Closed-Loop Technologies in Viscose Process

What is Viscose Fibre?

Viscose or rayon is a nature-based fibre made from sustainably sourced wood. It was invented in the 1890s by French scientist *Hilaire de Chardonnet*. In 1905, the first commercial viscose rayon was produced by a British company. In 1924, this 'artificial silk' attained the name **"Viscose Rayon"**.

To transform the goodness of natural cellulose from the raw form contained in wood to a usable one, cellulose needs to be extracted, dissolved, and extruded into fibres. Carbon disulphide (CS_2) is used as a solvent to dissolve cellulose contained in the pulp to form a solution called viscose, regenerated into pure and fine cellulosic fibres. Viscose fibres are a popular choice for fashion garments and hygiene products such as wipes.

Viscose is one of the most sustainable fibres available today. It is nature-based, biodegradable, and has a low environmental impact. This article focuses on the development of Closed-loop technologies that not only improve the health and safety aspect related to viscose manufacturing but also enable recycling and reuse of the resources such as chemicals, water, and energy, improving the overall sustainability of the process. This article describes the Closed-loop technologies used at Birla Cellulose's manmade cellulosic fibre manufacturing facilities, enabling safe handling of chemicals and managing the process in an eco-friendly manner.

Development of Closed-Loop Technologies for Safe Management of CS_2 in Viscose Process

By the late 1970s, the risks of CS_2 exposure to workers and the surrounding community were well understood. This awareness resulted in extensive work on the development of technologies that can control and mitigate these risks. By 2000, newer technologies emerged that enabled running of the viscose process with not only excellent controls to minimise emission of gases such as CS_2 and H_2S to environment but also helped in recovery of the solvent CS_2 up to 90-95%. Similar technologies emerged to improve the recovery and recycling of other resources used in the process. These technologies were collectively referred to as closed-loop technologies resulting in the creation of a safe working environment, achieving or exceeding the safe limits set by World Health Organisation (WHO) and Occupational Health and Safety Assessment Series (OSHAS) as well as setting new benchmarks in resource efficiency.

What is a Closed-Loop Process?

As the name suggests, closed-loop technology aims to carry out the manufacturing process in a way that chemicals and other resources used in the process are contained and emissions minimised. It also aims to recover and recycle chemicals to the extent possible as well as recover any by-products. There is no clear definition of a closed-loop process in the chemical industry. The term has been used in different contexts and interpretations. In the manmade cellulose process, the understanding on closed-loop process has been developed based on the EU BAT Standard (Reference Document on Best Available Techniques in the Production of Polymers, 2007) and more recently by ZDHC MMCF Guidelines released in 2020. These guidelines evaluate the best available technologies existing today, its capability on resource efficiency and emission control. Widely accepted as the most stringent norms available for the viscose manufacturing process, these standards describe closed-loop in two ways:

1. Defining the resource efficiency by specifying the limits for raw materials that should be used to produce one unit of product (consumption norms for chemicals, water, and energy)

2. Defining the efficiency of control technologies and allowable limits of emission to air and water, for producing one unit of product (e.g. emission of CS_2 to air or zinc or COD to wastewater)

The application of closed-loop technologies not only helped reduce the emissions to the environment but also improved sustainability of the overall process by achieving excellent resource efficiency.

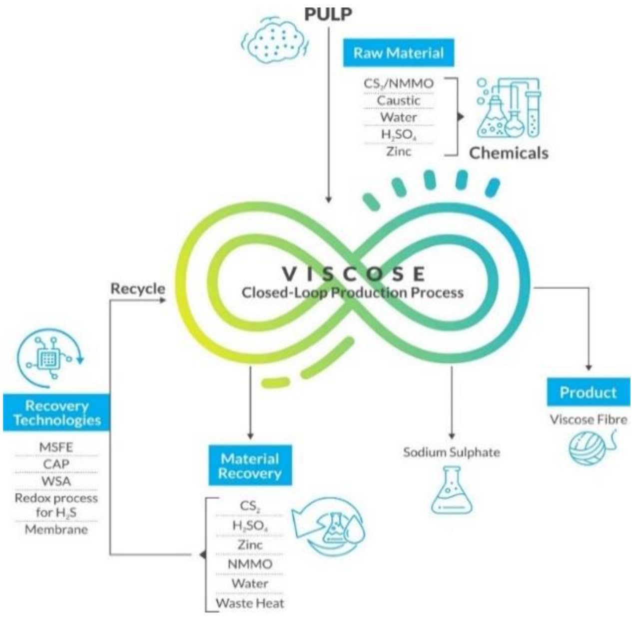

Figure 1 – Showing Inputs and Outputs of the viscose process and material recovery loops and technologies used for closed-loop process

What are ZDHC MMCF Guidelines and EU BAT Standard?

The EU BAT and ZDHC Guidelines define the most advanced technologies available today to control and minimise emissions to the environment from industrial processes and reduce resource consumptions. These documents also describe the associated emissions and consumption levels that can be achieved by applying BAT. ZDHC Guidelines are considered the most comprehensive and ambitious standard addressing emissions to air and water as well as defining the consumption norms of the viscose process. These guidelines can be accessed using the below link:

https://www.roadmaptozero.com/post/zdhc-man-made-cellulosic-guidelines-released

The most important part of the guideline is the extent to which chemicals and water can be recovered or recycled, and thus, emissions can be reduced. For example, the CS_2 solvent recovery in viscose process is as high as 95% in terms of sulphur recovery, meaning that net emission of sulphur to air is below 20 kg per tonne of fibre produced, (which used to be in the range of over 175 kg per tonne of fibre without these technologies). Similarly, sodium sulphate salt produced as a by-product from the process can be recovered up to 60% - 70% by application of closed-loop technologies. In the viscose process, sulphuric acid and zinc are continually recycled in the process by chemical recovery closed-loops.

Adaptation of Closed-Loop Technologies at Birla Cellulose

For several years, Birla Cellulose has established its leadership in sustainable business practices in the MMCF industry and adopted the most advanced and sustainable practices and technologies in sourcing practices, manufacturing, product design, and collaborative efforts towards sustainability.

The resources used in the viscose, modal, and lyocell process are chemicals, water, steam, and energy. The application of closed-loop technologies at Birla Cellulose sites has resulted in significantly improved consumption ratios of raw materials compared to the conventional viscose process and resulted in new industry benchmarks.

Birla Cellulose is committed to applying closed-loop technologies at all its fibre manufacturing sites and achieving the stringent EU BAT Standards at all its sites by 2022. A major initiative with projects worth USD 170 million is in progress at its sites to upgrade the closed-loop technologies to improve process efficiencies. Birla Cellulose is also committed to adopting the ZDHC MMCF Guidelines according to the published timelines by ZDHC at all its viscose and modal fibre facilities as well as at all its integrated sites. Manmade Cellulosic fibres viscose, modal and lyocell are nature-based fibres made from cellulose and wood. Birla Cellulose pulp sources its wood from sustainably managed forests and applies closed-loop technologies in its production process. In the production process, pulp from wood-based cellulose and cellulose are dissolved in a solvent to form a viscous solution, which is subsequently regenerated as cellulosic fibre by extruding the solution through fine spinnerets dipped in a dilute acid bath. The solvent used in the viscose process is carbon disulphide, and other chemicals used in the process are caustic, sulphuric acid, and zinc. In the case of lyocell dissolution and regeneration process, the solvent used is NMMO with water, and no other chemicals are used. In addition to chemicals, water and steam are other resources used in the production process. From the perspective of closed-loop process, chemicals recovery is key for the solvent (CS_2), sodium sulphate (by-product), sulphuric acid, zinc, water, and waste heat.

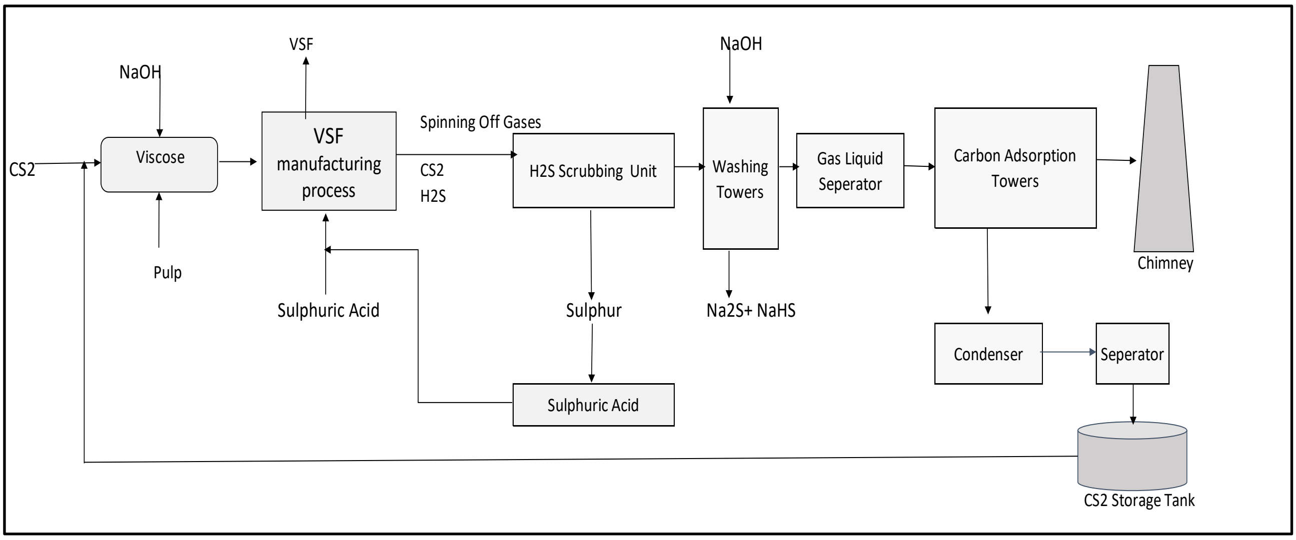

Figure 2 – Viscose Manufacturing Process Flow Chart: Closed-loop production

The recovery of CS_2 is of particular interest as the solvent is recovered using a combination of different technologies. The CS_2 and H_2S are evolved during the regeneration stage and recovered as CS_2, sulphur, or sulphuric acid. At Birla Cellulose sites, these chemicals are recycled back to the process. Applying the latest technology, it is possible to recover the solvent up to 95% in the viscose process. For recovering CS_2, condensation technology and carbon adsorption bed are used in combination with H_2S recovery technologies such as wet sulphuric acid plants and redox processes.

Another important chemical to recover is sodium sulphate salt. At Birla Cellulose sites, chemical recovery technologies allow the salt to be recovered up to 70%, among the highest in the industry. Apart from salt recovery, the acid and zinc recycling processes ensure minimal consumption of these chemicals. The chemical consumptions achieved at Birla sites are among the lowest globally and much lower than EU BAT limits.

Water is another most important resource that must be conserved. Birla Cellulose sites apply the 4R approach to reduce, reuse, recycle, and regenerate water at its sites. These initiatives have resulted in the sites becoming global benchmarks for water consumption with the lowest water consumption numbers in the industry, one-third of EU BAT norms, and several times lower water consumption than the conventional viscose process.

Furthermore, exhaust steam and low-grade heat from condensate is recovered and reused in the heating process. The utilisation of low-grade steam not only ensures that GHG emissions are lower but also minimum energy is used.

The lyocell process applied at Birla Cellulose is state-of-the-art technology and applies closed-loop technologies to recover the solvent up to 99.7% to 99.8%, among the most efficient processes in the world. The chemical consumption remains low, and there are no emissions to air from this process.

Lyocell process only uses NMMO (N-Methyl Morpholine Oxide) solvent and water for dissolution, and regeneration takes place in water. The solvent used is recovered in the solvent recovery section.

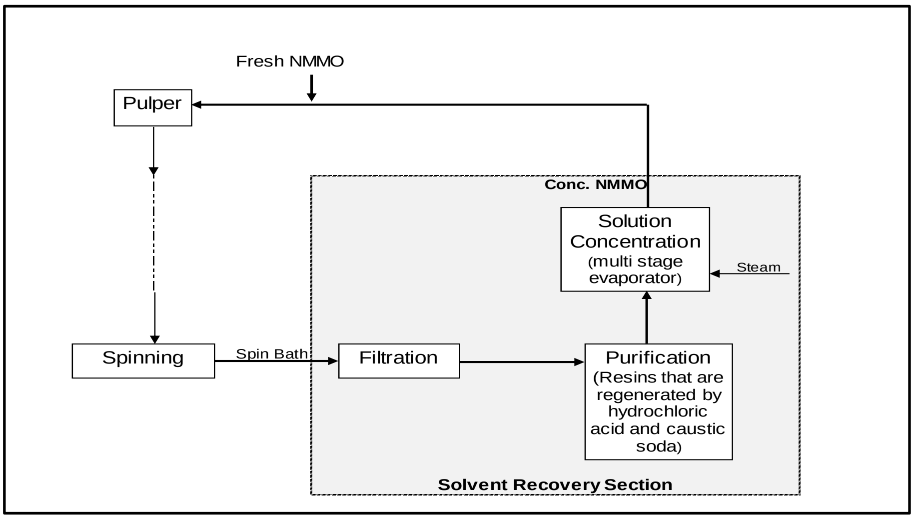

Figure 3 – Lyocell Fibre Manufacturing Process Flow Chart

Birla Cellulose had already introduced H_2S scrubbing and Activated Carbon Systems (CAP) at Thai Rayon Public Co. Ltd. (TRC) - Thailand in 2015-16. Moreover, the wet sulphuric acid technology was adapted during the same period, with the first unit coming up at PT Indo Bharat Rayon, Indonesia. Birla Cellulose developed its own indigenous technology for sulphur from recovering H_2S in a highly efficient process.

In recent years, the CAP unit at TRC was expanded with increase its capacity in 2018, taking it to the level of sulphur emission to air of below 30 kg/tonne of fibre, i.e. as per EU Ecolabel norms. Birla Cellulose is committed to implementing this technology with enhanced efficiency to move towards closed-loop production processes to minimise sulphur to air emission and thereby, meeting global standards by 2022.

Accordingly, Birla Cellulose is investing substantially towards installing new technologies across its units in India, Indonesia, and China in a phased plan. Based on the TRC experience, a sulphur and CS_2 recovery project was set up at BJFCL-China Unit in July 2019 with additional changes to overcome the shortcomings of TRC and improve gas recovery systems.

In the Spinning department, machines with glass shutters and proper sealing in all joints have been introduced to avoid any vapour leakages. The shutters are always kept closed and opened only during any maintenance activity. CS_2 and H_2S sensors with alarm systems are provided on all spinning machines that will alert the working personnel in case of any leakage. Exhaust ducts and fresh air blowers are located in the machine area. The presence of CS_2 in the ambient air inside and outside each workstation is also monitored. Tight control on emission ensures that gas levels remain within safe limits. All these systems are continuously monitored, well-maintained, and reviewed in all units to ensure a safe working environment.

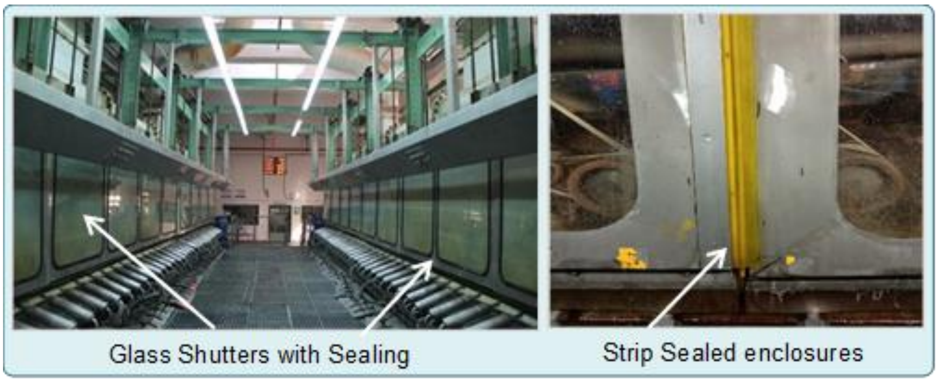

Figure 4 – Spinning Machine with Closed-loop Technologies

Results and Future Steps

The adaptation of closed-loop technologies at Birla Cellulose's viscose manufacturing site has yielded excellent results in improving the sustainability aspects related to manufacturing. In the last six years, sulphur emissions have reduced by around 28%, water consumption by 34%, COD emissions by 50% and zinc emissions by 58%. Several of our sites are already exceeding the EU BAT norms for several parameters, and we target to achieve the EU BAT norms at all our sites by 2022. Birla Cellulose is not stopping here; continuous efforts and actions are ongoing at all our other sites to constantly improve our operations and achieve new benchmarks.

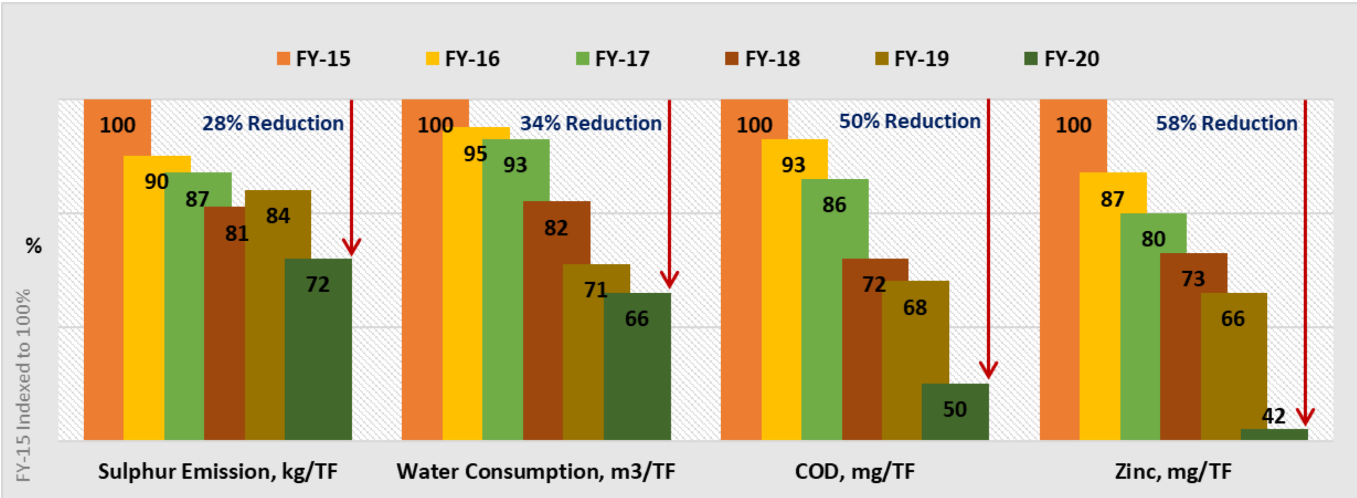

Figure 5 – Trend Graphs

Birla Cellulose believes that sustainability is a continuous journey, and the adaptation of new technologies and best practices into our value chain would result in the long-term sustainability of our process and value creation to all our stakeholders. With this aim, Birla Cellulose has set ambitious targets on sustainability and aspires to be the leader of sustainable business practices in the MMCF industry.