1	1	1	1	1	1	0	0	0	0
77	Back	1	1	1	1	1	1	1	0	0	0	0
78	Back	1	1	1	1	1	1	1	0	0	0	0
79	Back	1	1	1	1	1	1	1	0	0	0	0
80	Back	1	1	1	1	1	1	1	0	0	0	0
81	Back	1	1	1	1	1	1	0	0	0	0	0
82	Back	1	1	1	1	1	1	0	0	0	0	0
83	Back	1	1	1	1	1	1	0	0	0	0	0
84	Back	1	1	1	1	1	1	0	0	0	0	0
85	Back	1	1	1	1	1	1	0	0	0	0	0
86	Back	1	1	1	1	1	1	0	0	0	0	0
87	Back	1	1	1	1	1	1	0	0	0	0	0
88	Back	1	1	1	1	1	1	0	0	0	0	0
89	Back	1	1	1	1	1	1	0	0	0	0	0
90	Back	1	1	1	1	1	1	0	0	0	0	0
91	Back	1	1	1	1	1	0	0	0	0	0	0
92	Back	1	1	1	1	1	0	0	0	0	0	0
93	Back	1	1	1	1	1	0	0	0	0	0	0
94	Back	1	1	1	1	1	1	0	0	0	0	0
95	Back	1	1	1	1	1	1	0	0	0	0	0

Table 1. Example of test data and interpretation of results for a homogeneous ITN with a total number of 120 samples.

Sample number	Fabric side	Number of rubs										
		10	25	50	75	100	125	150	175	200	250	300
96	Back	1	1	1	1	1	1	0	0	0	0	0
97	Back	1	1	1	1	1	0	0	0	0	0	0
98	Back	1	1	1	1	1	0	0	0	0	0	0
99	Back	1	1	1	1	1	1	1	0	0	0	0
100	Back	1	1	1	1	1	1	0	0	0	0	0
101	Back	1	1	1	1	1	1	0	0	0	0	0
102	Back	1	1	1	1	1	1	0	0	0	0	0
103	Back	1	1	1	1	1	1	0	0	0	0	0
104	Back	1	1	1	1	1	0	0	0	0	0	0
105	Back	1	1	1	1	1	1	1	1	0	0	0
106	Back	1	1	1	1	1	1	1	1	0	0	0
107	Back	1	1	1	1	1	1	1	0	0	0	0
108	Back	1	1	1	1	1	1	1	0	0	0	0
109	Back	1	1	1	1	1	0	0	0	0	0	0
110	Back	1	1	1	1	1	0	0	0	0	0	0
111	Back	1	1	1	1	1	0	0	0	0	0	0
112	Back	1	1	1	1	1	1	0	0	0	0	0
113	Back	1	1	1	1	1	1	0	0	0	0	0
114	Back	1	1	1	1	1	1	0	0	0	0	0
115	Back	1	1	1	1	1	1	0	0	0	0	0
116	Back	1	1	1	1	1	1	0	0	0	0	0
117	Back	1	1	1	1	1	1	0	0	0	0	0
118	Back	1	1	1	1	1	1	1	1	0	0	0
119	Back	1	1	1	1	1	1	1	0	0	0	0
120	Back	1	1	1	1	1	1	1	1	0	0	0

Table 1. Example of test data and interpretation of results for a homogeneous ITN with a total number of 120 samples.

Sample number	Fabric side	Number of rubs										
		10	25	50	75	100	125	150	175	200	250	300
Intact Samples		(120/120) *100 =100%	(120/120) *100 =100%	(120/120) *100 =100%	(120/120) *100 =100%	(120/120) *100 =100%	(96/120) *100 =80%	(48/120) *100 =40%	(24/120) *100 =20%	(0/120) *100 =0%	(0/120) *100 =0%	(0/120) *100 =0%

The abrasion resistance score is the number of rubs at which ≥ 66.7% of the samples remain intact (i.e. 80 out of 120 for a homogeneous ITN). In the example shown in Table 1 the final abrasion resistance score is 125 rubs (80% of samples are intact).

If the failure of samples is spread across five or more inspection intervals, then the test should be repeated to determine better accuracy.

8. Test Report

Include in the test report:

1. Sample details and identity.
2. The date the test is conducted.
3. Martindale tester manufacturer and model.
4. The test operator.
5. The location and laboratory.
6. The conditions of testing if outside standard testing conditions outlined in this document.
7. The pressure (kPa) at which the test is undertaken.
8. The test data matrix as outlined in section 7 Results (Table 1).
9. The abrasion resistance score (number of rubs at which ≥ 66.7% of samples remain intact).

9. Related Documents

- WHO PQT/VCP Implementation guidance - Declaration of ITN construction and sampling Procedure
- WHO PQT/VCP Implementation guidance - Data requirements table – Module 3
- WHO PQT/VCP Implementation guidance - IG - Snag strength
- WHO PQT/VCP Implementation guidance - IG - Resistance to hole formation
- Physical testing requirements for ITNs: Accreditation and compliance with international standards for the generation of data intended to be submitted to WHO prequalification

10. References

When using the normative references for physical tests, the updated version of the standard should always be used when available.

1. International Organization for Standardization. ISO 12947-1:1998. *Textiles – Determination of the abrasion resistance of fabrics by the Martindale method – Part 1: Martindale abrasion testing apparatus*. Geneva: ISO; 1998.
2. International Organization for Standardization. ISO 139:2005. *Textiles – Standard atmospheres for conditioning and testing*. Geneva: ISO; 2005.
3. Example of acceptably mounted sandpaper. No creases, flat top. 15th December 2023, Leeds (UK), Phys/Chem tests for ITNs: Abrasion resistance, NIRI/Technical Team, Nonwovens Innovation & Research Institute (NIRI Ltd.).
4. Example of unacceptably mounted sandpaper. Creases are visible around the edge leading to an uneven testing surface. 15th December 2023, Leeds (UK), Phys/Chem tests for ITNs: Abrasion resistance, NIRI/Technical Team, Nonwovens Innovation & Research Institute (NIRI Ltd.).

11. Bibliography

- Wheldrake A, Guillemois E, Arouni H, Russell SJ. Textile testing to assess the resistance to damage of long-lasting insecticidal nets for malaria control and prevention. Malar J. 2021;20:47. doi: 10.1186/s12936-020-03571-4.
- Wheldrake A, Guillemois E, Arouni H, Chetty V, Russell SJ. The causes of holes and loss of physical integrity in long-lasting insecticidal nets. Malar J. 2021;20:45. doi.org/10.1186/s12936-020-03567-0.
- International Organization for Standardization. ISO 12947-2:1998. *Determination of abrasion resistance of fabrics by the Martindale method – Part 2: Determination of specimen breakdown*. Geneva: ISO; 1998.