Final report on lotus fibres analysis
Project with VALMA. Caring Luxury. Liechtenstein

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Specialist filing “Natural Fibres”

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1 Background

1.1 Situation

VALMA, a start-up company from Liechtenstein, contacted the Swiss Textile College (STC) at the end of last year. The company plans to develop sustainable fashion based on rare yarns such as lotus fibres. However, in order to do so, they need a partner with the corresponding technological know-how in the textiles sector. STC has offered to provide assistance and support within its capabilities.

In a preliminary phase, an analysis of the properties of lotus fibres from Myanmar will be carried out and deductions for possible processing using conventional preparation and spinning machinery established.

1.2 Task

- Prepare the fibres of the lotus plant and analyse them fibres under the microscope
- Evaluate the key mechanical properties of the fibres
- On the basis of the results, determine which processes would be required to spin usable yarn from lotus fibres

1.3 Objective

- Determine the key characteristic values of the fibres
- Draw conclusions about possible behaviour during the preparation or spinning processes and make deductions for subsequent processing of the fibres
- Indicate additional steps in the development process and the possible costs for further development stages

2 Internet search on the topic of lotus fibres

The information below is a summary of the key aspects of an article published in the “Zeit” online newspaper (www.zeit.de) in 2011. [1]

2.1 Harvest

The lotus stems are harvested at the end of the rainy season. They are around 2-3 metres long and are completely submerged under water. During harvesting, pieces with a length of approximately 10 cm are cut off and loose threads are formed, which are then combined together from several stems (4 pieces). The fibres are exposed and can be spun manually and processed further.

2.2 Yarn production

Fibres from several stems are rolled or turned together and the loose end is stuck onto the loose end of the loop when wet. This produces an endless thread.

2.3 Weaving

Prior to weaving, the lotus yarn is moistened with rice starch, and during weaving it must be repeatedly remoistened to prevent it from breaking.

The images below are from a reportage on the “Pro Sieben” channel (Galileo – topic: Lotus silk) from 2012: [2]






3 Microscopic analyses

As described in Section 2, the lotus fibres in Myanmar are processed when they are wet. To be able to perform the analyses in Switzerland, it was necessary to dry out the fibre material so that it could be sent via post. Firstly, microscope examinations are performed at the STC and at Testex in Zurich (Testex AG is a materials testing institute with its head office in Zurich).

3.1 Longitudinal view of the fibres

Figure 1: Longitudinal view of the fibres, microscope image, source STC

The image shows a number of elementary fibres of the lotus plant, which are mainly present as a bundle i.e. in the form of a fibre composite structure. Some bundles appear to have a corkscrew-like appearance that clearly shows how several lotus elementary fibres are arranged in parallel next to each other. It is likely that the corkscrew-like condition occurred during the drying process, or when the fibres were remoistened under the microscope.

All the microscope images below were taken by Testex in Zurich using a scanning electron microscope (SEM). The images facilitate even better resolution and offer exceptional image sharpness.

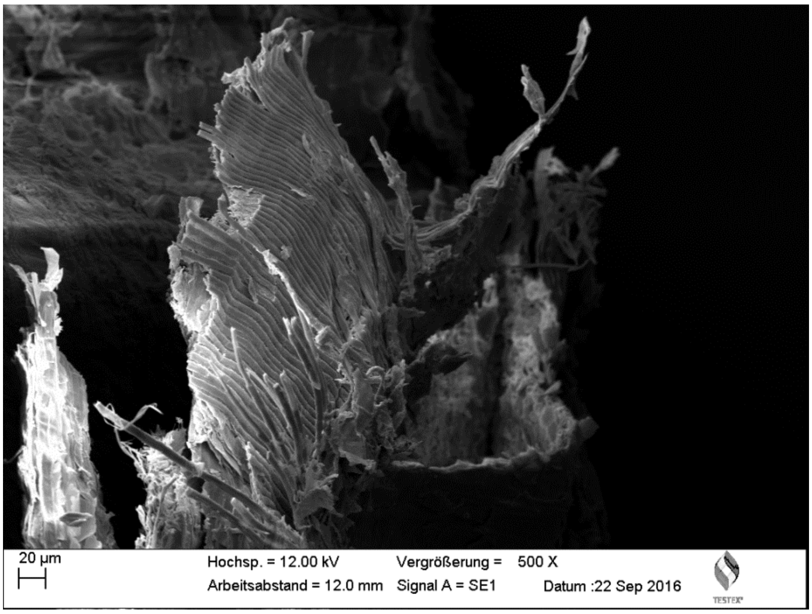

Figure 2: Testex SEM imaging, magnified 500 times

The image clearly shows part of a completely torn lotus stem, enlarged 500 times with excellent resolution. Here it can also be observed that the lotus elementary fibres are interconnected.

Figure 3: Testex SEM imaging, magnified 1,220 times

With a magnification of 1,220 times, the connection points between the fibres are visible with a certain regularity i.e. at specific intervals. Furthermore, the aforementioned torsion of the fibres can be seen.

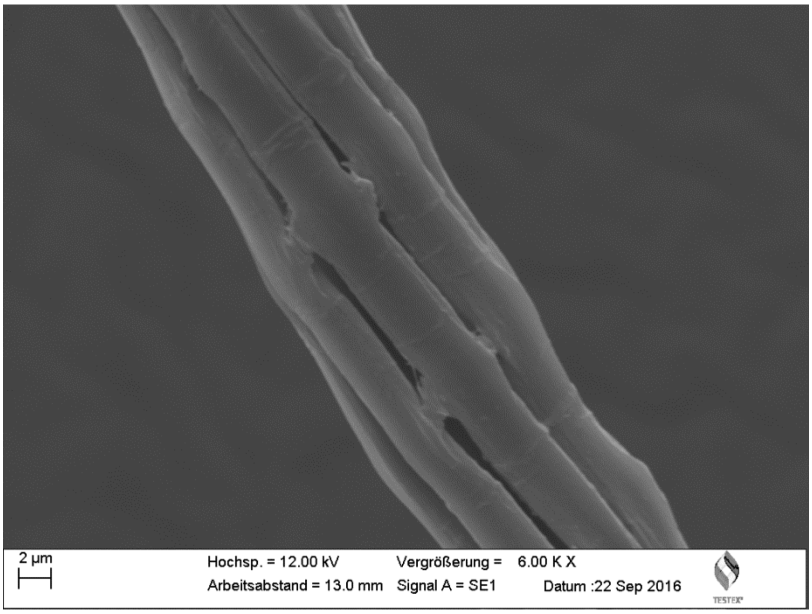

Figure 4: Testex SEM imaging, magnified 6,000 times

The 6,000 times magnification reveals that the fibres have a specific distribution in terms of thickness i.e. in terms of the fibre fineness. The fibres do not all have the same diameter and also vary in terms of length versus diameter. This is normal for natural fibres and confirms the regularity, as is also known from other fibre types.

The binding points mentioned earlier are also clearly visible. It would now be necessary to investigate the substances that constitute the actual fibres and connections themselves, and which organic or chemical substances can be used to loosen or dissolve the binding points.

In general, the question arises as to whether further processing of the fibres will only be possible as a bundle, or whether it will also be feasible to separate the elementary fibres by dissolving the binding points, to enable these fibres to then be fed into further processes. It should also be possible to break up the binding points using mechanical action.

3.2 Cross-section

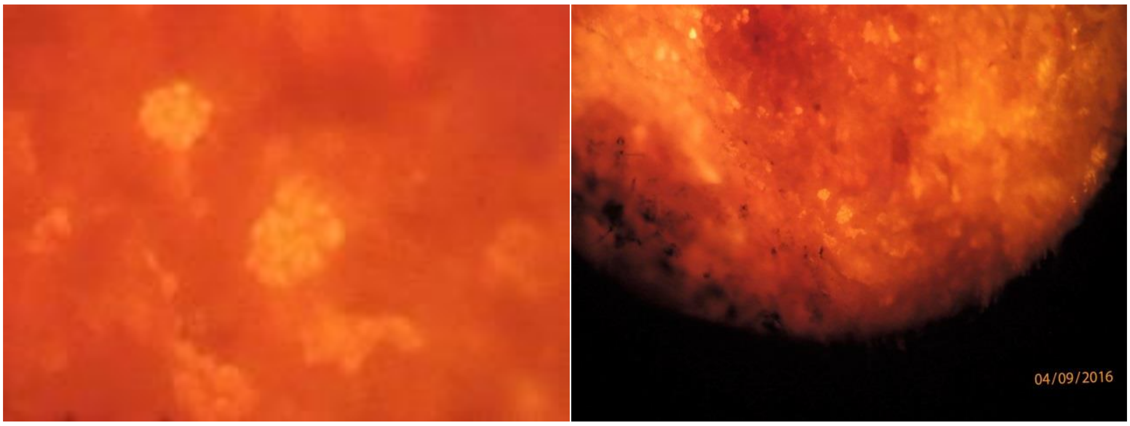

Figure5: Microscopic images by STC

Preparation of the fibre cross-sections was problematic, as it was extremely difficult to prepare the exceptionally fine primary fibres in such a way that an acceptable image could be taken. It can be seen that the fibres in the images above are in bundles. As expected, the diameter is not circular and is more an oval or even trilobal shape, similar to silk. Further deductions with respect to cavities or the like are not possible using these images.

Better images of the fibre cross-section could be obtained by embedding the fibres in wax using a microtome. This would need to be carried out in an additional step.

3.3 Fibre diameter

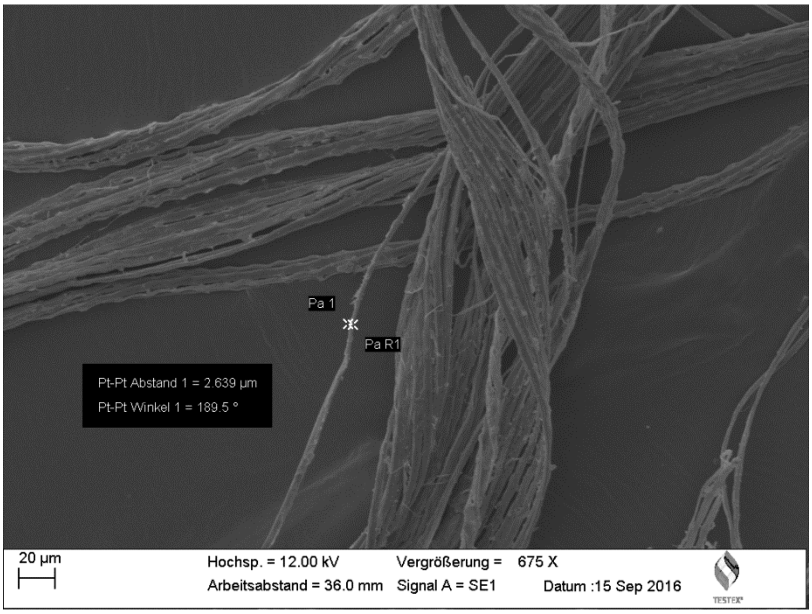

Figure 6: Testex SEM imaging, magnified 675 times

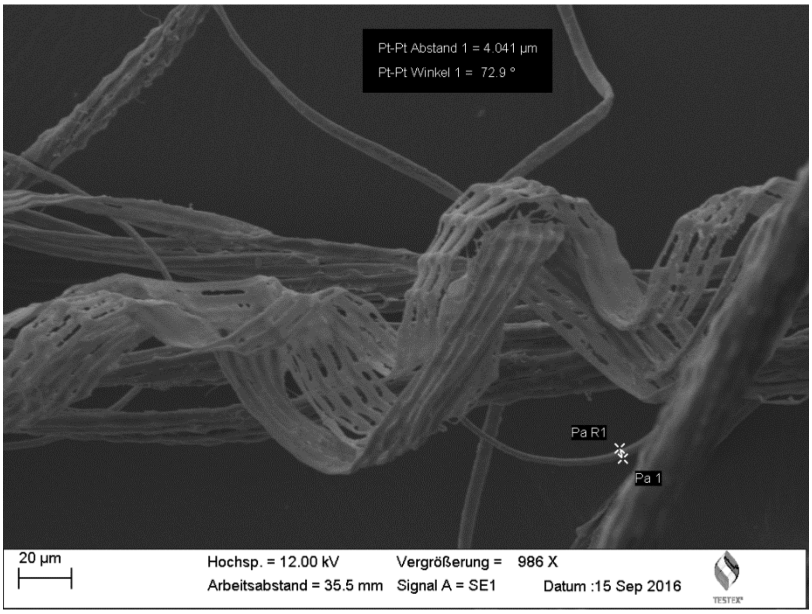

Figure 7: Testex SEM imaging, magnified 986 times

In the next step, an attempt was made to investigate the diameter of individual fibres. Both the images above show fibre thicknesses of 2.6 µm and 4.0 µm.

These diameters can be graded as extremely fine and occur in this form only very rarely in nature. Cotton fibres generally have a diameter of approximately 5-10 µm, a human hair 50-70 µm and top-quality cashmere 12-15 µm.

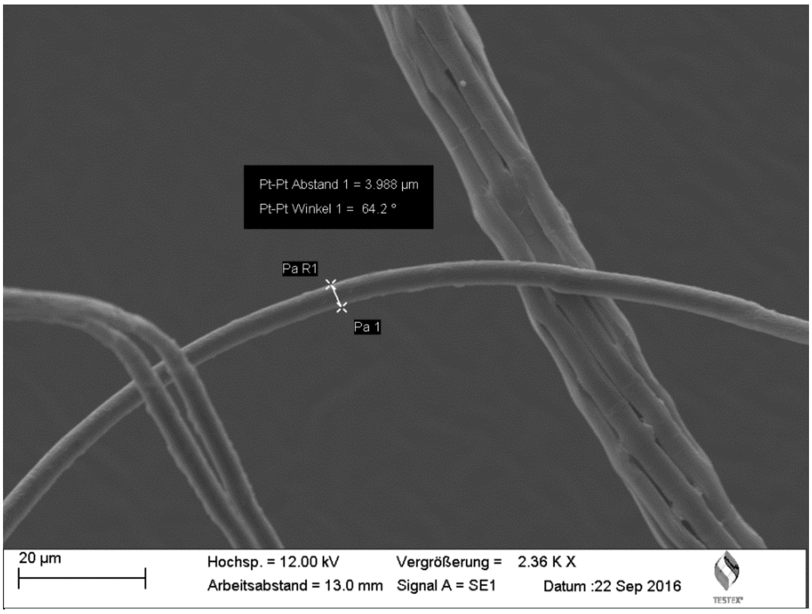

Figure 8: Testex SEM imaging, magnified 2,360 times

The 2,360 times magnification confirms the accuracy of the measurement, as it is apparent in this image that the fibre thickness has been recorded with absolute precision. In this case the measurement was 4.0 µm.

If separation of the individual lotus stem fibres were successful and the physical properties suitable for textile processes, extremely fine staple fibre yarns could then be manufactured. However, in addition to the strength/elongation values, fibre length must also be taken into account, given that if the ratio of fibre fineness to fibre length is unfavourable, further processing to produce a consistent yarn with an even texture will be practically impossible.

4 Fibre strength and elongation / fibre fineness

In the tests described below, an attempt was made to determine additional physical parameters using common testing equipment. The tests were performed at the Rieter company in Winterthur in an air-conditioned test laboratory by trained personnel. The tests were carried out using the “Lenzing-Technik Vibrojet 2000”.

Firstly, fibre fineness was measured. The load weight was then removed and the fibres automatically re-transported. To test the “strength and elongation” parameter, an additional load weight is not required due to automatic clamping and the subsequent electronic pretension of the fibres. The fibres are placed in a rotary magazine and the subsequent measurement procedure is fully automated. The area of application for all fibre types is a minimum staple length of 26 mm and a maximum tensile strength of 500 cN. The fibre fineness range is 0.5 to 200 dtex. [3]

Vibrodyn 400

Determination of the strength and elongation of individual fibres. The test is carried out according to the principle of the constant deformation speed of the sample in the tensile direction. The fibre is stretched in two electromagnetically actuated clamps, with the top end of the fibre being secured to the force-sensing device and the bottom end remaining mobile.

Vibroskop 400

Determination of the fineness of individual fibres (synthetic fibres) and monofilaments. The fibre is suspended and an alternating electrical field with a constant frequency causes the fibre to oscillate. The oscillation length is modified by moving a contact sheath until the maximum oscillation length is achieved (resonance). The titre (fibre fineness) can then be calculated, taking the pretension into account. [3]

4.1 Measurement results for strength / elongation properties

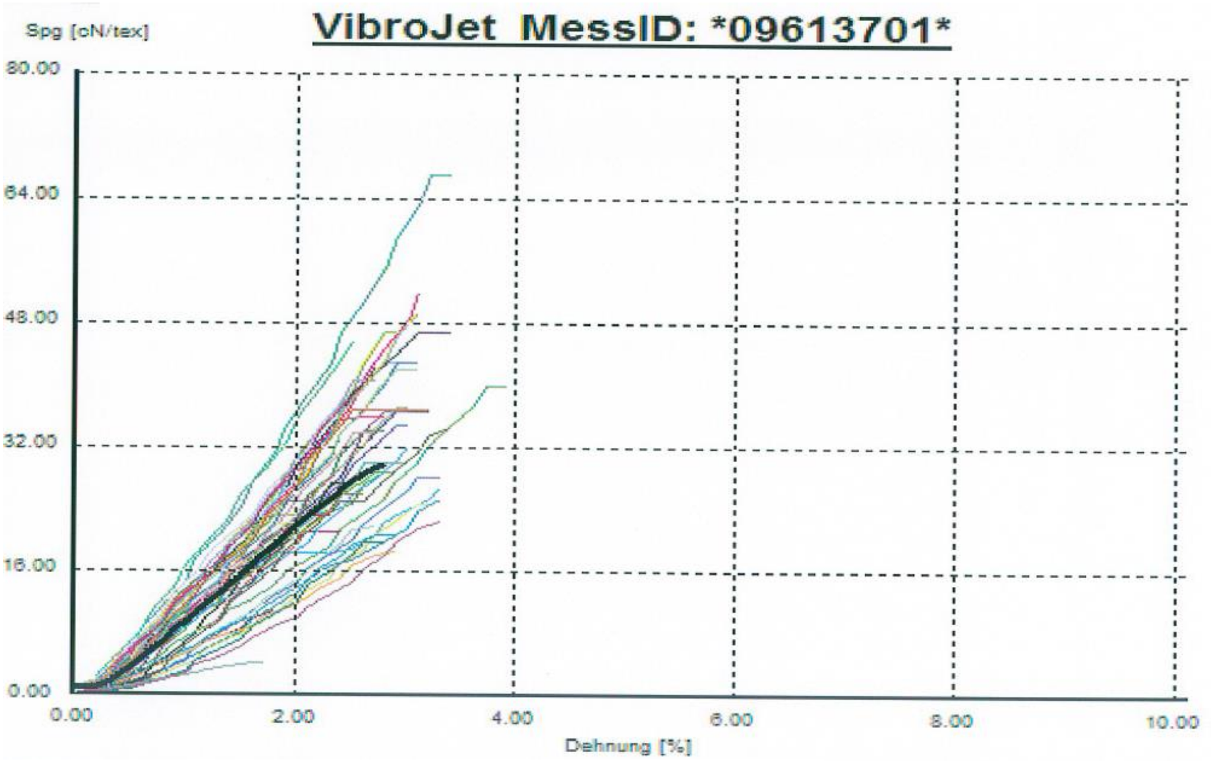

Figure 9: Vibrojet measurement protocol, test performed by the Rieter company

The measurement protocol shows a very high dispersion of the values overall. The mean strength is 36.83 cN/tex. 48 fibres were tested in total. The standard deviation is 11.54. This would indicate either that there were difficulties during the measurement, caused by extremely fine fibres, and/or the fact that some fibres are in bundles. A high dispersion of the fibre fineness could also be one reason for this outcome.

Strength is at a good level overall. For comparison, here are some strength values for well-known natural fibres (1):

- Cotton approx. 25-50 cN/tex
- Flax approx. 30-55 cN/tex
- Wool approx. 10-16 cN/tex

The mean elongation values are around 2.78%. The standard deviation here is 0.5%. The elongation values can be graded as extremely low. Flax fibre also has very low elongation at around 1.5 - 4 % (1).

This can be seen in the diagram, as the fibres have virtually no elastic elongation. Rather than an elastic progression, the curves indicate an abrupt end as a result of breakage. This confirms the claim generally found in online searches that the fibres break very easily. Fibres without elastic elongation are highly unlikely to deform and are actually highly unsuitable for textile processes, or can only be processed using specific yarn conversion methods. Consequently, the result can also be seen in the working capacity of the fibres. The mean value here is 0.07 cN*cm (standard deviation 0.04 cN*cm).

This means that the lotus fibres have practically no working capacity. In practice during a normal production process, it is almost impossible to feed this type of fibre in the short or long staple range. The fibres would inevitably tear during carding/combing, and during the final spinning process would also lead to elevated fibre breakage ratios and increased fly formation. It would certainly be advisable to confirm the results one more time by using a further batch and, in this context, also to test the wet strength, which will probably be higher.

4.2 Fibre fineness measurement results

The fibre fineness measurement performed with the Vibrojet produced an average fineness of 1.69 dtex. The standard deviation here was 0.56, which is an extremely high value and shows that certain thickness distributions are present in the fibres. The result is also higher distributions in the strength/elongation behaviour. For the purpose of comparison, cotton and silk both have a fibre fineness of 1-4 dtex (1). The test protocols are attached in the annex.

5 Fibre length

According to online searches, the fibres in the bundle are checked, cut to a specific length, then twisted and spun.

Generally speaking, fibres in short or long staple spinning machinery must possess similar length ratios to cotton (short staple) or wool (long staple). Hence, if the lotus fibre are to undergo further processing as elementary fibres, they would need to be shortened in an additional process (e.g. cottonisation of flax fibres).

However, as the fibres are extremely fine, the fibre length may not be too long, otherwise processing will not be possible due to the slenderness ratio of the fibres being too low.

The slenderness ratio of the fibres is the ratio of fibre fineness to fibre length. Then the fibre stiffness can either be too high (-> poor integration into the yarn structure) or too low (-> fibre parallelisation is difficult and the formation of burls), leading to various problems during process and yarn formation.

6 Spinning the fibres

Dry spinning of the lotus fibres alone and without carrier fibres appears to be practically impossible in short or long staple spinning machinery based on the available strength/elongation values. Provided that the fibres are available as elementary fibres, a low-percentage admixture would be feasible, e.g. with cotton. For this to happen, the lotus fibres must be separated into elementary fibres in a preliminary step, then shortened to the mean fibre length of cotton.

What would be much more realistic given the results is wet spinning of the elementary fibres as a bundle. To a certain extent, flax fibres are spun in a similar way. During flax processing, the fibres are combined in a bundle or band format and then stretched. The elementary fibres are exposed during roving in a hot water bath at approx. 70 °C, the pectins disintegrate, and stretching and separation of the long fibres is then possible on the final spinning machine when the fibres are wet.

With lotus fibres, the elementary fibres would also remain together as a bundle, with sufficient other bundles/fibres to achieve a required strength, then stretched and spun on the wet spinning machine. For trials in this direction, there must be sufficient dried fibre material available, which is then prepared and spun on a flax spinner. Here also it can generally be assumed that it will probably be necessary to add another raw material.

7 Conclusion and deductions

The microscopic analyses and physical testing have shown that the elementary fibres of the lotus plant have a **very low fibre diameter**, which lies in the **range of 2.5-4 µm**. Consequently, the fibre fineness of the elementary fibres is extremely high.

The microscope images show that the fibres are in a bundle. The **elementary fibres** are interconnected by **connection points** located at regular intervals.

The **strength/elongation behaviour** of the fibres has shown **significant weaknesses** of the fibres. At 2%, the maximum tensile force/expansion is extremely low. The fibres possess virtually no elastic elongation and consequently very low deformability for potential processing in the textile industry. The result is high fibre brittleness, and as a result, poor process stability.

The strength/elongation values are definitely **too low** for **short staple and long staple spinning machinery**, hence the use of lotus fibre in potential processing will only be possible if it is blended as an admixture. However, this would require cottonisation of the fibres to achieve a similar fibre length dispersion as cotton, for example, and to produce elementary fibres.

Spinning as per the **wet spinning procedure** for flax is feasible. For this purpose, the fibres would not need to be shortened for the process. They can be stretched as a bundle. One possibility would be to dry the bundles after the harvest, collect them, and then attempt to process them on a flax spinner. The extent to which only an **admixture** with **another raw material** would also be possible for wet spinning will greatly depend on the wet strength of the fibres. Sufficient fibre materials must be available for testing. For spinning trials, raw material quantities of around 50 kg of fibre material are advisable.

8 Source list

[1] Internet, http://www.zeit.de/reisen/2011-09/birma-lotos, report dated 14.10.2011 on www.zeit.de

[2] Internet, http://www.prosieben.de/tv/galileo/videos/4347-lotusseide-clip, reportage on Pro Sieben channel, Galileo – Topic Lotus Silk, 21.12.12

[3] Operator Manual, Lenzing Vibrojet, Lenzing company, Lenzing, Austria

List of images