

**NIT Raipur**

**Topic: -** Waste water management in pulp and paper industry

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**Abstract:**

Depending on the sort of processes employed in the plant, pulp-and-paper mills create a variety of pollutants as well as a substantial volume of effluent. The produced wastewaters should be treated in effluent treatment facilities before being discharged into the environment since they are potentially harmful and hazardous. This article evaluates and contrasts several wastewater treatment techniques used in the pulp and paper industry in terms of pollutant removal efficiency and greenhouse gas (GHG) emissions. It also assesses how operational parameters affect the performance of various treatment methods. To estimate GHG emissions in common biological treatment methods used in the pulp and paper sector, two mathematical models were utilised. The procedures of nutrient removal and sludge treatment are addressed, as well as the accompanying GHG emissions. Although both aerobic and anaerobic biological processes are suitable for wastewater treatment, hybrid procedures demonstrated a greater pollutant removal capability at higher efficiencies under optimum operating conditions, with lower GHG emissions and energy costs.

**Introduction:**

The wastewater produced by industrial processes has a large environmental impact. The pulp-and-paper business consumes a lot of fresh water and produces a lot of effluent at different phases of the pulping and papermaking process. The wastewater produced has a negative influence on the environment and constitutes a major threat to wildlife and human life. After the key metals and chemicals sectors, this industry produces the third most wastewater [1]. According to the World Bank Group (1999), the pulp and paper sector in Canada produces 20-100 m3 of effluent every tonne of air-dried pulp. Tannins, lignins, resins, and chlorine compounds are the most common organic and inorganic pollutants found in this effluent [2]. The principal pollutants that should be eliminated and/or reduced in wastewater treatment plants (WWTPs) through a succession of treatment procedures include COD, TSS, nitrogen compounds, and adsorbable organic halides (AOX). If the quality of the treated wastewater permits, it can be recycled for reuse in the pulp and paper sector, or it can be discharged into the environment if it fulfils environmental criteria. The pulp and paper industry's wastewater treatment procedures create solid sludge and greenhouse gases (GHGs) that have substantial environmental implications and are subject to environmental restrictions. Biological, chemical, and mechanical treatment procedures are on-site sources for the generation of GHGs in pulp-and-paper sector WWTPs. This business has been found to create important GHGs such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) [3]. The thorough calculation of GHG emissions aids in identifying the major sources of GHG emissions, allowing them to be controlled and/or reduced. By exchanging CO2 credits on the market, the GHG reduction helps the industry safeguard the environment while also providing financial advantages. The main goal of this article is to look at the different wastewater treatment procedures used in the pulp and paper sector, as well as their corresponding GHG emissions.

**Source of waste water in Industry:**

The pulp-and-paper industry's key wastewater generators include wood preparation, pulp washing, pulp bleaching, and paper producing operations, as well as the digester house. The amount of wastewater created in each step is proportional to the amount of pulp generated in that process. As shown in Table 1, the produced wastewaters contain a high amount of BOD and varying quantities of other pollutants, which vary depending on the types of applied operations. Wood preparation wastewater, for example, comprises suspended particles, BOD, dirt, and fibres, whereas digesters house generated wastewater contains resins, fatty acids, colour, BOD, COD, AOX, and VOCs [4]. Treatment procedures can eliminate or minimise these pollutants. Through a variety of processes and technologies, such as energy production units, combustion, and transportation, WWTPs utilise energy while emitting GHGs [3]. The amount of GHG released in WWTPs is determined by nutrient contents in wastewater, reactor operating temperature, treatment process type, and pollutant removal effectiveness.

Table List of Pollutants [5], [6]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Pollutants** | pH | TS | SS | BOD | COD | N |
| TMP Whitewater | 4.6 | — | 127 | 1541 | 2713 | 7 |
| TMP | 4.2 | — | 810 | 2800 | 5600 | 12 |
| CTMP | 6.2 | — | 500 | 2500 | 7300 | — |
| Kraft Mill | 8.2 | 8260 | 3620 | — | 4112 | 350 |
| Bleach Kraft Mill | 10.1 | — | 37–74 | 128–184 | 1124-1738 | 2 |
| Sulphite Mill | 2.5 | — | — | 2000-4000 | 4000-8000 | — |
| Pulping | 10 | 1810 | 256 | 360 | — | — |
| Bleaching | 2.5 | 2285 | 216 | 140 | — | — |
| Bleached Pulp Mill | 7.5 | — | 1133 | 1566 | 2572 | — |
| Wood Preparation | — | 1160 | 600 | 250 | — | — |

**Waste water treatment:**

The importance of water management and effective wastewater treatment in the pulp and paper industry has been underscored by rising concerns about the use of fresh water, greater economic considerations, and rigorous environmental legislation. The key to reducing fresh water usage is the recycling and reuse of produced wastewater once it has been properly treated. This process will reduce fresh water use and reduce external discharges to the environment, so increasing environmental conservation. As a result, WWTPs' primary goal is to remove pollutants from wastewater using a combination of physicochemical, biological, and integrated treatment methods. To estimate the produced GHG emission by WWTPs, complete mathematical models (steady-state and dynamic models) were built [3], [7]. The bioreactors were considered to be totally mixed in the construction of these models:

GHG emissions were calculated using BOD concentrations obtained from several pulp and paper factories. It's worth noting that the Intergovernmental Panel on Climate Change (IPCC) advised that CO2 produced by biogenic sources not be taken into account when calculating GHGs. This assumption, however, does not apply to GHGs produced in industrial WWTPs, such as those in the pulp and paper sector. It only applies when GHGs are created without the use of fossil fuels. To calculate GHG emissions, researchers examined the kinetics of chemical and biological connections, as well as mass balances surrounding important processes and activities. The quantity of GHGs generated in the treatment systems was estimated using the calculated substrate and biomass concentrations in bioreactors. The steady-state model was used to calculate overall GHG emissions in each treatment system, while the dynamic model was used to forecast large fluctuations in each treatment plant's output and to detect time-dependent GHG emissions.

**Biological Treatment**

To remove organic pollutants from wastewaters, most WWTPs utilise aerobic and/or anaerobic biological processes. Aerobic methods are preferred in most pulp and paper mills because they are simple to operate and have minimal capital and operational expenses [8]. Activated sludge and aerated lagoons are two aerobic technologies extensively employed in the pulp and paper industry. Although anaerobic methods are not widely used in the pulp and paper sector, a few of mills have used them because of decreased sludge output, renewable energy generation (biogas), less area requirements, and the ability to further degrade pollutants [9], [10]. Both aerobic and anaerobic processes have drawbacks, such as aerobic methods' high sludge output and anaerobic bacteria's susceptibility to hazardous chemicals. The pollutant removal ability of anaerobic processes was demonstrated to be harmed by high sulphur content in chemical pulping effluent, especially at low pH levels [11]. Integrated treatment, which consists of combined biological processes working under distinct environmental conditions (aerobic and anaerobic), or physicochemical and biological processes, has been used to treat pulp-and-paper wastewaters in order to benefit from diverse treatment processes [4].

GHG emissions from WWTPs are an essential aspect to consider when deciding the sort of biological process to use in the treatment system. While aerobic activities only create CO2, anaerobic processes generate biogas, which contains methane, a strong greenhouse gas. If possible, it was suggested that the created biogas be recovered and used as a source of energy [3]. As a result, the GHG emissions and energy needs of these processes vary greatly depending on the operating circumstances and final products created.

1. **Aerobic Processes**

The most prevalent aerobic processes utilised in pulp and paper sector WWTPs are AS and aerated lagoons or aerated stabilisation basins (ASB). In a laboratory-scale system, AS was utilised to remove COD from various pulp-and-paper wastewaters. Although the AS process was shown to be capable of eliminating COD from most wastewaters in this investigation [12], there were significant discrepancies between the generated effluents at laboratory size and full-scale WWTP operations. Wastewater was treated from a paper mill using AS in a batch process to produce liner board from recycled fibres and removed 95 percent of soluble COD [13].

Other studies [14]–[16] have shown that the AS process may efficiently reduce pollutants such as BOD, COD, AOX, and chlorinated compounds in pulp-and-paper wastewaters. The high removal efficiency of COD, BOD, and AOX in the AS process (70 percent, 90 percent, and 60 percent, respectively) led to the conclusion that AS was a viable method for the treatment of pulp-and-paper wastewaters, despite the significant sludge output. The effect of bulking on bacterial growth, which resulted in a drop in removal efficiency, was neglected in these investigations.

ASB was used to treat a variety of pulp-and-paper wastewaters [17]–[20]. It was discovered that the ASB process could remove 50 percent to 70 percent BOD, 30 percent to 40 percent COD, as well as AOX and chlorinated chemicals, while requiring less nutrient input than the AS method. Long HRT, greater area needs compared to the AS process, and biological solid generation during the treatment of low flow rate wastewaters are all noted features of ASB systems. During the treatment of kraft mill effluent with ASB [21], nitrogen and phosphorus discharge rates were monitored.

They demonstrated that BOD removal efficiency is influenced by the rate of nutrient supply. The treatment of pulp-and-paper effluent in ASB was simulated, and it was discovered that while the treatment system was capable of removing up to 67 percent COD from the wastewater, certain restrictions, such as nitrogen supply, had an impact on the removal effectiveness of pollutants. In treating high rate and low rate Kraft mill wastewaters, three distinct laboratory-scale systems, namely AS, facultative stabilisation basin (FSB), and ASB, were examined [22]. Despite the fact that their SRT was rather long, the findings revealed that all three systems were capable of removing up to 70% COD and 56% AOX from wastewater. They found no difference in eliminating AOX from wastewater using FSB, ASB, or AS systems, although ASB had a lower efficiency in removing chlorinated chemicals.

Sequencing batch reactors are an alternate treatment method used in the pulp and paper sector (SBR). Using a lab-scale SBR, chemi-thermomechanical pulping (CTMP) wastewater was treated to remove up to 77 percent BOD. They advised using SBR instead of AS for wastewater treatment because it produces less sludge, allows wastewater to be treated at a higher organic loading rate, and has superior sludge settling qualities.

1. **Anaerobic Processes**

To treat pulp-and-paper wastewaters, anaerobic technologies such as the up-flow anaerobic sludge blanket (UASB) reactor and the fluidized-bed reactor (FBR) have been utilised. To remove COD and sulfite from newsprint paper mill effluent, a UASB reactor was utilised [23] and obtained 66 percent and 73 percent removal efficiency, respectively. They measured methane and sludge generation during COD removal and found that the rates of sludge and methane production were unaffected by the length of the operation. With respect to the strength of wastewater, the estimated GHG emission in this study was roughly 60% of the theoretical emission.

For the treatment of agro-based pulp-and-paper mill effluent, UASB reactor [24] was used instead of an anaerobic lagoon and achieved COD removal efficiencies of 80-93 percent. The new system had a greater COD removal efficiency, a smaller footprint, and was easier to extract biogas from. Methane is emitted into the atmosphere in an anaerobic lagoon without a biogas recovery system.

Both bleached and unbleached Kraft mill wastewaters were treated with UASB reactors. These investigations found that COD and chlorinated organics removal efficiencies ranged from 79 percent to 82 percent and 71 percent to 99 percent, respectively, and that partial effluent recycling had no effect on COD removal efficiency. TMP was treated with whitewater in a UASB reactor at influent temperatures of 35 C, 55 C, and 65 C, yielding COD removal efficiencies of 82 percent, 92 percent, and 86 percent, respectively. Furthermore, using an AS process following the UASB reactor resulted in removal efficiencies of 50 percent to 60 percent for carbohydrates and volatile fatty acids. They came to the conclusion that adding aerobic post-treatment to treated effluent improves its quality. For the treatment of wastewaters containing low and high molecular weight lignins generated by the TMP process, two laboratory-scale UASB reactors[25] were employed. They demonstrated that UASB technique is suitable for the treatment of TMP wastewaters. The system successfully removed low molecular weight lignin and COD, with a COD removal efficiency of roughly 73 percent.

For the treatment of anaerobically processed weak black liquor from Kraft pulping effluent, packed-bed reactors [26] and fluidized-bed reactors (FBR) were utilised. They increased the treatment process' effectiveness by introducing ligninolytic fungus to both reactors to increase pollutants removal efficiency. The inclusion of different fungi in the two reactors resulted in increased COD and colour removal efficiency in the PBR, according to the findings. The treatment of wastewaters with several types of anaerobic reactors, including UASB, fixed-film, and fluidized-bed, was researched [27] and compared in terms of simplicity of operation, energy consumption, and capital cost. They found that the UASB reactor used less energy and had a lower capital cost than the fixed-film reactor, but that the FBR removed more contaminants throughout the treatment of pulp-and-paper wastewaters.

**Conclusion:**

The treatment of wastewater created in the pulp and paper industry removes impurities and complies with environmental laws, while also allowing the treated effluent to be used as process water in the mills if its quality permits. Aerobic procedures, particularly AS and ASB, are more extensively employed in the pulp and paper sector than other treatment methods due to their ease of operation and high COD removal efficiency. Despite the high initial cost and high control and maintenance requirements of MBR systems, the technology's various advantages make it a viable alternative for the treatment of pulp and paper wastewaters. Because of their capacity to remove TSS and AOX, alternative aerobic treatment methods such as SBR and FSB have been utilised to treat pulp-and-paper wastewaters. However, due to the high sludge formation and energy consumption of aerobic processes, anaerobic techniques have gained popularity.

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