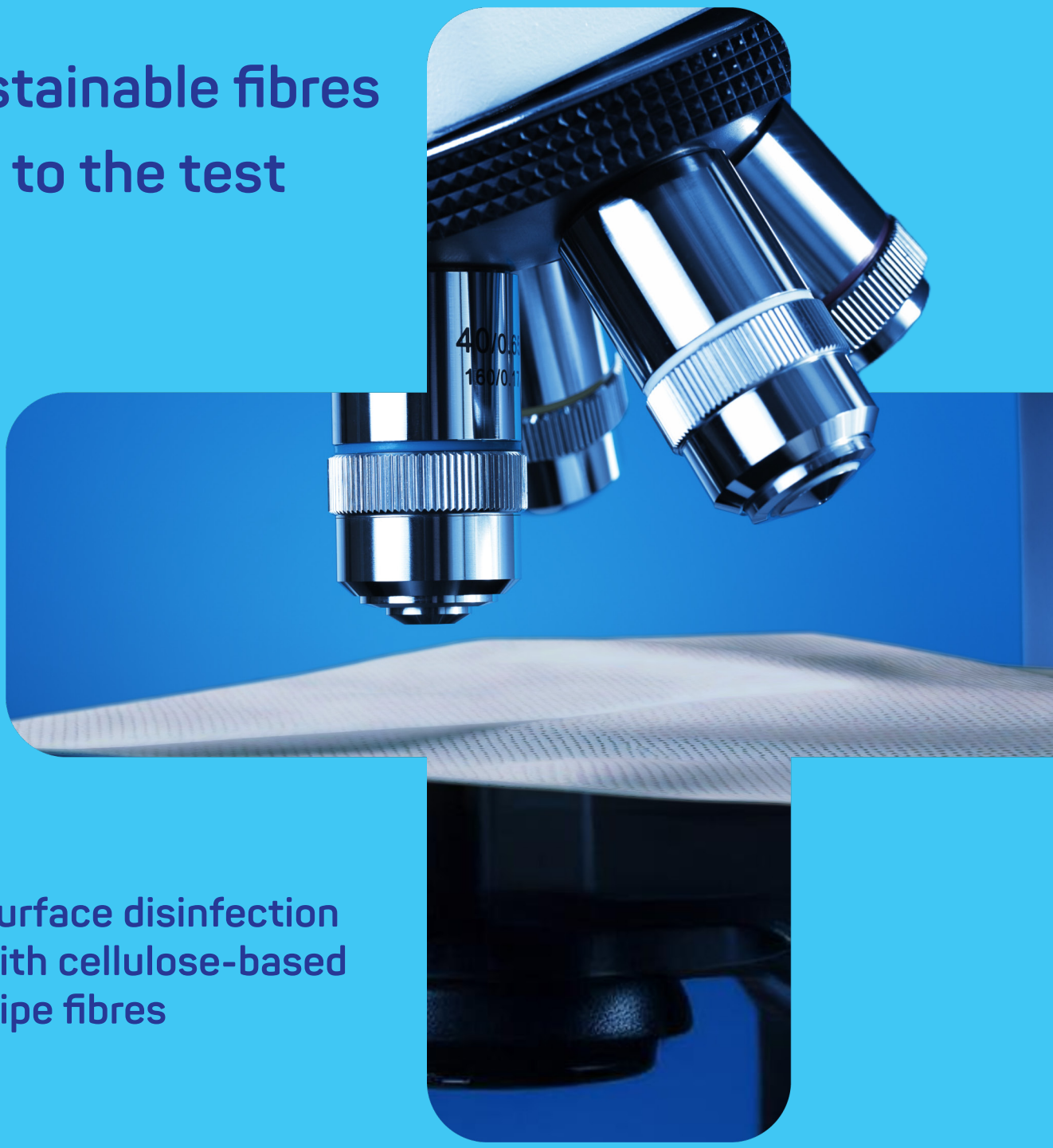
HARTMANN

Helps. Cares. Protects.

Sustainable fibres put to the test



+ Surface disinfection with cellulose-based wipe fibres

Whitepaper

Sustainable fibres put to the test

Surface disinfection with cellulose-based wipe fibres

Content

1 Introduction

Simple, safe, fast: pre-soaked disinfectant wipes

They have become an integral part of everyday hospital life: ready-to-use wipes in **flowpack** packaging. Their use eliminates the need to prepare disinfectant solutions and reprocess reusable systems, both of which are error-prone processes that are carried out at the expense of **patient safety** [1,2].

Until 2022, disinfectant wipes in medical facilities, both pre-soaked and dry wipe systems, were largely based on **plastic wipe fibres** made of PP (polypropylene) or PET (polyethylene terephthalate). In 2022, around 1,800 tons of plastic waste were generated in German hospitals, which was ultimately incinerated as potentially contaminated (**Figure 1**).

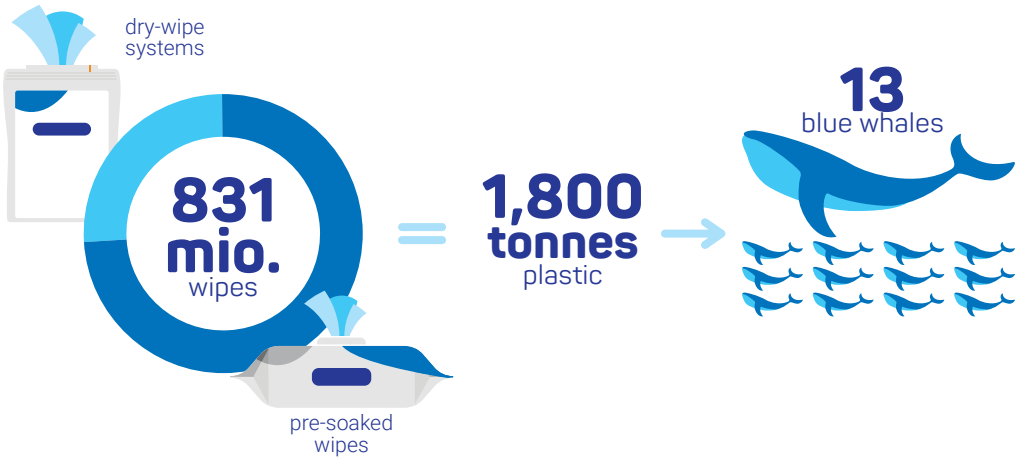


Figure 1:
The plastic fibre in wipes used for disinfection in 2022 generated a total of around 1,800 tonnes of plastic waste in German hospitals, which is equivalent to the weight of 13 adult blue whales.

In 2023, Bacillol® Zero Tissues were launched on the market, using a novel and sustainable chemical formulation and wipe fibres made from sustainable cellulose. Shortly afterwards, Bacillol® 30 Sensitive Tissues underwent a **transformation** and are now also available with sustainable cellulose-based wipe fibres as Bacillol® 30 Sensitive Green Tissues.

By using cellulose-based fibre materials, not only can enormous amounts of plastic be saved, but the **CO_2 footprint** in disinfection and hygiene can also be further reduced.

Introduction

1 → Non-woven fibres inspired by nature

Interest in sustainable fibres has increased steadily in recent years, not only for disinfecting wipes but also for everyday textiles. If the raw materials for these fibres come from sustainable forestry, cellulose fibres can have a very **favourable environmental balance** (**Figure 2**) [3].

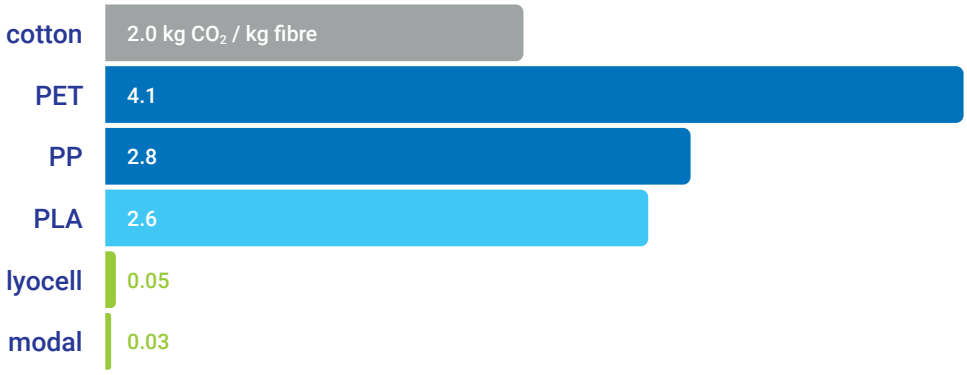


Figure 2:
CO_2 emissions of various fibre types. The emissions refer to the production per kilogram of fibre [3].
PET: polyethylene terephthalate, PLA: polylactic acid, PP: polypropylene.

Cellulose fibres: same same, but different

There are many different types of cellulose-based fibres with different properties. The best known and most widely used is viscose (rayon), with an annual production of 5.8 million tonnes per year; this corresponds to about 5.1% of global fibre production [4]. Other well-known cellulose-based fibres include lyocell or modal fibres. (**Figure 3**).

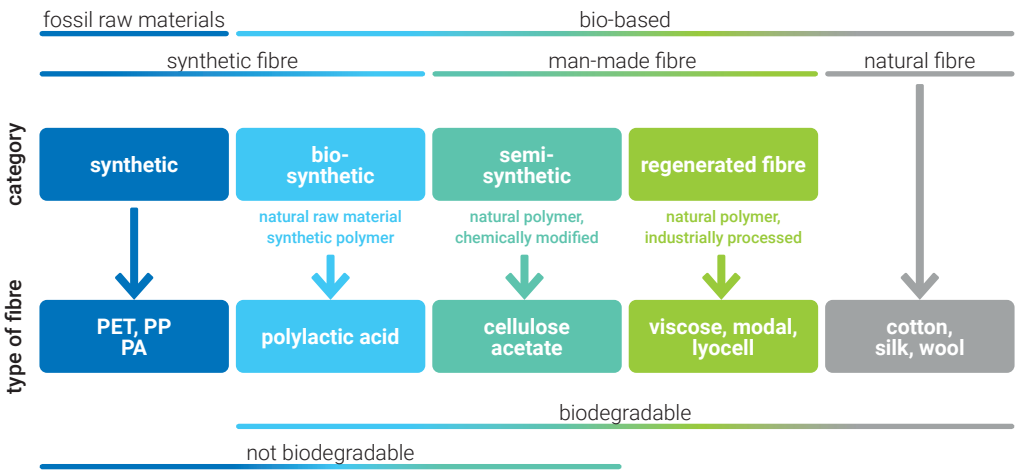


Figure 3:
Overview of different fibre types for non-woven wipes. Depending on the manufacturing process, certain fibre types are biodegradable or not.
PA: polyamide, PET: polyethylene terephthalate, PP: polypropylene.

Before the application...
The carbon cycle

"Disinfectant wipes are incinerated in the end anyway, so why make it sustainable?"

In fact, potentially contaminated disinfectant wipes must be incinerated to **minimise the risk of infection** for others. The advantage of disinfectant wipes made from sustainable raw materials therefore only becomes apparent at second glance:

The carbon cycle shows that with cellulose-based fibres, carbon moves in a cycle and is constantly bound and released (**Figure 4**). Overall, therefore, the amount of CO_2 in the atmosphere does not change (with the exception of CO_2 emissions from production and transport, for example) [5,6]. However, it is crucial here that the wood comes **from sustainable forestry**.

With a wipe made from petroleum-based plastics, carbon is extracted from millions of years old reservoirs and ultimately released; the global amount of CO_2 in the atmosphere increases.

This means that even if sustainable disinfectant wipes are incinerated after use, they make a contribution to **climate protection**.

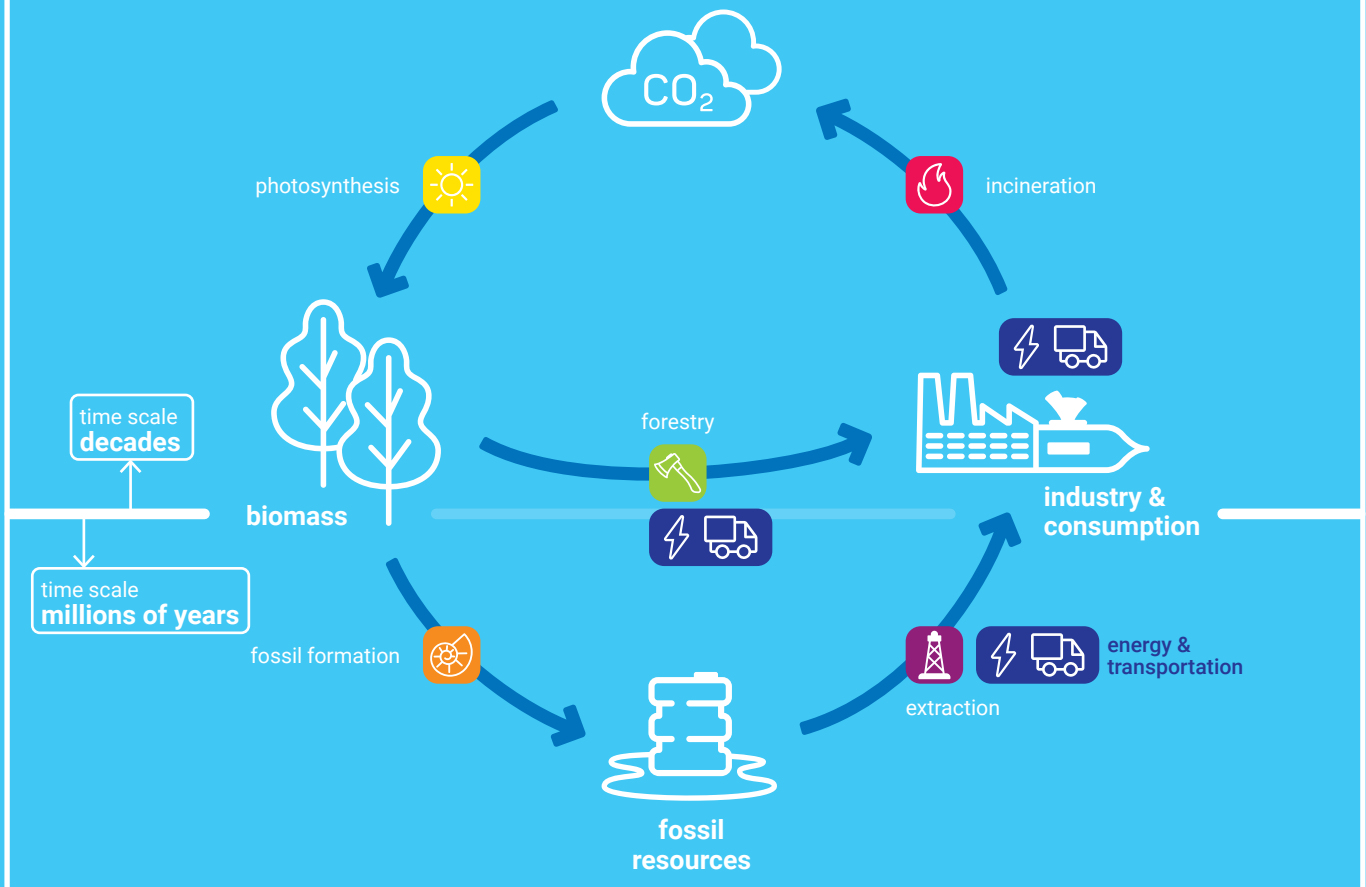


Figure 4:
In the global carbon cycle, it is clear that the direct use of biomass in products binds the CO_2, that is ultimately produced, more quickly than the use of fossil resources, which take millions of years to form [5,6].

2 Effective. From the first to the last wipe

Gravity pulls the liquid downwards

In flowpacks with pre-soaked disinfectant wipes, two forces are continuously at work that are largely responsible for the distribution of the liquid within the wipe stack:

Gravity, which pulls the disinfectant downwards, and the **capillary forces** of the wipe fibres, which distribute the liquid equally (isotropically) in all directions within the wipe stack (**Figure 5**). The downward forces add up and outweigh the isotropic capillary forces, so that when flowpacks are stored over a longer period of time, the liquid can sink and thus be distributed unevenly [7].

This gradient can also be made visible by colouring the disinfectant before soaking the dry wipes. Due to gravity, the liquid and therefore also the dye collects in the lower part of the wipe stack and the lower wipes are darker (**Figure 6**).

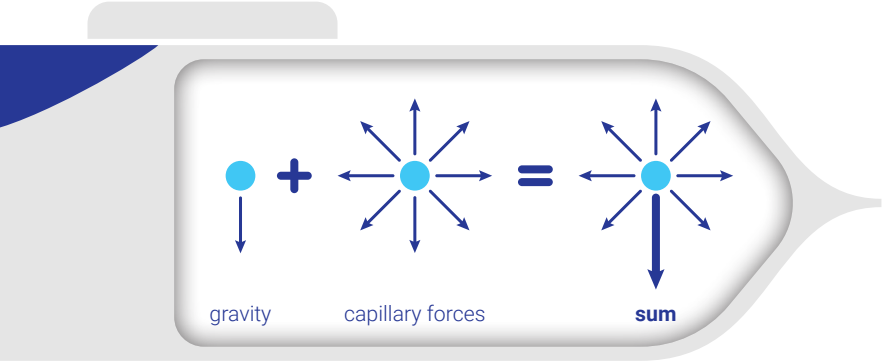


Figure 5:
Gravity and capillary forces are forces within a stack of pre-soaked disinfectant wipes. The downward forces add up and cause the liquid to sink in the long term.

Figure 6:
The disinfectant was coloured blue before impregnating a flowpack. After the flowpack had been stored for 3 days with the lid up, the stack of cloths was removed from the packaging and photographed.

Effective. From the first to the last wipe

2 →

The liquid is more evenly distributed with sustainable fibres

Sustainable, cellulose-based wipe fibres have a different chemical structure to petrochemical fibres, such as those made from PET. Therefore, different capillary forces act in cellulose-based fibres.

Preliminary tests showed that the distribution of the liquid in a flowpack stabilises after 3 days and no further changes are to be expected. Therefore, flowpacks with PET or **cellulose-based wipe fibres** were stored for 3 days with the lid facing upwards. The flowpacks were either soaked with a low-alcohol disinfectant or with an agent based on organic acids. After storage, the weight of each wipe was determined (**Figure 7**).

For the flowpacks tested, it was shown that the first wipes were lighter and therefore less soaked than the wipes further down in the wipe stack. The difference in weight was more than twice as great for the PET-based wipes of Bacillol® 30 Sensitive (8.8 g) compared to **Bacillol® 30 Sensitive Green Tissues** (3.5 g) or **Bacillol® Zero Tissues** (2.6 g), both of which contain cellulose-based wipes.

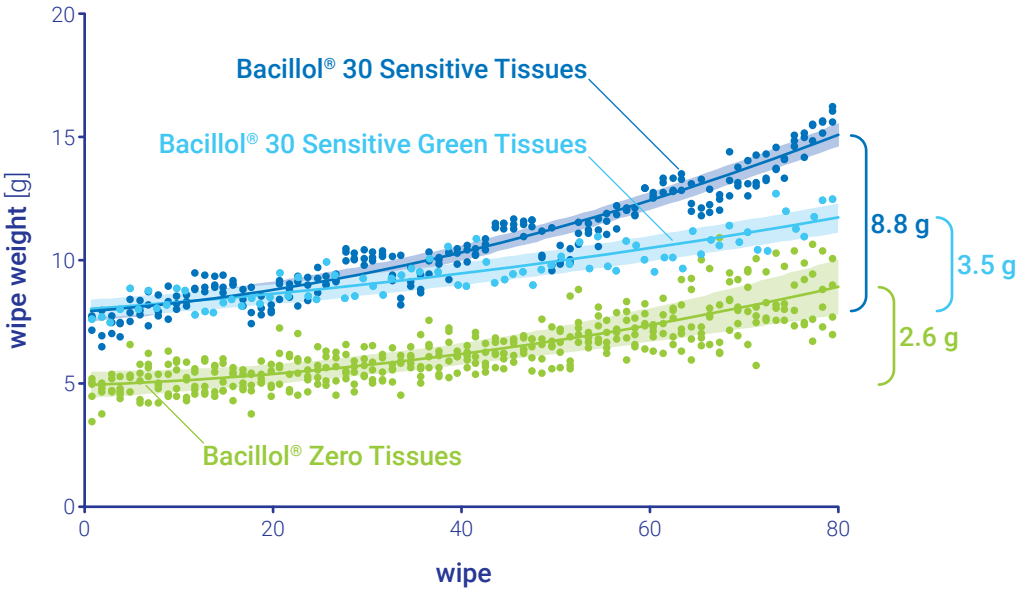


Figure 7:
Weight of the wipes in flowpacks of the Bacillol® product family after the flowpacks had been stored for 3 days with the lid up. Wipes further down in the stack had a higher weight and thus a higher impregnation than the first wipes. The difference in mean weight between the first and last wipe is shown. Lines show the mean. The 95% confidence interval is shown as a lighter band.

Effective. From the first to the last wipe

2

Despite differences in impregnation, each wipe is effective

The **microbiological effectiveness** of a disinfectant wipe depends, among other factors, on the degree of impregnation and the amount of liquid released onto the surface [7]. The first wipes in the tested flowpacks have a lower impregnation than the average of all wipes (**Figure 7**) thus, the antimicrobial efficacy can be questioned.

Therefore, the effectiveness of the first wipe in each flowpack was determined after 3 days of storage with the lid up in **4-field tests** according to EN 16615. The test was carried out under high organic load with exposure times in accordance with the product claims.

Flowpacks of Bacillol® 30 Sensitive Tissues and Bacillol® Zero Tissues were tested against the pathogens *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Enterococcus hirae*, and *Candida albicans*; for Bacillol® 30 Sensitive Green Tissues, a benchmark test was performed with *S. aureus* and *C. albicans* (**Figure 8**).

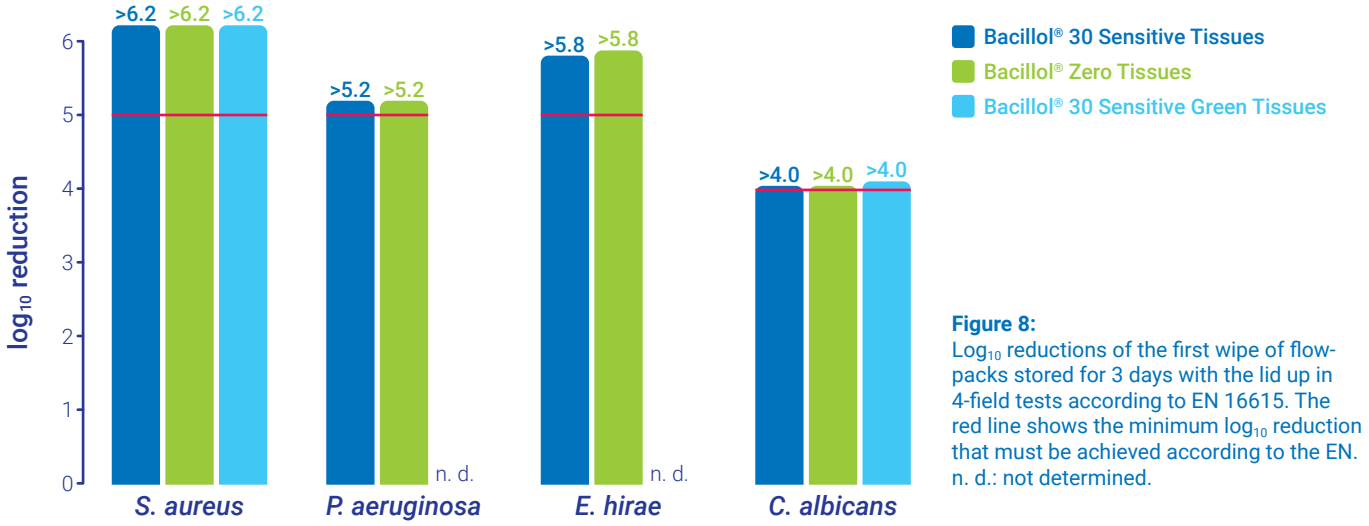


Figure 8:
Log_{10} reductions of the first wipe of flowpacks stored for 3 days with the lid up in 4-field tests according to EN 16615. The red line shows the minimum log_{10} reduction that must be achieved according to the EN. n. d.: not determined.

The liquid in pre-soaked disinfectant wipes sinks during prolonged storage.

The first wipes in a flowpack are less saturated than the last wipes. This difference is significantly less with cellulose-based wipes than with PET wipes.

Despite the difference in impregnation, the tested ready-to-use wipes in the Bacillol® range are effective from the first to the last wipe.

Glossary

Grammage

In order to be able to compare different wipes, their weight is often given in grams per square metre (g/m^2). This value is also called grammage and depends on the type of fibre, fibre thickness, and fibre density. Wipes for surface disinfection usually have a grammage of between 30-60 g/m^2.

Organic load

Surface disinfectants can be tested under two different conditions: with low organic load (clean conditions) or with high organic load (dirty conditions). In the case of low load, 0.3% bovine albumin is added to the testing. Products labelled with this load may only be used on optically clean surfaces.

Products tested under **high organic load** (**Figure 9**), on the other hand, may also be used on surfaces that are visually slightly soiled. These products were tested with the addition of 3% bovine albumin and 3% sheep erythrocytes.

In the case of heavy soiling, the two-stage process is always preferable, in which the soiling is removed in the first cleaning step and then the surface disinfected in a second step.

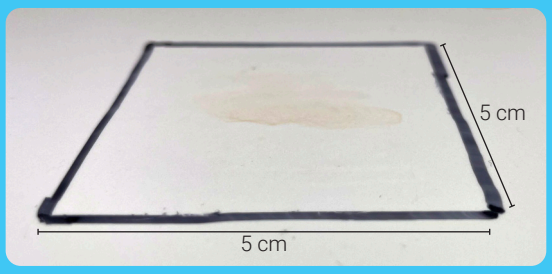


Figure 9:
0.05 mL of a high organic load was spread on a 5x5 cm^2 field and dried for 60 minutes according to the 4-field test (EN 16615).

Pulp

In the production of wood-based fibres, pulp is the cotton wool-like intermediate stage between wood and fibre. Pulp is produced from wood by chemical pulping and consists of high-purity cellulose, the starting material for sustainable non-woven fibres.

Impregnation

The degree of impregnation describes the amount of liquid with which the dry wipe is soaked. The maximum impregnation quantity is limited by parameters such as wipe size, material, grammage, or chemical composition of the impregnation solution.

3 Interaction of fibre and chemistry

The fibre influences the efficacy of the disinfectant

Cellulose is a biological molecule and, due to its complex structure, can **interact** with the chemicals in disinfectants in a different way to PET, for example. In the worst case, this can reduce the efficacy of the disinfectant. It is already known that some combinations of fibre and active ingredient can lead to a **loss of active ingredient** [8] and modern, sustainable cellulose-based viscose fibres have also been described as being able to retain active ingredients such as quaternary ammonium compounds (QAC) [9].

The influence of the non-woven wipe fibre on the disinfectant is not always subtle and can only be identified using complex detection methods. Certain combinations of fibre quality and disinfectant can lead to a change in colour that can even be seen with the naked eye (**Figure 10**).

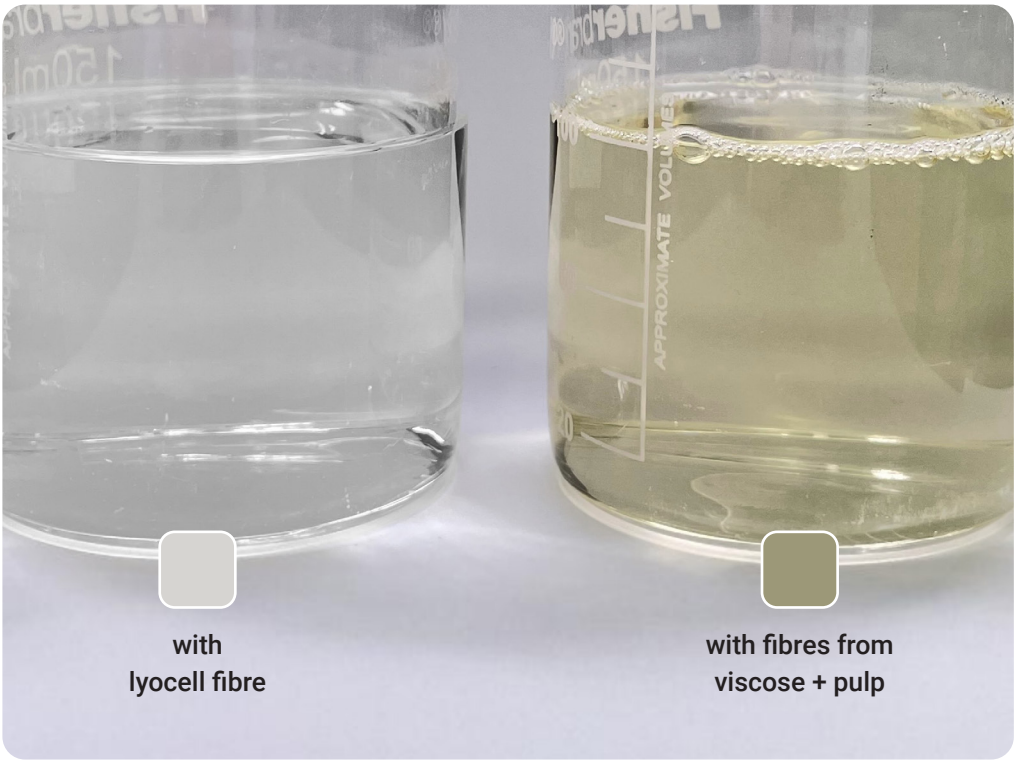


Figure 10:
Squeezed liquid from two flowpacks. Both contained the same disinfectant, but either with lyocell (left) or with a fibre made of viscose + pulp (right) as a non-woven wipe material. A reaction of viscose + pulp with the disinfectant can lead to discolouration of the solution.

Interaction of fibre and chemistry

3 →

In order to characterise the interaction of fibre and disinfectant in more detail, four different non-woven wipes were soaked in an alcohol mixture (**Table 1**), stored for 72 hours and then the liquid squeezed out of the wipes was examined. The **pH value** and the **efficacy against adenoviruses** were determined in accordance with EN 14476 under high organic load (**Figure 11**). Adenoviruses limit the efficacy of low-alcohol disinfectants, so that even a slight influence of the wipe material is noticeable here. Non-woven wipes made of (a) PET fibre, (b) lyocell, (c) a mixture of viscose and pulp and (d) viscose alone were tested.

Table 1: Composition of the alcohol mixture used.

Component	Amount (% w/w)
Ethanol	14%
1-Propanol	6%
2-Propanol	10%
Water	*ad* 100%
pH adjuster	*ad* pH 8

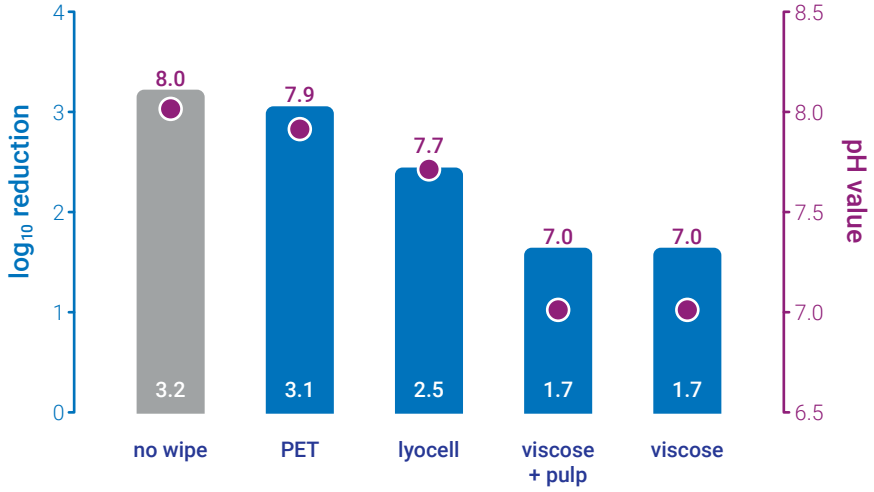


Figure 11:
Characterisation of the impregnating liquid squeezed out of various cellulose-based wipes. For comparison, the values of the alcohol soaking solution (**Table 1**) without wipe are also shown. The log_{10} reduction of the squeezed solution against adenoviruses was determined (bars) as well as the pH value (dots).

↓pH Cellulose fibres reduce the pH value of alcoholic impregnating solutions.

With simple alcoholic mixtures, the efficacy decreases after contact with cellulose-based wipe fibres; with more complex formulations, sufficient efficacy can be expected regardless of the fibre material.

Viscose has the strongest influence on the pH value (ΔpH = 1.0) and reduces the efficacy by 1.5 log_{10} levels. Lyocell has a significantly lower influence.

4 High tensile strength brings high efficiency

Tear-resistant wipes offer advantages in everyday clinical practice

Although it may not be obvious at first glance why a disposable disinfectant wipe should have a high tensile strength, this property has a subtle but important influence on efficiency during disinfection:

Powerful application: A strong and tear-resistant wipe can be applied with more pressure over the surface. This makes it possible to remove dirt or contamination more effectively.

Surface-independent: Some surfaces are structured or rough, such as patient couches. Tear-resistant disinfecting wipes can be used here without tearing regardless of the surface's properties.

Cost savings and greater sustainability: Fewer wipes are needed for an application with a non-woven wipe with high tensile strength, and the knee-jerk reaction of pulling out several wipes at once is no longer necessary.

Tensile strength and fibre residues: High tensile strength means that the fibres do not break as quickly, leaving fewer small fibre fragments (lint) on the surface (see **chapter 5**).

High tensile strength brings high efficiency

The maximum tensile strength of non-woven fabrics made of different fibres and with different grammages and impregnations was determined in accordance with DIN EN 29073 in an independent laboratory (**Figure 12**). A schematic representation of the different fibres can be found on **page 15**.

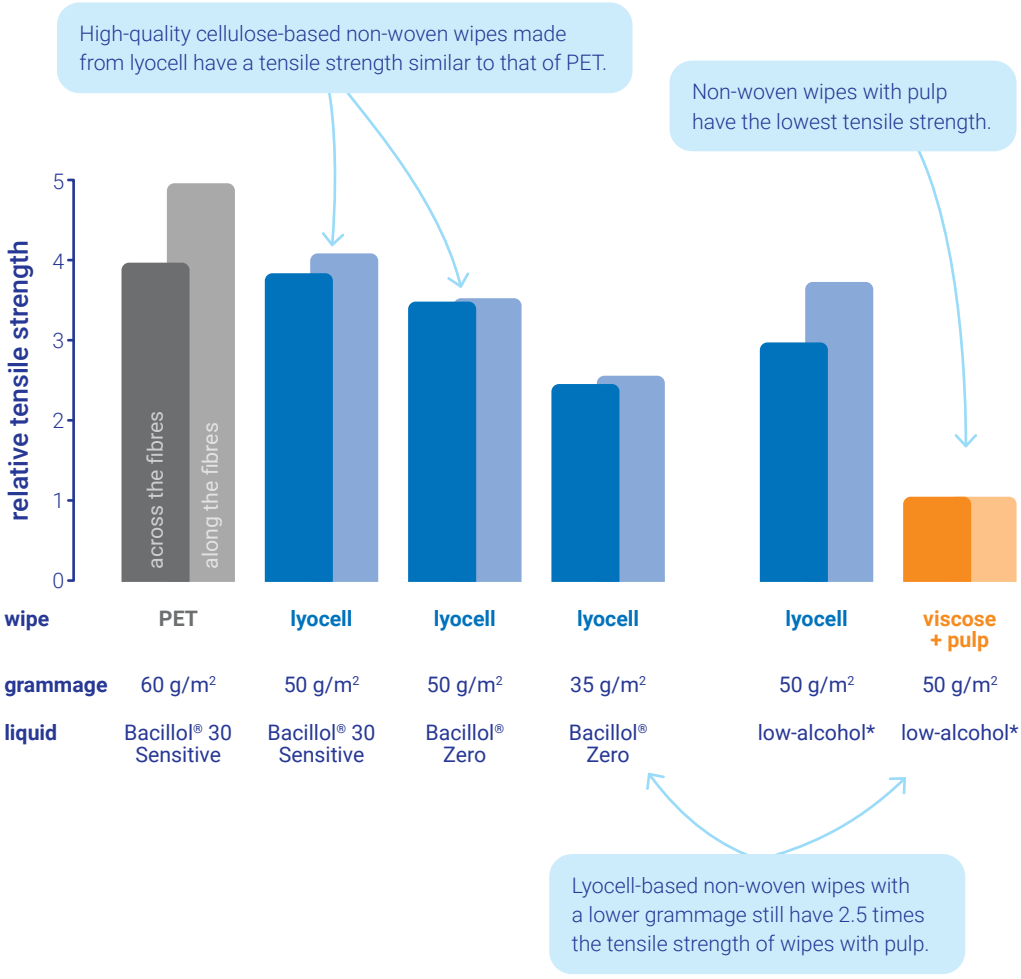


Figure 12:
Maximum tensile strength of impregnated wipes made of various non-woven fibres according to DIN EN 29073. The tensile strength of the wipes was determined along and across the fibres.

Not all cellulose-based non-woven fibres have the same tensile strength: high-quality lyocell fibres are as stable as PET fibres and more than four times more tear-resistant than combinations of viscose and pulp.

*about 30% total alcohol content

5 Small lint, big risk

Fibre residue can cause serious problems

Fibre residue and lint from surgical textiles used to pose a risk to patient safety. Modern textiles in operating theatres are particularly low-lint, significantly reducing the risk to patients. However, the transformation of the healthcare system towards greater sustainability requires the use of new materials, such as cellulose-based wipe fibres for surface disinfection. Old problems that were thought to have been overcome, such as fibre residues, could thus reoccur (**Figure 13**).

Contamination risk: Fibre residues can potentially be contaminated with pathogens and transport the pathogens to patients; this also applies to disinfectant wipes when an active ingredient such as alcohol has evaporated.

Wound healing: When introduced into a wound, cellulose particles of a few micrometres in size can impede the healing process, cause granulomas, and lead to tissue adhesions [10,11].

Hygiene compliance: Linting wipes can be perceived as inefficient by users. In addition, surfaces need to be cleaned more frequently to remove fibre residues. Both can have a negative impact on compliance.

Sensitive devices: Fibre residues can cause malfunctions in devices. They can accumulate in devices or affect precise measurements in laboratories, for example.

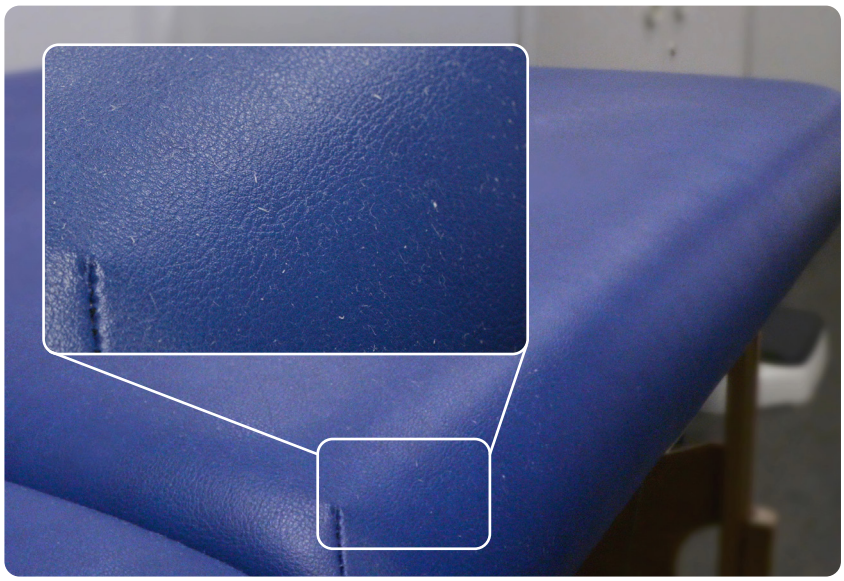


Figure 13:
Fibre residues after disinfection with a heavily linting disinfectant wipe on a patient couch with a textured surface.

Small lint, big risk

5

Not all cellulose fibres are the same

To determine the amount of fibre residue, the liquid was **squeezed out** of the wipe stacks of flowpacks and **filtered** (pore size of the filter: 0.45 µm). The filters were dried overnight and the weight of the fibre residues was weighed. The determined weight of the fibre residues was compared to a product containing PET fibres (**Figure 14**).

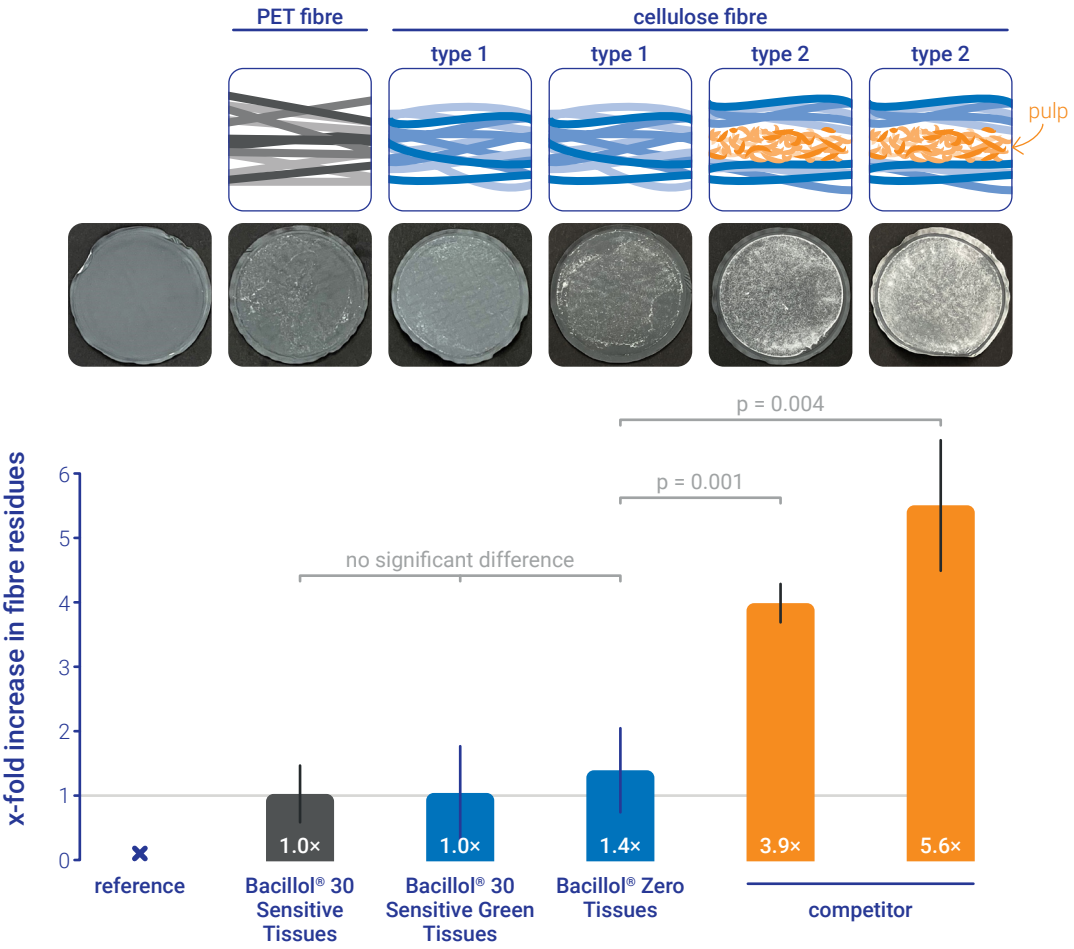


Figure 14:
The amount of fibre residue in flowpacks was determined by squeezing out the liquid and filtering. Cellulose-based wipes containing pulp as an intermediate layer (type 2) left more than five times as much fibre residue as wipes without pulp.
For comparison, a filter through which only water was filtered (reference) is also shown.

The tested wipes of the Bacillol® product family leave approximately the same amount of fibre residue, regardless of whether they are PET or cellulose-based wipes.

5× Non-woven wipes containing pulp leave more than five times as much fibre residue.

6 New material, well-known area output

The area output is influenced by many factors

The area output or surface coverage is the total area that can be continuously wetted with a wipe soaked in liquid **before the liquid film on the surface breaks off**.

The coverage of pre-soaked disinfectant wipes does not only depend on the size of the wipes. There are a number of other factors that together influence the area output of ready-to-use disinfectant wipes:

size & weight

The larger the wipe and the more densely the fibres are bonded together (see grammage, page 9), the more liquid can be absorbed and transferred to the surface.

ingredients

The chemical formulation influences the surface tension of the liquid and thus the distribution on a solid surface.

wipe material

Examples of different wipe materials can be seen on page 4.

impregnation level

For detailed explanation see page 9.

The average area output of a disinfectant wipe can be determined by specialised testing and textile laboratories. The wipe is applied to a standardised surface under controlled conditions until the liquid film breaks off. The size of the wetted surface is then determined (**Figure 15**).

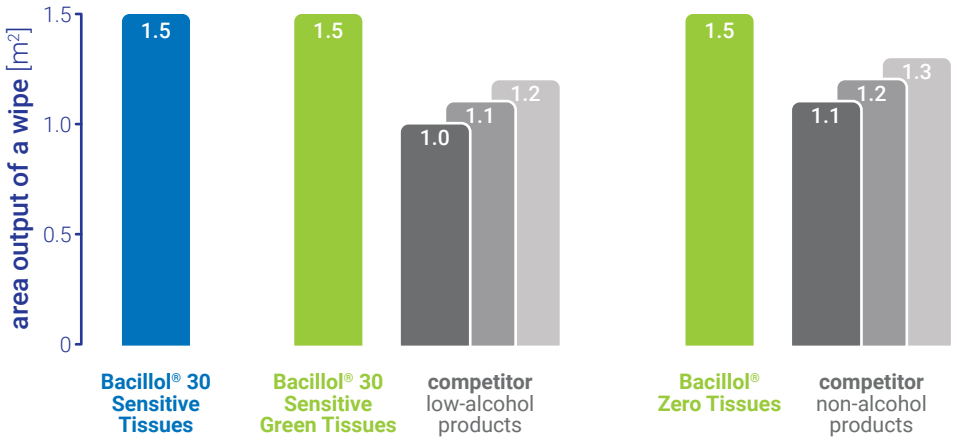


Figure 15:
The ranges of Bacillol® wipes and competitor products were determined by an independent institute.

With an average coverage of 1.5 m² per wipe, Bacillol® Zero Tissues and Bacillol® 30 Sensitive (Green) Tissues achieved the highest area output.

... after the application

"Disinfectant wipes are incinerated in the end anyway, so why make it sustainable?"

Microplastic accumulation

During use, but also afterwards in the course of disposal, fibre residues (see **page 15**) and microparticles of disinfectant wipes can become detached , for example through abrasion. Some of these particles are only a few micrometres (thousandths of a millimetre) in size and cannot be seen with the naked eye.

Petroleum-based plastics are not biodegradable, thus, plastic particles (microplastics) accumulate in the environment and also in living things: in a 2022 study for instance, microplastics were detected in human breast milk [12]. Cellulose-based disinfectant wipes also leave behind microparticles, but these do not accumulate in the environment or in living things (**Figure 16**) [13].

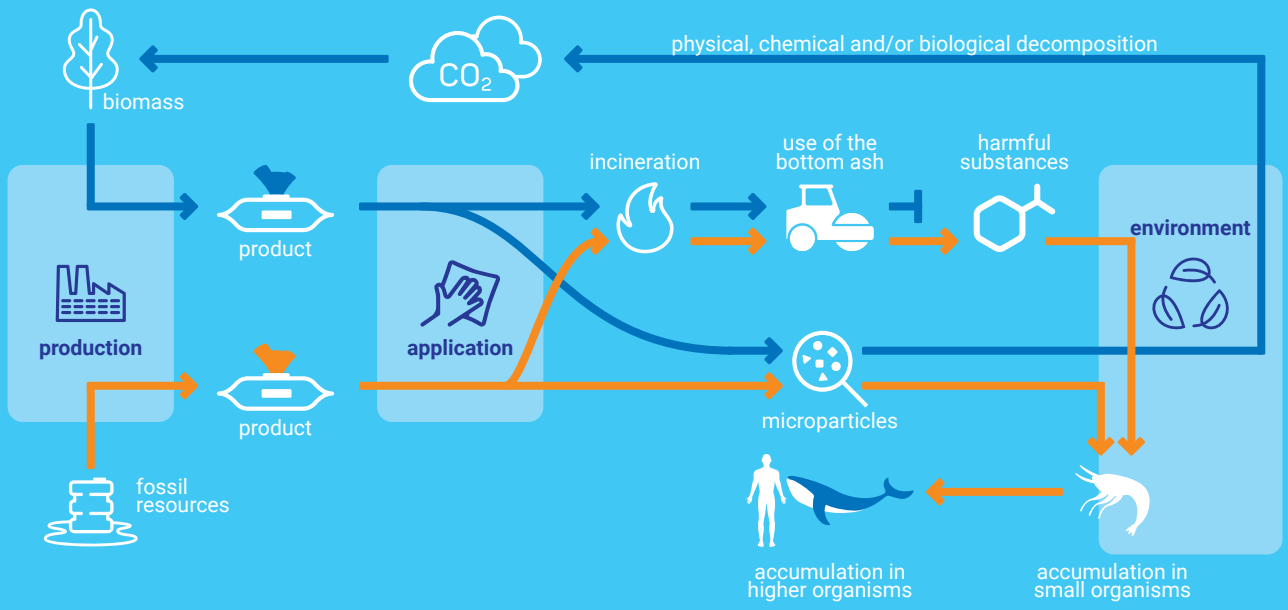


Figure 16:
Material flows of cellulose (blue) and PET-based (orange) disinfectant wipes after use. The paths after use and incineration are considered, as well as the fate of microparticles that may be released.

Thermal treatment and utilisation

To prevent infection, potentially contaminated disinfectant wipes must be incinerated after use. Even if a wipe is certified as biodegradable, it cannot be composted or recycled [14]. Incineration of medical waste in designated incinerators is accompanied by thermal utilisation: the heat generated is converted into electricity, process steam and/or district heating and after the recovery of metals, the remaining bottom ash is used in road construction or cement, among other things.

The **highly toxic substances** produced during incineration are removed from the dusts and ash, but according to the German Heinrich Böll Foundation and BUND, it is not possible to ensure that they are completely filtered out [15]. Thus, under certain circumstances, toxic pollutants can find their way back into the environment as road surfaces.

Studies have shown that the combustion of cellulose causes significantly fewer toxic emissions and residues [16] than the incineration of plastic waste [16-19]. **In conclusion**, cellulose-based disinfecting wipes help to reduce environmental pollution.

7 Summary

Effective. From the first to the last wipe

Over time, the liquid in flowpacks sinks to the bottom, and the first wipes are less saturated than the last. Despite the varying degrees of impregnation, the tested ready-to-use Bacillol® wipes are effective from the first to the last wipe.

Interaction of fibre and chemistry

Cellulose fibres can affect the chemical formulation of a disinfectant: there may be changes in pH and efficacy. Viscose has a significantly more negative influence than lyocell fibres.

High tensile strength brings high efficiency

Fibres made of PET or lyocell have a tear resistance that is up to four times higher than fibres made of viscose and pulp. Even if the grammage is reduced, lyocell is superior to a wipe containing pulp in terms of tear resistance.

Small lint, big risk

Whether PET or cellulose-based, the wipes in the Bacillol® product family leave behind roughly the same amount of lint. Wipes made of non-woven fibres that contain pulp, on the other hand, can leave behind more than five times as many fibre residues.

New material, well-known area output

The low-alcohol and alcohol-free wipes in the Bacillol® product family achieve a coverage of 1.5 m^2 per wipe, regardless of the wipe material, giving a higher yield than the market average.

References

1. **Siani *et al.*** (2018). Impact of antimicrobial wipes compared with hypochlorite solution on environmental surface contamination in a health care setting: A double-crossover study. Am J Infect Control. 46(10):1180-1187.
2. **Song *et al.*** (2019). Efficacy of disinfectant-impregnated wipes used for surface disinfection in hospitals: a review. Antimicrob Resis Infect Control. 8:139.
3. **Shen & Patel** (2010). Life cycle assessment of man-made cellulose fibers. Lenzinger Berichte. 8:1-59.
4. **Opperskalski *et al.*** (2022). Preferred Fiber & Materials Market Report, Textile Exchange. (accessed on 08/2024).
5. **Lenzing Group** (2023) Focus Paper: End of Use.
6. **Sudheshwar *et al.*** (2024). Unraveling the climate neutrality of wood derivatives and biopolymers. RSC Sustain. 2:1487-1497.
7. **Knieler** (2019). Quality and testing of ready-to-use disinfection wipes. Hyg-Med. 44(4): D33-D40.
8. **Bloß *et al.*** (2010). Adsorption of active ingredients of surface disinfectants depends on the type of fabric used for surface treatment. J Hosp Infect. 75(1):56-61.
9. **Pascoe *et al.*** (2022). Impact of material properties in determining quaternary ammonium compound adsorption and wipe product efficacy against biofilms. J Hosp Infect. 126:37-43.
10. **Janoff *et al.*** (1984). Foreign body reactions secondary to cellulose lint fibers. Am J Surg. 147(5):598-600.
11. **Truscott** (2004). Impact of microscopic foreign debris on post-surgical complications. Surg Technol Int. 12:34-36.
12. **Ragusa *et al.*** (2022). Raman microspectroscopy detection and characterisation of microplastics in human breastmilk. Polymers (Basel). 14(13):2700.
13. **Royer *et al.*** (2021). Degradation of synthetic and wood-based cellulose fabrics in the marine environment: Comparative assessment of field, aquarium, and bioreactor experiments. Sci Total Environ. 791:148060.
14. **Bund/Länder-Arbeitsgemeinschaft Abfall** (LAGA) (2021). Vollzugshilfe zur Entsorgung von Abfällen aus Einrichtungen des Gesundheitsdienstes (accessed on 01/2025).
15. **Heinrich-Böll-Stiftung & Bund für Umwelt und Naturschutz Deutschland** (BUND) (2019). Plastikatlas (accessed on 01/2025).
16. **Young *et al.*** (2013). Release of harmful air pollutants from open burning of domestic municipal solid wastes in a metropolitan area of Korea. Aerosol Air Qual Res. 13:1365-1372.
17. **Valavanidis *et al.*** (2008). Persistent free radicals, heavy metals and PAHs generated in particulate soot emissions and residue ash from controlled combustion of common types of plastic. J Hazard Mater. 156(1-3):277-284.
18. **Vijayakumar & Fink** (1982). Pyrolysis studies of aromatic polyesters. Thermochimica Acta. 59(1):51-61.
19. **Webb *et al.*** (2013). Plastic Degradation and its environmental implications with special reference to poly(ethylene terephthalate). Polymers. 5(1):1-18.

Hazardous substance classification
Bacillol® 30 Sensitive (Green) Tissues

Warning

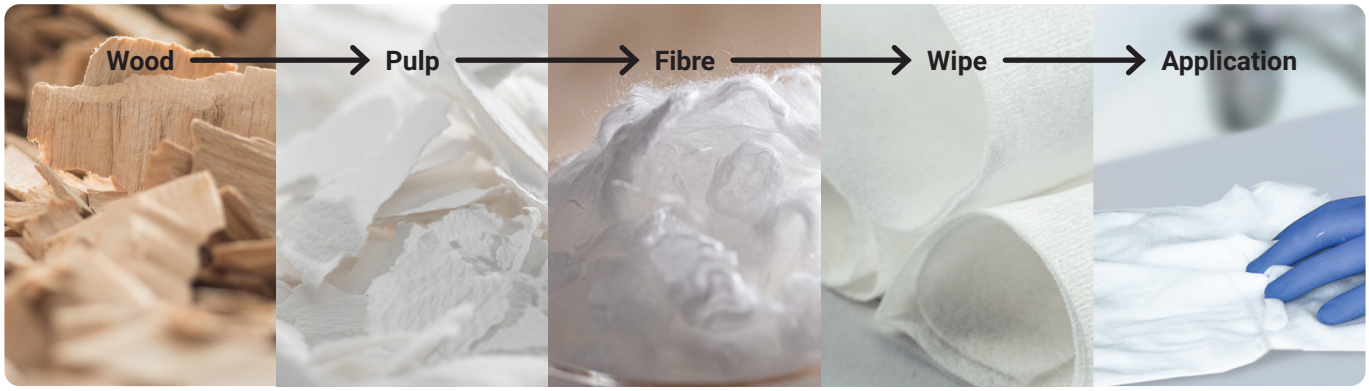
H226 Flammable liquid and vapour.
H319 Causes serious eye irritation.

Use disinfectants safely.
Always read the label and product information before use.

Non-woven fibres from responsible sources

Wood-based fibres

The raw material for VEOCEL™ Lyocell fibres comes from sustainably managed and certified forests*. The **wood** is chemically broken down to extract the valuable **cellulose** – the raw material used to make modern disinfectant wipes. In this state, the cellulose is also known as **pulp**. The cellulose is chemically liquefied and spun into **fibres**. In the case of Lyocell fibres, more than 99% of the chemicals used in this process are reused. Finally, the fibres are bonded to form a **non-woven wipe**.



* Further information can be found in Lenzing's guidelines for wood and pulp procurement. VEOCEL™ is a trademark of Lenzing AG.

Veocel™
Purely for you

HARTMANN

SCIENCE CENTER HARTMANN
Research for infection protection
hartmann-science-center.com

PAUL HARTMANN AG
Paul-Hartmann-Straße 12
89522 Heidenheim
Germany

Telefon: +49-7321-36-0
Telefax: +49-7321-36-3636
info@hartmann.info
www.hartmann.info