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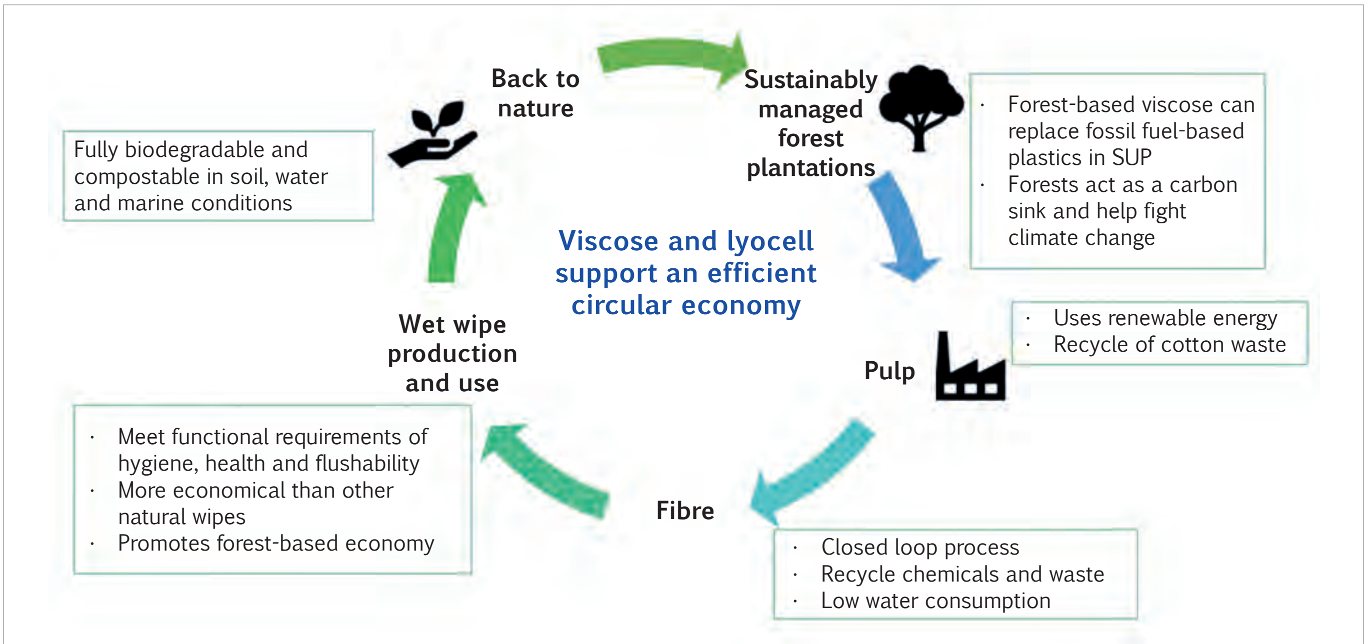
‘Cellulose supports sustainable production’

Members of the viscose industry, including Birla Cellulose, explain why they believe that sustainable production and consumption solutions should include cellulosic polymers, in response to a recent report on plastic waste



Abstract

As the EU leads global efforts to reduce the level of plastic pollution caused by single-use plastics, the Single-Use Plastics Directive (SUPD)[1] is a critical part of the process to drive the change to more sustainable production and consumption. It is a significant challenge to balance the need to meet the functional requirements that many single-use plastics deliver while transitioning to materials that are based on natural resources, are compostable or biodegradable, and are renewable or reusable. Fortunately, for some applications like wet wipes, there are products available that meet both performance and environmental requirements and can meet the intent of the SUPD to prevent the pollution of marine and terrestrial environments due to plastics, while contributing to the efficient functioning of internal markets. Cellulosic polymers, known as viscose and lyocell, meet all the requirements to be considered natural polymers as the polymerisation happens in nature and they both pass current testing standards of biodegradability and compostability in different conditions. Most importantly, viscose and lyocell support EU goals of sustainable production and consumption by meeting performance standards with reduced environmental impacts and encouraging a circular economy.

What are viscose and lyocell?

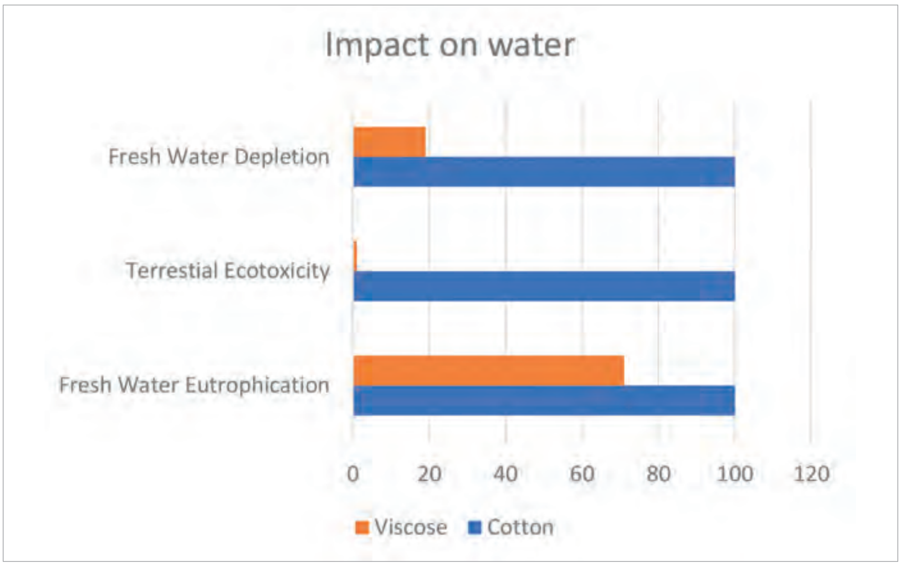
Viscose and lyocell are made of cellulose derived from fully renewable natural resources – typically pulp which itself is derived from woody plants like trees. Cellulose is difficult to dissolve due to a dense hydrogen bonding network between the cellulose molecular chains, which needs to be reduced in order to make a solution of cellulose. The solution is then forced through a spinneret to produce filaments that are solidified, resulting in fibres of nearly pure cellulose[2]. While traditionally, manufacturers paid little attention to the source of their wood for pulp, many fibre suppliers have committed to assuring that their wood is sourced from sustainably managed locations and not old growth forests. The Canopy's Hot Button report[3] assesses viscose and lyocell suppliers on how they are performing in terms of sustainable sourcing of their wood supplies, with the expectation that transparency will drive higher performance of the industry. Over 80% of viscose producers, by volume, have now committed to policies of sustainable wood sourcing. In recent exciting developments, pre- and post-consumer cotton waste is being recycled into viscose and lyocell fibres, and fibre producers have already placed products containing recycled cellulosic textile waste in markets, further strengthening the circularity of the value chain.

Well-managed forest plantations serve as carbon sinks, pulling CO_2 from the atmosphere at a greater rate than older forests. Once this wood is harvested, the wood pulp is converted to fibres, therefore creating long-term storage of the carbon. Unlike cotton, which requires large amounts of land, water, fertilisers and crop protection chemicals to drive higher yields, forest plantations do not require added resources, so the impacts of viscose and lyocell raw materials on water, land and soil health and chemicals consumption is significantly lower.

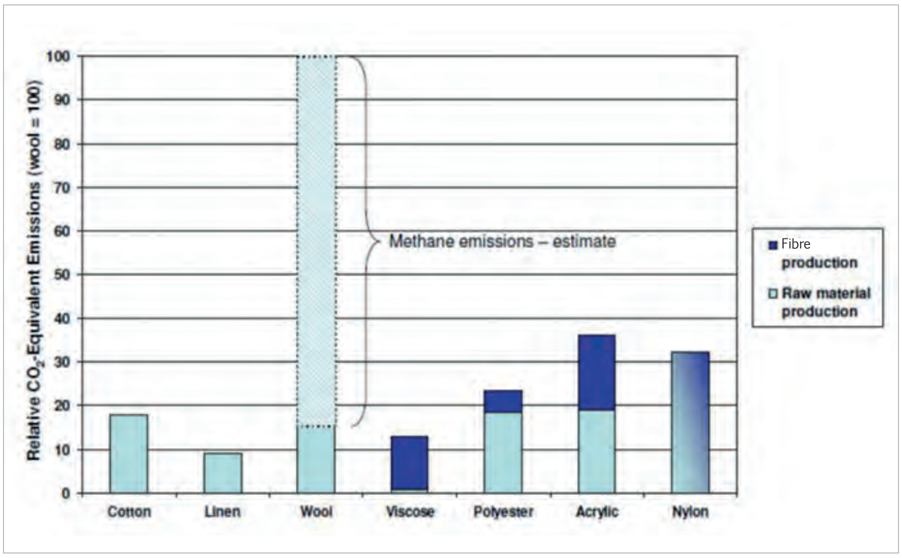
Within natural fibre options for wet wipes there are two major options: man-made cellulosic fibres and cotton. And when we look at the environmental impacts of both, viscose is much preferable due to its low impact on the environment. A study conducted by SEED[4] (Sustainable Development, Environment, Science and Engineering, KTH) on the LCA of cotton and viscose garments reveals that viscose has a much lower impact on the environment compared to cotton. The impact of viscose on water is much lower than cotton and it is important to note that a significant portion of the cotton is grown in water-stressed areas.

A study conducted by Business for Social Responsibility (BSR)[5] compared the Relative GHG emissions of different fibres and indicates that viscose is one of the fibres with the lowest greenhouse gas emissions, thus supporting the United Nation's Sustainable Development Goals (SDG) 13.

Climate change and water stress are the two biggest challenges the Earth faces today. The natural-based fibres viscose and lyocell can significantly contribute to reducing the impact of water stress and climate change.



Viscose and lyocell are produced using chemicals to dissolve the cellulose contained in wood and then rebuilt in fibre form by regenerating the cellulose. Global leaders have invested in processes to achieve a recycle rate for solvents used up to 99.7% in the lyocell process and greater than 90% in the viscose process (based on sulfur recovery). Those same leaders have also made major strides in improving water and energy efficiencies. Newer technologies have enabled significant reduction in wastewater pollutants, therefore improving the quality of water that is discharged from the manufacturing site. The UN's SDG 12 aims to promote sustainable consumption, recycling and reuse of resources, environmentally sound management of all types of waste, and use of more sustainable material choices. The EU's SUPD is an important contribution to the achievement of SDG 12 because it aims primarily to prevent and reduce the impact of plastic products on the environment, particularly the aquatic environment. It also aims to promote the transition to a circular economy with innovative and sustainable business models, products and materials, while contributing to the efficient functioning of internal markets. Viscose and lyocell help support the achievement of the EU's SUPD objectives to minimise plastic waste while still providing products that meet the needs of the population. Wet wipe applications include baby wipes, face wipes, personal hygiene, cleaning, industrial wipes and medical applications. Currently, wet wipes are made mainly with polyester, which is blended with a small proportion of cotton, viscose or lyocell. In its current form, a used wet wipe persists in the environment



for hundreds of years, because most of its constituent is non-biodegradable polyester. Since viscose and lyocell fibres are biodegradable and compostable, these provide a good option to eliminate the pollution of marine and terrestrial environments by plastics from used wet wipes, while meeting the performance of the wet wipes applications[6].

Meeting tough standards

The SUP Impact Assessment study[7] by the EU commission emphasised that plastic litter is a major concern because non-biodegradability and persistence is creating both land and marine-based issues globally. The study suggested that an important option is to transition single-use plastics to be based on materials that are biodegradable such as paper and wood. Microbial degradation is an important mechanism of the natural degradation of cellulose. It is achieved through hydrolytic enzymes known as 'cellulases' that convert long chain cellulose into gradually reducing lengths through scission of the β-1, 4 linkages in cellulose chains[8]. Such biodegradation of cellulose proceeds under aerobic (forming CO_2 and H_2O) as well as anaerobic (forming CO_2, CH4 and H_2O) conditions.

This is followed by a typical comparison of the biodegradation of cellulosic fibres (including man-made rayon) in weeks, as compared to other alternatives currently employed in single-use applications, as depicted in the below graph.

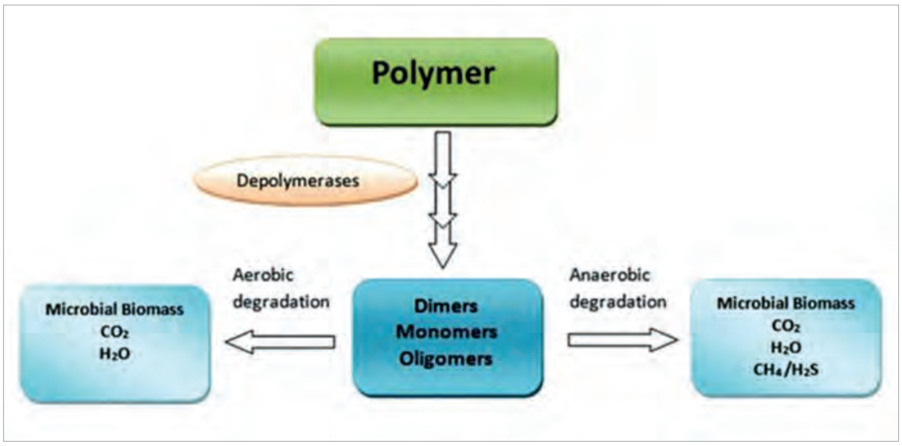
This study shows that viscose degrades faster than any other major fibres evaluated.

Deep ocean environments, however, are different due to limited availability of oxygen. Here, the prevalent biodegradation by fungi is anaerobic in nature[11], as the marine environment also hosts a remarkably high and diverse microbial population. Several studies have described biodegradation of cellulose under these conditions[12], and processed cellulosic fibres are reported to degrade faster than unprocessed wood[13]. Further, marine degradation of cellulose is several times faster than plastics[14].

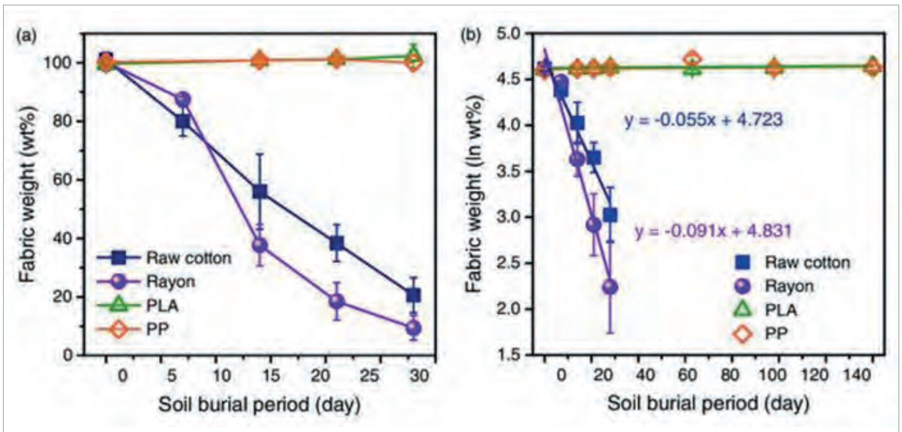
Various manufacturers of man-made cellulosic fibres have reported testing by OWS (Organic Water Systems, Belgium) for the certification body TÜV Austria, to further demonstrate that viscose staple fibre passed testing requirements for composting and biodegradability in soil, water and marine conditions[15]. Compostability and biodegradability studies in soil were done in compliance with the European Standard EN 13432. Biodegradability in the marine environment studies were done in compliance with ASTM D6691 standards. Highlights of some of the test results include:

- **Aqueous aerobic conditions:** Viscose fulfilled the 90% biodegradability requirement within 28 days.
- **Marine biodegradation test:** Viscose fibre was completely biodegradable within 28 days of testing under marine aerobic conditions.
- **OK12 edition A 'Bioproducts – degradation in seawater' Marine disintegration test:** Viscose fibre fulfilled the requirement and can be considered for OK biodegradable Marine conformity mark of TÜV Austria Belgium. The disintegration test is described in the document ref. TS-OK-23 (30°C ± 2°C, 3 months- Pass: >90%).
- **Toxicity test with barley and cress plants:** After composting the test sample, no residuals were left such as metabolites, undegraded components and inorganic components that exert a negative influence on the germination and growth of barley or cress plants.

In summary, there are several methods to measure biodegradability of substances in different conditions and there are also new methods being developed. However, the relative degree of ease and speed with which viscose and lyocell biodegrades and composts compared to other substances such as cotton and polyester, is not likely to change by changing the test method. There is enough scientific evidence already available that establishes that viscose and lyocell biodegrade significantly faster than other fibres under various conditions (soil, aquatic, marine, at different temperatures and humidity, aerobic and anaerobic), and the only factor that can be improved by new methods would be perhaps establishing these facts with even more comprehensive measurements. Thus, viscose and lyocell are well positioned to meet the intent of the SUPD to reduce the impact of SUP waste on the terrestrial and marine environments.



Schematic of the biodegration of polymers in aerobic and anaerobic conditions[9]



The above graph shows biodegradation of nonwoven fabrics in a Captina silt loam soil: (a) weight of recovered fabric versus burial period and (b) regression analysis by the first-order rate equation[10]

Viscose and lyocell are natural polymers

Natural polymeric materials such as hemp, shellac, amber, cotton, wool, silk, paper, and starch have been used for centuries. While it is of great importance to discuss the definition of what can be called a natural polymer or substance, there is a risk that alternate interpretations of the same definitions can lead to exclusion of substances that could be the best solutions to problems created by SUP, if these materials are defined as plastics. Materials such as paper, mercerised cotton, pulp, viscose and lyocell, which are understood as natural polymers in everyday life, risk being called plastics because they all are extracted using a chemical process and all have intermediate temporary products formed, even though their final structure is still cellulose, similar to the original structure.

Different countries define plastics differently. Within EU regulations and ECHA guidance notes, there are definitions for what can be considered as natural polymers. Notable within these are:

Natural polymers[16] are a result of a polymerisation process that has taken place in nature, independently of the extraction process with which they have been extracted.

A plastic means a material consisting of a polymer as defined in article 3(40) of the REACH regulation (EC) No 1907/2006, to which additives or other substances may have been added, and which can function as a main structural component of a final product with the exception of natural polymers which have not been chemically modified.

A 'not chemically modified substance' is defined as a substance whose chemical structure remains unchanged, even if it has undergone a chemical process or treatment, or a physical mineralogical transformation, for instance to remove impurities[17]. (Unlike the draft guidelines that limited this definition to 'no chemical reaction during the process',[18] the final version of the guideline[19] did away with this restrictive definition and emphasised 'as long as the chemical structure of the molecule is not modified').

A recent report on 'What is Plastic?' from Eunomia[20] misleadingly suggested to use a decision tree for determining if a substance is a natural polymer, where they changed the original definition given by the European Chemicals Agency (ECHA) of what is 'not a chemically modified substance' by redefining it as **'a substance whose chemical structure remains unchanged during the entire process of chemical treatment'**.

It is worth applying this new definition to some cases to illustrate how it can fail the very purpose of the SUPD by eliminating the substances that would help solve the problems resulting from pollution of the environment by waste from single-use plastics. The table below evaluates some commonly used substances using the new definition and original ECHA definition.

Thus, from the table we can see that products such as paper, pulp, mercerised cotton, starch, viscose and lyocell risk being called plastics, going against the long-established conventional wisdom. There are several other examples that would fit the illustrations of how playing with a few words of a well thought out definition by ECHA can lead to serious lapses in judgement.

For example, mercerisation is a key stage in cotton textile finishing. Mercerised cotton, lyocell and viscose have the same cellulose structure. All three are based on natural plant-based raw materials and have the same modified structure of intermolecular arrangement changed from cellulose I to cellulose II[21], but without a change in the structure of the molecules themselves. Further, the pulp-making process for making paper also involves the same change to cellulose II[22], albeit to a small extent. Cellulose II is also produced naturally, such as by some organisms[23]. All three fibres as well as paper go through intermediate 'Na-alkoxide of cellulose' or reduced intermolecular hydrogen-bonding during the purification/extraction processes, but revert from these weak/labile intermediates to the same final chemical structure of the cellulose molecule. All three are compostable and biodegradable. During the purification/extraction processes, there is also a macromolecular chain-scission resulting in a chain-length reduction in these fibres to a varying extent, and some have also

Criteria for natural fibres	Result of application of the criteria on substances			
	Viscose, lyocell	**Paper and pulp**	**Textile cotton (mercerised)**	**Synthetics polymers such as polyester, nylon**
Have the polymers been produced by biological organism?	Yes	Yes	Yes	No
Did the initial polymerisation occur in nature?	Yes	Yes	Yes	No
The extraction process should not cause polymerisation	Yes	Yes	Yes	No
Is the final structure same as the initial structure?	Yes	Yes	Yes	No
Is the material understood as a natural substance in everyday life?	Yes	Yes	Yes	No
Is the material understood as not being a plastic substance in everyday life?	Yes	Yes	Yes	No
Classification of the material based on definitions within ECHA and EU regulations	**Not a chemically modified substance**	**Not a chemically modified substance**	**Not a chemically modified substance**	**Not a natural polymer**
New definition by Eunomia *The chemical structure is not modified during the process*	No	No	No	No
Classification of material based on Eunomia definitions	**Chemically modified substance**	**Chemically modified substance**	**Chemically modified substance**	**Not a natural polymer**

interpreted this chain-scission as 'chemical modification'. It is important to recognise that such chain-scission is not only inherently harmless, but is also the very enabler and result of biodegradation of cellulose in wood, paper and cotton by the 'cellulase' enzymes produced by microorganisms in nature, and is also part of the omnipresent processes of pulp-paper making and cotton mercerising and bleaching processes. There is no scientific basis for treating lyocell, viscose, mercerised cotton and paper differently, and for calling any of these 'chemically modified' and others 'not chemically modified', as they all follow chemical processes for extraction.

Starch used in various foods is often chemically modified[24]. Similarly, starch-based disposable cutlery is made using a form of starch that has been modified through a chemical process. The move to starch-based cutlery is considered a successful example of a transition from a fossil fuel-based, non-biodegradable plastic product to a biodegradable product. This innovation serves the purpose of disposable single-use cutlery which is fully biodegradable and meets the functional need and eliminates plastics pollution. Vegetable oils are often chemically altered following their extraction from plants, consumed as foods, and not considered as plastics[25].

Flushable and non-flushable wipes

There are two types of wipes – flushable and normal wipes. Both can be made using viscose or lyocell. It is important to note that not all wipes made from viscose or lyocell are flushable. Flushable wipes are made using a totally different technology which provides certain unique features to the wipe that make them suitable for flushing, such as quick wet disintegration, biodegradability, settling tendency, sinking velocities and others.

These wipes are clearly marked as 'Flushable' or 'Fully Flushable'. All other wipes are not flushable and should be clearly marked as 'Do Not Flush'.

A study conducted by Water UK 21, called Wipes in the Sewage Blockages, reveals the true reasons:

1. The majority of the sewer blockage material recovered comprised non-flushable wipes that were not designed to be flushed and should not have been disposed of via the WC. Baby wipes accounted for over 75% by weight of identifiable products. Surface wipes, cosmetic removal wipes and feminine hygiene products accounted for approximately 20% by weight of identifiable products.
2. The products recovered that were designed to be flushed accounted for a small proportion of the products recovered – approximately 0.88% by total weight and 1.9% by weight of products that could be identified. However, it is accepted that during the blockage recovery process some toilet tissue and other weaker material is lost in the blockage removal process.

So, it is clear from the above that 99% of the problem is caused by the flushing of non-flushable wipes and products such as feminine hygiene and cosmetic removal wipes. Consumer awareness programmes could help to solve some of the major causes of sewage clogging, and millions of euros being spent on cleaning clogged sewage systems could be put to more productive use.

There are flushable wipes available in the market that have been in use for more than a decade and meet flushability standards such as GD4. There could be stricter standards available for flushability compared to GD4 that could help improve flushable wipes. This could further reduce instances of clogging caused by flushable wipes, even though this is less than 1% of the total causes of clogging. It is also important to focus on the major causes of sewage clogging that could have a greater impact on this problem.

Nature-based wipes made from viscose and lyocell support internal markets

An important objective of the SUPD is that plastics are replaced with more sustainable substances and products that promote a circular economy and contribute to the efficient functioning of internal markets. SDG 12 calls for the use of more sustainable material choices by disincentivising fossil fuel-based products.

Viscose and lyocell are two products that could help fulfil all the above stated objectives. They are based on wood derived from sustainable forests and will replace fossil fuel-based products with nature-based products. They are produced using the closed loop production system which recycles important chemicals used in the process, consuming significantly less water, land and chemicals compared to other natural fibres. Moreover, recent innovations allow cotton waste to be recycled into viscose production and potentially save millions of tons of cotton waste from going to landfill/incineration annually. Viscose and lyocell, with 20% to 50% recycled content, are already commercially available[26] in the market and are being promoted by brands among consumers.

It is anticipated that if wet wipes production is to move to viscose and lyocell, it could potentially increase the demand of dissolving pulp by 1%, estimated by Eunomia, which is insignificant and could easily be absorbed by the value chain without any impact on pricing.

The potential Extended Producers Responsibility (EPR) cost of a polyester wipe estimated by Eunomia[27] is €1.60 cents per wipe. This means that for every wipe of €1.10# cents, €1.60 cents are required to manage the environmental impact of waste created by synthetic wipes. The EPR cost of lyocell and viscose wipes are estimated to be nil in this report, if they are treated as natural substances. The report also estimates the total global market of wet wipes is €10bn. This means that EPR costs could run into billions of euros in the case of non-biodegradable wipes, and much of it would have to be borne by member nations and its citizens. A clear definition of a natural polymer, which includes viscose and lyocell as natural substances, could help reduce this wasteful expenditure on EPR in managing non-biodegradable plastic waste which would add to the already worsening climate conditions without any productive output and hurt the economy.

In summary, the impact of a shift of materials used in manufacturing wet wipes from polyester to viscose or lyocell would support the efficient functioning of internal markets, and would not lead to any distortion in viscose prices and place any significant stress on the demand and supply of pulp. This would also reduce the EPR cost as viscose and lyocell are easily compostable and biodegradable and waste management expenses are much lower – contributing to efficient internal markets.

Conclusion

Natural polymers viscose and lyocell are consistent with the EU's sustainable production and consumption strategy and meet the intent of the high standards developed in the SUPD and support the UN's SDG 12 as they:

- Are produced from sustainably sourced wood from renewable forests and replace fossil fuel-based products.
- Use closed loop manufacturing to recycle

chemicals and other natural resources
- Biodegrade and compost significantly faster compared to other fibres under various conditions (soil, aqueous, marine) and meet international standards of biodegradability
- Have lower environmental impact compared to other naturally grown fibres like cotton as they consume less water, land and energy, and do not need fertilisers and pesticides
- Can be used to make flushable wipes that meet international flushability standards
- Reduce the burden on landfills and incinerators, supporting the circular economy, due to recent advances allowing cotton waste to be recycled into viscose
- Are expected to contribute to the efficient functioning of internal markets and to not cause any distortion of prices in the markets.

In addition to meeting the intent of SUPD and SDG 12, viscose and lyocell fit the definitions of natural polymer substances, as outlined by ECHA, as the initial and final structure is both cellulose and structures are similar, and the polymerisation happens in nature.

Thus, viscose and lyocell are the most suitable substances for SUP applications such as wet wipes and would help in achieving the objectives of the SUPD and SDG 12.

What is the Eunomia report?

Published on 21 January 2020, the Eunomia report 'What is Plastic?' explores the potential for certain materials to be considered as exempt from the EU's Single-Use Plastics Directive, with particular focus on man-made cellulosic fibres.

The report examines the scope for two of these polymers, lyocell and viscose, to be included under the Directive, investigating both their chemical makeup and their behaviour in the natural environment. The research evaluates the body of evidence for the environmental impact of these polymers when used in wet wipes, with a particular focus on the marine environment and the material's biodegradability.

"Researchers found that there is not sufficient evidence to prove that these materials will not have a similarly detrimental impact on the environment as a synthetic plastic product," states Eunomia.

The report goes on to identify the current market for these materials, and the impact of an extended producer responsibility (EPR) system on these markets as part of the SUP Directive regulations.

More information can be found at www.eunomia.co.uk

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