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Review Article

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Bioaugmentation to Treat Total Nitrogen Effluent Levels in a Leather Manufacturing Unit in South Korea

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ABSTRACT

This study explores into the application of bioaugmentation as a method to mitigate total nitrogen (TN) levels in the wastewater of a South Korean leather manufacturing unit. Through a comprehensive 5-week trial, the study demonstrates the effectiveness of bioaugmentation in reducing TN levels by an impressive 53%, a notable achievement when compared to the control treatment where no significant alterations in TN levels were observed. The findings of this study hold promising implications for the field of industrial wastewater treatment. Beyond the immediate context of the South Korean leather manufacturing unit, the study suggests potential future applications of bioaugmentation as a viable and efficient approach for addressing TN levels in industrial wastewater. The primary goal is to align with local discharge standards, ensuring that treated wastewater meets regulatory requirements. This research contributes valuable insights to the ongoing efforts in sustainable industrial practices, highlighting bioaugmentation as a prospective solution to enhance environmental compliance and wastewater management.

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Introduction

This South Korean company makes leather for different uses, offering customers top-quality leather goods. The company is dedicated to reducing the amount of waste it produces in an industry that's often criticized for its environmental impact. Even though they tried various advanced methods to treat the waste, the levels of Total Nitrogen (TN) in the industrial waste remained a problem. Despite trying different advanced designs to treat the waste, the plant's Effluent Treatment Plant (ETP) couldn't reach the required discharge limits for TN levels.

The leather industry manufactures essential raw materials that are deemed crucial inputs for both the footwear and leather wear sectors, both recognized as leading industries worldwide. The leather industry utilizes around 130 different chemicals such as vegetable and synthetic tannins, auxiliaries, and large volumes of water in its processes [1]. The manufacturing stages generate substantial amounts of wastewater containing high concentrations of various pollutants [2]. The leather industry, on average, uses 10-25 m3 of water throughout its various stages and typically produces 8-20 m3 of wastewater. The specific flow can vary based on the technological advancements implemented by each industry [3].

If the wastewater from the leather industry is not properly treated, these pollutants can pose serious threats to the environment. Commonly monitored wastewater pollutants include chemical oxygen demand (COD), biochemical oxygen demand (BOD), total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), Total Nitrogen (TN), among others. The degree of pollution varies among tanneries, influenced by factors such as the technology employed, the volume of process water, types of chemicals used, dosage rates, and other contributing factors [2].

Biological treatment has been proven to be eco-friendly when it comes to removing specific organic pollutants, especially when compared to alternative technologies [3].

Bioaugmentation involves introducing specialized microbial strains with the capability to break down specific pollutants into a polluted environment [4]. A five-week experiment was carried out using bioaugmentation technology to address Total Nitrogen (TN) levels in the wastewater. This technology involves a mix of various bacillus species, which enhances the biological removal of nutrients from wastewater. It possesses a distinct capability to rapidly decrease nitrogen loading through multiple bacterial facilitated metabolic pathways.

Table 1: Different forms of Nitrogen in Wastewater [5]

Definition	Formula	Formula
Total Nitrogen (TN)	Concentration of all nitrogen forms in wastewater	TN = TKN + NO_3 + NO_2
Total Kjeldahl Nitrogen (TKN)	Sum of Ammonia (NH_4) and organic-Nitrogen in wastewater	TKN = NH_4 = org-N
Ammonia (NH_3 or NH_4)	Predominantly NH_4^+ in acidic or neutral pH; mostly NH_3 when pH>7.0	-
Organic-Nitrogen (org-N)	Small fraction resistant to biological treatment	-
Nitrate (NO_3)	Indicates the presence of nitrification and denitrification; can be low in well or poorly treated effluent	

Treatment Plant Design & Application Methodology

The experiment was conducted in two distinct treatment units to assess the effectiveness of bioaugmentation compared to a control plant. In the unit where bioaugmentation was applied, the chosen technology was consistently dosed at 0.5 ppm throughout the entire trial using drip dosing. About two weeks into the bioaugmentation, adjustments were made in the Bioaugmented unit to improve the process flow. The modification specifically involved converting the initial aeration tank into an anoxic tank to enhance denitrification.

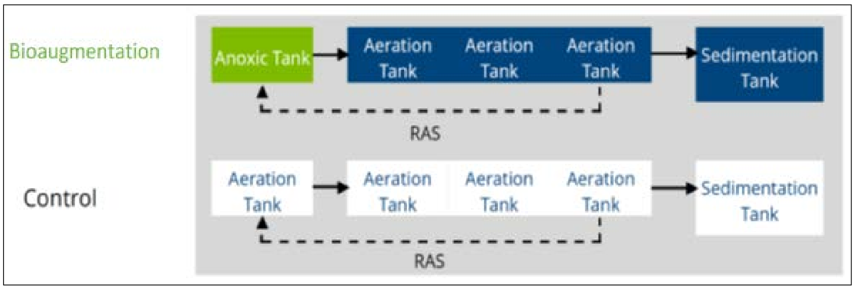

Figure 1: After Modification – The First Aeration Tank was Modified and Converted to Anoxic Tank to Enhance Denitrification

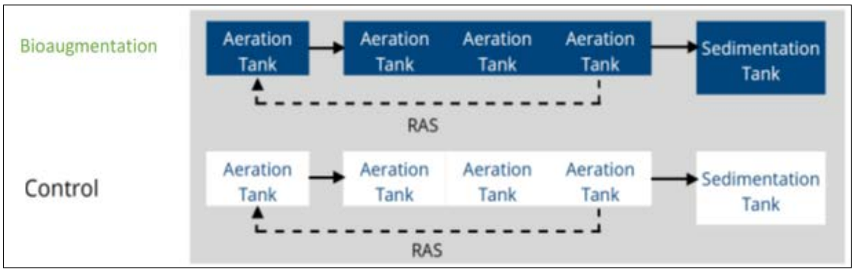

Figure 2: Before Modification

A common activated sludge process used for biological nitrogen removal consists of an anoxic tank followed by an aerobic tank. The anoxic tanks provide conditions favorable for bacteria to use nitrate instead of oxygen as a terminal electron acceptor during organic substrate consumption. The aerobic tank provides oxygenated conditions that allow the nitrifying bacteria to convert the organic nitrogen and ammonia within the influent wastewater to nitrate. A portion of the nitrified mixed liquor is recycled back to the anoxic tank, providing nitrate for the denitrification step [6]. The series of aeration tanks in the Bioaugmented treatment unit followed by anoxic tank provided improved efficiency for both nitrification and denitrification – see Figure 1.

Results

The Total Nitrogen (TN) levels in the plant that underwent bioaugmentation technology dropped down from 109.2mg/l to 51.1mg/l in 5 weeks. This translated to a substantial 53.2% decrease in TN levels within the bioaugmented unit. On the other hand, the control treatment exhibited no noticeable improvement in TN levels throughout the entire duration of the trial. Additionally, the application of bioaugmentation played a pivotal role in ensuring that the discharged water met the stringent local discharge limits for TN levels, successfully achieving compliance with the specified threshold of <60 mg/L.

Table 2: Total Nitrogen (TN) levels Data – Bioaugmentation vs Control

	Unit	10/29	11/1	11/6	11/11	11/14	11/17	11/21	11/27
Bioaugmentation	mg/l	109.2	102.5	94.7	92.5	88.4	47.5	63.76	51.1
Control	mg/l	105.8	117.3	112.3	108.4	122.7	117	123.6	113.3

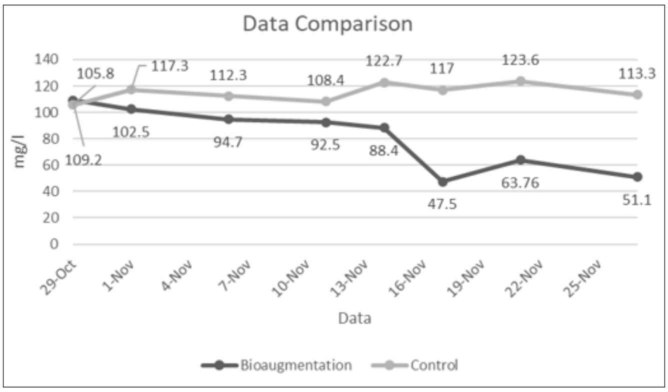

Figure 3: Total Nitrogen Levels (Bioaugmentation vs Control Treatment

Conclusion

Bioaugmentation has been proven to significantly enhance effluent quality, demonstrated by Total Nitrogen (TN) levels in the treated effluent consistently measuring below 60 mg/L, thereby meeting the required local discharge limit requirements. Furthermore, the implementation of bioaugmentation resulted in a significant reduction in odor across various unit operations within the plant.

This study firmly establishes bioaugmentation as a viable and effective strategy for diminishing Total Nitrogen levels in wastewater originating from textile manufacturing units. Especially, the research highlights the pivotal importance of considering plant design factors when determining the optimal location for bioaugmentation implementation.

Additionally, the application of bioaugmentation played an important role in ensuring strict compliance with local discharge limits for TN levels. The treated water from the bioaugmented unit consistently adhered to the specified threshold of <60 mg/L, aligning with local regulations. This successful compliance highlights the practical significance of bioaugmentation, not only in enhancing treatment efficacy but also in surpassing regulatory standards for environmental discharge. The study's findings contribute valuable insights into the dual benefits of bioaugmentation, showcasing its effectiveness in TN reduction and its pivotal role in meeting stringent discharge limits.

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