

[Microbiological contamination in paper mills]

The paper, pulp, and board industry faces a dual challenge – ensuring high levels of productivity while minimizing environmental impact. The innovations introduced to improve paper mill's efficiency and reduce environmental impact – such as the optimized use of virgin or recycled fibers, water reuse, and emission reduction – significantly alter traditional production processes. While these changes are strategic for sustainability, they can modify the usual operating conditions (e.g., pH, available nutrients, or material retention times), creating environments more favorable to the growth of unwanted microorganisms. As a result, production systems become more vulnerable to microbiological incidents, requiring closer and more targeted monitoring. Process water, essential in all operational stages such as washing, pulping, bleaching, and papermaking, creates ideal conditions for microbial proliferation. Indeed, it contains large amounts of biodegradable material derived from wood, starch, and other raw materials, and it typically presents temperatures between 25 and 50 °C. It is estimated that producing one ton of paper requires between 250 and 300 m³ of water, making paper mills highly sensitive systems to microbial contamination. Among the main challenges there is the formation of biofilm and biological deposit, which can clog filters, generate unpleasant odors, promote microbiologically influenced corrosion (MIC), and cause breaks or defects in paper sheets, leading to increased waste and unplanned downtime. Biofilm is a structured community of microorganisms that adhere to surfaces and produce a protective extracellular matrix, making them more resistant to cleaning and chemical treatments. This contributes to explain why more than 90% of bacteria live in biofilm, not free in the water. To maintain industrial plants free from biofilm and to maintain high standards of hygiene, quality, and safety, paper mills require advanced monitoring tools and integrated management strategies capable of detecting early biofilm growth and preventing its negative impacts. The adoption of innovative technologies for microbiological monitoring has become a key factor in reconciling industrial competitiveness, environmental sustainability, and compliance with evolving international regulations.



Figure 1: Paper mill

Paper mill operations

Paper production follows a structured and highly engineered cycle where raw materials are progressively transformed into finished products and, after use, can be reintroduced into the process through recycling. This cycle integrates mechanical, chemical, and physical treatments to optimize quality and efficiency while increasingly adopting sustainable practices. The process begins with the procurement of raw materials – primarily virgin fibers derived from wood, and recovered fibers sourced from post-consumer waste paper. Wood is processed through mechanical or chemical treatments to separate cellulose fibers, while waste paper is carefully sorted and treated to remove contaminants such as inks, adhesives, and mineral fillers. In both cases, the result is a pulp that serves as the base for paper manufacturing. Once the fibers are prepared, they are mixed with water

to form a diluted suspension, known as pulp, in which additives such as mineral fillers, retention aids, or binding agents are often incorporated to confer specific properties to the paper, including brightness, smoothness, or resistance to ink absorption. At this stage, water plays a central role, not only as a medium for fiber dispersion but also as a process agent and utility fluid, ensuring uniform fiber distribution and facilitating subsequent mechanical and chemical treatments. During refining, where fibers are fibrillated and made more suitable for interlocking, water acts both as a vehicle and lubricant, enabling proper functioning of the equipment, while additives are evenly dispersed in aqueous suspension. The pulp is then fed into the paper machine, where sheet formation begins. Water accounts for up to 99% of the suspension distributed onto the moving wire mesh, and as it drains away through suction and mechanical pressing, fibers interlace to form a continuous wet sheet. The collected process water, known as “white water,” is largely recycled upstream, reducing overall water consumption. The sheet proceeds to the drying section, passing over steam-heated cylinders to reduce residual moisture to the desired level, a thermal phase critical for ensuring dimensional stability and strength of the final product. Water consumption in drying is indirect, linked to steam generation and circulation, while finishing stages such as surface sizing, coating, and calendaring may also involve water in the preparation of aqueous solutions or in cooling circuits. Upon completion of drying and finishing, the paper is wound into large reels ready for further processing, cut, packaged, and distributed to various industrial sectors from publishing and packaging to stationery products.

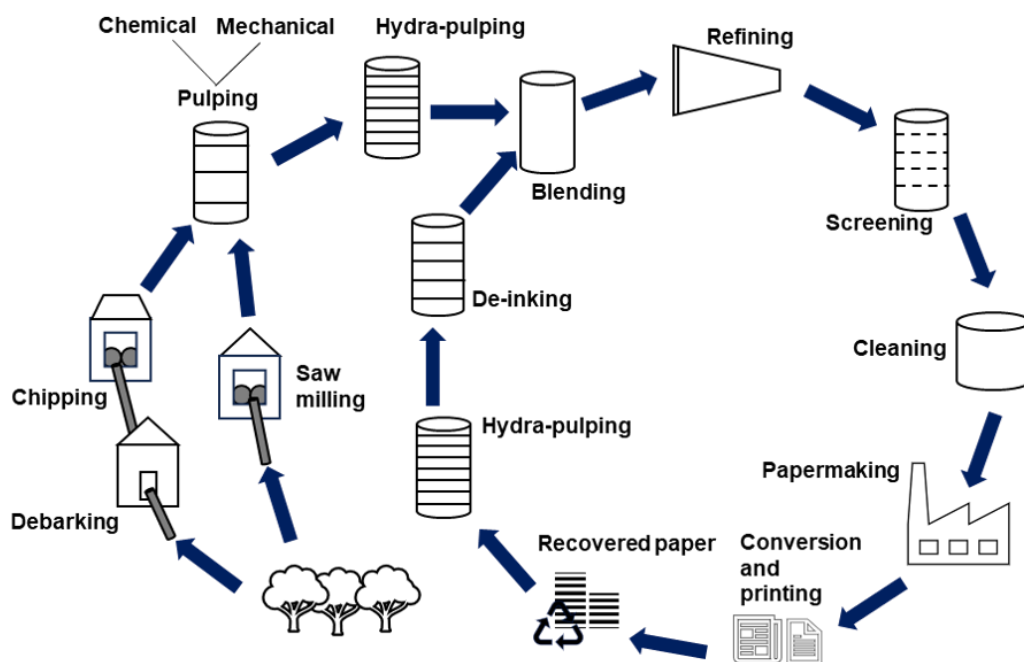


Figure 2: Diagram of the paper production process

The production cycle does not end with consumption – used paper can be collected, sorted, and reprocessed, re-entering the production cycle as recycled fiber, reducing the need for virgin raw materials, lowering environmental impact, and supporting circular economy strategies. Beyond direct production, water is extensively employed throughout the plant for cooling, steam generation, machine cleaning, and auxiliary circuits, with process effluent containing fine fibers, mineral fillers, and organic substances requiring treatment through mechanical clarification, biological processes, and sometimes physico-chemical methods before reuse or discharge. In summary, the paper production cycle is a complex integration of resource preparation, sheet formation, mechanical and thermal treatments, and finishing stages, with water management and recycling playing a strategic role, enabling the industry to produce high-quality materials while addressing environmental and economic challenges through efficiency and sustainability.

Chemical and physical treatments in paper mills

Paper mills do not limit themselves to treating wastewater intended for discharge, to ensure production continuity and maintain high quality standards, but devote great attention to the treatments applied to process water, which is continuously recycled and reintegrated into the production cycle. About 90% of the water used in a paper mill is returned to its source thanks to meticulous treatment prior to discharge. The water used represents a complex environment, rich in organic matter and nutrients that favor microbial growth, and therefore requires targeted disinfection measures. Chemical treatment has historically been the most widely used strategy for microbiological control, as discussed more in details in [another paper](#). The use of oxidizing biocides, such as chlorine, chlorine dioxide, and peracetic acid, enables rapid action against microorganisms, and it is particularly effective in the early stages of contamination. These products are also selected for their ability to adapt to different operating conditions. However, their stability and antimicrobial activity can be significantly reduced at elevated temperatures. In industrial settings, such as paper mills, where temperatures may exceed 40°C, the effectiveness of oxidizing biocides tends to decrease.



Figure 3: Water use in a paper mill

To ensure reliable microbiological control, they are often used in combination with non-oxidizing biocides, which are more stable and less sensitive to temperature variations. The non-oxidizing biocides such as a glutaraldehyde and isothiazolinones are characterized by a slower but more prolonged action, which ensures more stable microbiological control over time. The combination of the two types of agents allows interventions to be modulated according to plant need, alternating between shock treatments and maintenance programs. The use of ozone and hydrogen peroxide in advanced oxidation processes allows for the rapid degradation of organic contaminants and the inactivation of microorganisms, improving the overall quality of process water. In addition to chemical treatments, physical methods are gaining increasing importance. Disinfection through ultraviolet (UV) radiation, for example, is capable of reducing microbial load without the addition of chemicals and without

generating unwanted residues. In modern paper mills, UV disinfection units are often installed at critical points of the water circuit – such as after filtration or prior to water reuse – to inactivate bacteria, molds, and algae spores that could otherwise promote slime formation on machine surfaces. Some facilities also integrate ultrafiltration or membrane systems as complementary physical barriers to remove suspended solids and microbial cells before recirculation. However, the application of these treatments presents some challenges. Prolonged use of chemical agents may lead to microbial resistance, increase operating costs, and raise the environmental impact due to residuals released into the water cycle. Physical treatments, while effective, often require significant energy investments and do not always guarantee residual effects over time. For these reasons, the optimal management of process water in paper mills requires not only the availability of chemical agents and physical technologies, but also a continuous monitoring system that allows interventions to be calibrated based on the actual presence of biofilm and microbiological contamination.

Traditional microbiological control methods in paper mills

Historically, paper mills have relied on various techniques to monitor microbial contamination, aiming to control the proliferation of microorganisms within water circuits. Among the most commonly used methods there are laboratory-based microbiological analyses, which involve sample collection followed by cultivation on selective media. These analyses provide some information on the microorganisms present in a sample, but they require a long time to provide results – often several days – and their ability to represent the entire system is limited, due to heterogeneity in bacterial colonization and the inherent challenges of sampling. Moreover, in most cases just water samples are collected and analyzed while, as previously mentioned, the vast majority of bacteria live attached to surfaces.

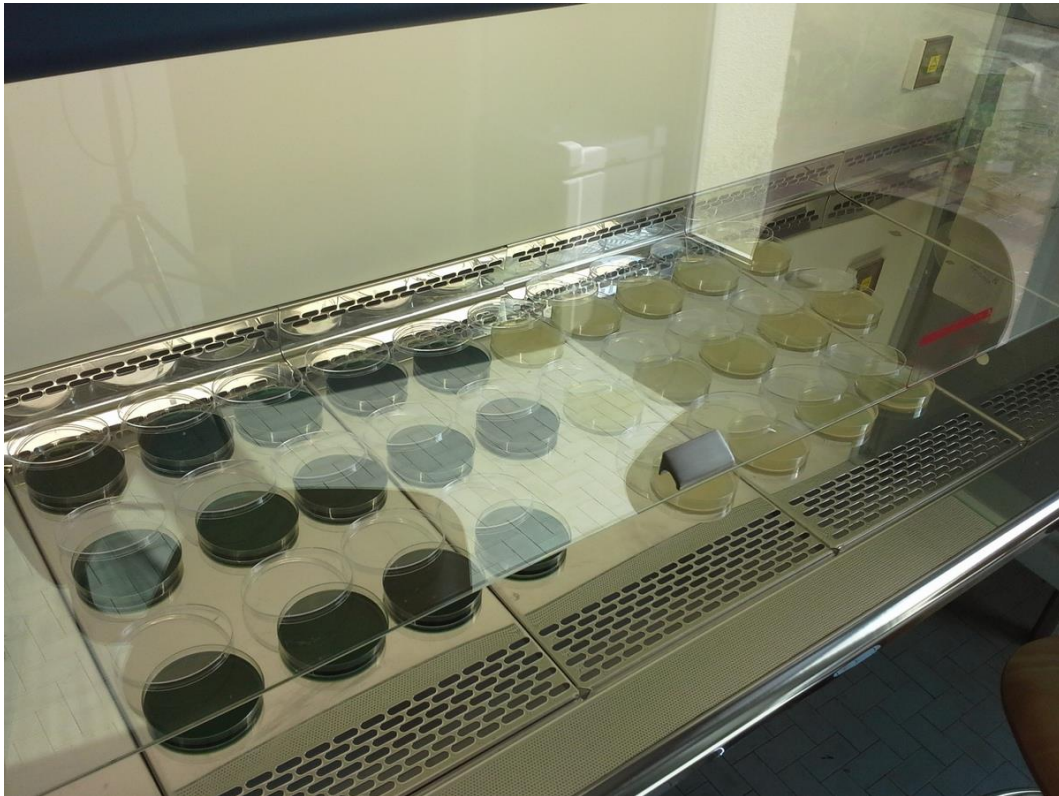


Figure 4: Laboratory culturing of samples for bacterial count

An alternative approach is represented by ATP (Adenosine Triphosphate) analyses, which allow rapid estimation of the total microbial biomass, including both planktonic and surface-adhered microorganisms. However, the information obtained strongly depends on the type of sample analyzed: ATP tests performed on bulk water reflect the planktonic microbial load, while analyses conducted on surface swabs or coupons provide insights into biofilm-associated communities. For this reason, the interpretation of ATP data must consider the sampling strategy and the specific objective of the monitoring program, to ensure a representative and meaningful assessment of the microbiological status of the system. Nevertheless, none of these traditional methods fully address the main challenge related to biofilm – the most hazardous form of contamination. In parallel with these methods, indirect monitoring approaches are often employed, based on the measurement of physico-chemical parameters such as turbidity, conductivity, or pH fluctuations. While these measurements can offer a general overview of process trends, they do not allow for direct or reliable detection of bacteria. Despite their widespread use, all these techniques are insufficient to prevent biofilm-related issues, as they provide partial, non-real-time information and rarely support the planning of targeted interventions. Consequently, paper mills have increasingly recognized the need

for continuous and specific monitoring tools capable of detecting biofilm at its early stage of development.

Biofilm monitoring in paper mills

Management of microbial contamination in paper mills cannot rely solely on chemical treatments or corrective interventions applied after the fact. To reduce costs, waste, and production downtime, it is essential to detect early signs of biofilm formation and act promptly and effectively. The ALVIM technology has been specifically developed for this purpose. ALVIM Sensors enable real-time monitoring of biofilm development within water circuits, detecting its presence from the earliest stages. Compared to periodic laboratory analyses or indirect checks, the ALVIM System provides continuous and precise information, allowing for proactive and targeted management strategies. This approach optimizes the use of biocides, resulting in reduced operational costs and environmental impact, while minimizing the risk of microbiologically influenced corrosion (MIC) and biological deposit formation, preventing production defects, and reducing waste generation. The outcome is improved stability in



Figure 6: Traditional monitoring coupled with ALVIM probe



Figure 5: ALVIM Biofilm Sensors

product quality, and a more sustainable resource management. Integrating a monitoring system like ALVIM into production processes provides a tangible tool to balance productivity, quality, and sustainability, strengthening plant resilience while ensuring compliance with increasingly stringent environmental regulations. In a European paper mill specialized in tissue paper, the [ALVIM System was installed on a white water recirculation line](#), a known critical point for biological deposit formation. After only a few weeks of monitoring, the Sensors detected initial biofilm growth that had not been identified by either periodic microbiological analyses or ATP measurements. This early warning enabled staff to check and adjust biocide dosing. At the same time, a decrease in production defects (sheet breaks and biological stains) was observed, with an estimated annual savings of several tens of thousands of euros in downtime and waste costs. This case demonstrates how continuous biofilm monitoring with ALVIM Sensors can become a solid competitive advantage, improving both final product quality and operational sustainability.

Conclusions

Water management in paper mills represents a critical challenge, requiring a careful balance between productivity, sustainability, and quality of the final product. The progressive reduction of water consumption and the increasing implementation of internal recycling, while improving environmental performance and process efficiency, raise the risk of microbial proliferation and biofilm formation. Even if chemical and physical treatments are still essential tools, they exhibit several limitations related to cost, microbial resistance, and environmental impact. In this context, the integration of continuous monitoring systems emerges as a key element for a truly proactive management approach. ALVIM Technology enables the early detection of biofilm growth, optimizing biocide usage and reducing both operational costs and environmental burden. This approach not

only enhances plant reliability and product quality, but also provides paper mills with a tangible competitive advantage, aligning with the strictest environmental regulations and global sustainability expectations. Ultimately, the combination of established treatment practices with innovative monitoring tools represents the most effective strategy to ensure production continuity, minimize waste, and promote responsible water use, while simultaneously strengthening the resilience and competitiveness of the paper industry.

Do you have a similar problem with biofilm? Contact our experts and ask for a free custom-tailored consultancy, you will receive further information about ALVIM products and services.

The ALVIM Biofilm Monitoring System is a reliable tool for the early detection of bacterial growth on surfaces, on-line and in real time, in industrial production lines, cooling water systems, etc.

The ALVIM Technology has been developed in collaboration with the Italian National Research Council, Institute of Marine Sciences, and it is currently used worldwide in many different application fields.

ALVIM Srl | +39 0108566345 | info@alvim.it | www.alvim.it | www.linkedin.com/company/alvimbiosensors