Effluent Quality Improvement in Fast Food Processing Plant: A Bioaugmentation Case Study from Jakarta, Indonesia

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Abstract: ***This study aims to enhance the overall treatment efficiency of a wastewater treatment plant at a fast - food processing plant located in the capital city of Jakarta, Indonesia, by introducing bioaugmentation technology. The production of fast food involves various food materials, ingredients, and seasonings within the processing plant, resulting in a high generation of fat, grease, and other organic pollutants in the effluent discharge. Conventional treatment units, such as grease trap tanks, have limitations in efficiently reducing the fat and grease content and heavily rely on manual maintenance. Bioaugmentation technology is implemented to assist the treatment plant in reducing excessive fat and grease levels in each of the meat and seasoning processing units, thereby improving the overall efficiency of the main treatment unit system. It was observed that major pollutant parameters were significantly reduced after Bioaugmentation implementation: 80% for BOD, 72% for COD, 26% for TSS, 64% for Ammonia, and 56% for FOG, respectively. The introduction of this bioaugmentation program led to improvements in meeting the targeted local standard discharge, the reduction of excessive solid fat and grease, and the simplification of overall handling maintenance.***

Keywords: Bioaugmentation, Effluent, Fat Oil & Grease (FOG), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia.

1. Introduction

Indonesia is one of the largest fast - food consumer countries. With its domestic consumption - driven economy, a fast - growing middle class, and world's fourth - largest population, Indonesia is considered an important market by global consumer goods companies. [1] Fast food, sold by international franchises, began its expansion to Indonesia around the 1990s, and its spread to various big cities in Indonesia was very rapid. [2] In Indonesia, the foodservice business grew from 5.03% to 6.92% annually between 2015 and 2019. [3] As the demand for fast - food consumption increases, along with the expansion of its production facilities, controlling the fat and grease, the main pollutants in the effluent, and other related organic pollutants becomes challenging for environmentally friendly discharge.

Fat, Oil, and Grease (FOG) are typically produced at food service establishments or other food preparation facilities. [4] One of the common treatments used to address FOG content is the use of a Grease Trap (GT). The GT system allows FOG to solidify on the surface, and it needs to be removed regularly to maintain removal efficiency. FOG, with a density less than water (specific gravity <1), floats on the water surface. [5] However, the efficiency of GT is highly dependent on the frequency of its maintenance. [6] Another disadvantage of this conventional technique is its low efficiency in the removal process. [7]

Biological treatment, utilizing microorganisms, serves as an alternative solution for reducing FOG content in wastewater, complementing chemical and mechanical treatments. The role of microorganisms in wastewater treatment is crucial for purifying wastewater and mitigating its environmental impact. [8] Microorganisms produce extracellular enzymes as part of the biodegradation process, facilitating the breakdown of the complex molecules of FOG. [9] The reduction in FOG content could impact the depletion of other related organic pollutants. FOG can account for approximately 25 - 35% of the total chemical oxygen demand (COD) in raw wastewater flowing into municipal wastewater treatment plants. [10]

The aim of this study is to assess the effectiveness of bioaugmentation technology in enhancing FOG removal and related organic pollutant parameters within existing treatment plants at fast - food facilities. In Jakarta, Indonesia, there are two fast - food processing plants that produce partially prepared food for their respective restaurants in each city mall. One plant specializes in meat processing, while the other focuses on food seasoning. Both facilities incorporate effluent treatment processes, managing their outlets centrally at a primary wastewater treatment plant.

2. Materials and Methods

Meat Processing Effluent Treatment Plant: The meat processing facility generates approximately 50 m3/day of wastewater. It comprises control tanks, grease traps, and aerated tanks, with their outputs pumped into the equalization (EQ) tank of the primary treatment plant. Grease is pumped out of the traps at the end of each month. Overall, the effluent treatment plant for meat processing maintains an average retention time of 2.5 days. The concentrations of pollutants before and after treatment are included in Table 1.

Table 1: Pollutant concentrations before and after meat processing effluent treatment

	COD (mg/l)	BOD (mg/l)	Ammonia (mg/l)	FOG (mg/l)
Before Effluent Treatment	2100	826	31	200
After Effluent Treatment	1721	650	59	157

Food - Seasoning The food - seasoning processing plant produced 20 m3/day of wastewater. To mitigate the inflow of excessive suspended solids and fat content into the main treatment plant, a simple 15 m3 grease trap was installed. The discharge from this 15 m3 grease trap was then pumped into the EQ tank of the main treatment plant, blending with the effluent from the meat processing treatment plant. The concentrations of pollutants before effluent treatment are presented below in Table 2.

Table 2: Pollutant concentrations before food seasoning effluent treatment

	COD (mg/l)	BOD (mg/l)	TSS (mg/l)	Ammonia (mg/l)	FOG (mg/l)
Before Effluent Treatment	2000	771	468	12	58

Main Treatment Plant: The main treatment plant consisted of an EQ tank, an electrocoagulation unit, a clarifier, and an effluent tank. The electrocoagulation unit was designed to separate solids from the wastewater and accumulate them in a sludge container. Routine samples were taken from the EQ tank to assess the quality of the wastewater mixing. Pollutant concentrations in the EQ tank and after the clarifier tank are presented in Table 3.

Table 3: Pollutant concentrations in the EQ tank and after the clarifier

	COD (mg/l)	BOD (mg/l)	TSS (mg/l)	Ammonia (mg/l)	FOG (mg/l)
EQ Tank	2159	768	730	48	121
After Clarifier	632	246	88	36	6

The Bioaugmentation Technology utilized in this study is a combination of proprietary beneficial microorganisms. The objective was to evaluate its efficacy in reducing COD, ammonia, and FOG content, as well as diminishing excessive fat sludge in the fat trap tanks at both stream sources. The initial dosing took place in February 2018. Each day, 500 g of the bioaugmentation technology was dissolved into a 300 L clean water tank for the meat processing treatment, while 300 g of the bioaugmentation technology was dissolved into a 300 L clean water tank for daily dosing in the food - seasoning effluent treatment process. These dosing tanks are strategically placed at the beginning of each pretreatment process as the pH and temperature levels in those tanks are in a suitable range for biological activity.

Samples were taken from 3 points: the outlet of the meat processing treatment plant, EQ tank of main treatment plant, and the final outlet of the main treatment plant. Samples were taken every week during the bioaugmentation program and were tested for BOD, COD, TSS, Ammonia, and FOG content.

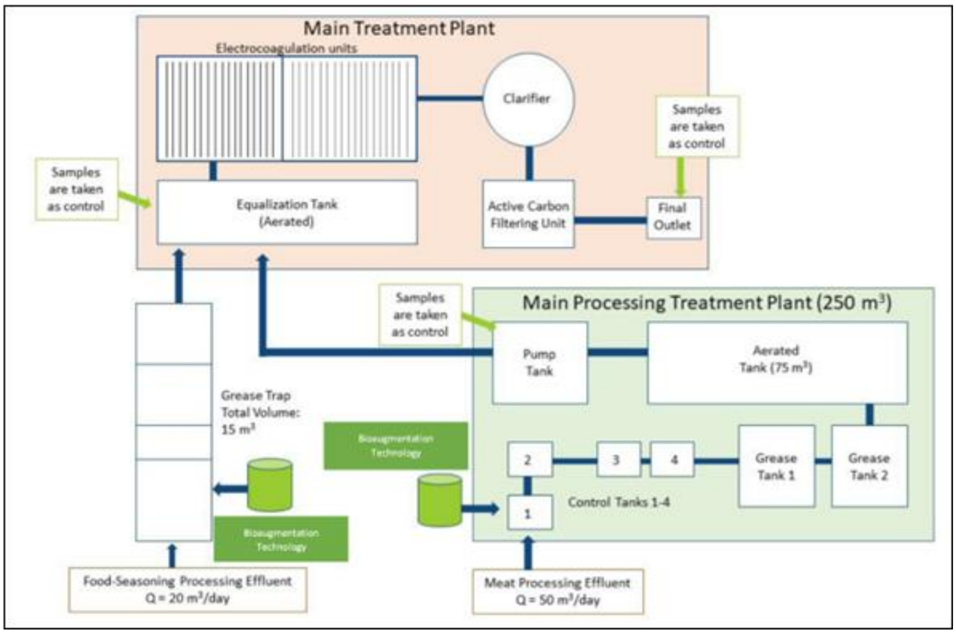
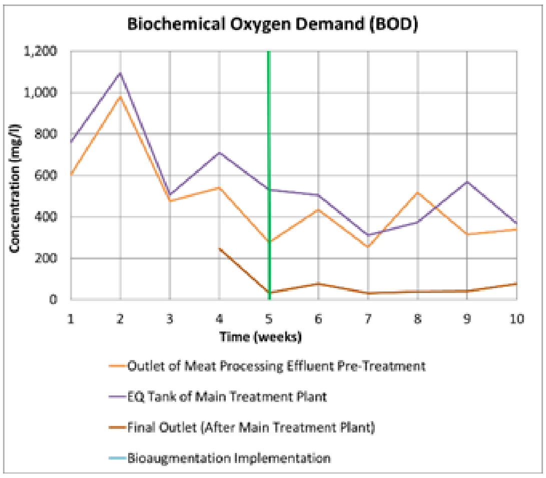


Figure 1: Process Flow Chart: 2 effluent treatment processes converging at the main treatment plant.

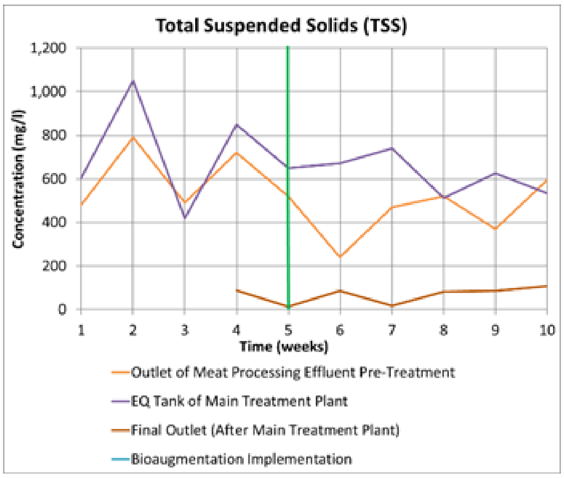
3. Results

Table 4: Data for the samples collected from the three locations

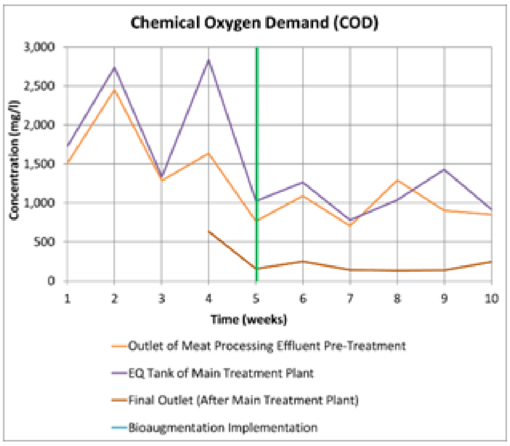
Parameter	Unit	Sampling Location	Before Bioaugmentation				After Bioagmentation					
			Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
BOD	mg/l	Outlet OF Meat Processing Effluent Treatment	601	981	476	540	276.00	435.00	254.00	517.00	315.00	340.00
	mg/l	EQ Tank of Main Treatment Plant	759	1,095	507	709	532	505.00	311.00	373.00	570.00	367.00
	mg/l	Final Outlet (After Main Treatment Plant)				246	33.00	77.00	32.00	39.00	41.00	78.00
COD	mg/l	Outlet OF Meat Processing Effluent Treatment	1,509	2,452	1,287	1,636	767.00	1,088.00	706.00	1,293.00	900.00	849.00
	mg/l	EQ Tank of Main Treatment Plant	1,725	2,738	1,335	2,836	1026	1,262.00	778.00	1,037.00	1,426.00	918.00
	mg/l	Final Outlet (After Main Treatment Plant)				632	157.00	247.00	139.00	131.00	135.00	243.00
TSS	mg/l	Outlet OF Meat Processing Effluent Treatment	480	790	491	720	520.00	240.00	470.00	520.00	370.00	594.00
	mg/l	EQ Tank of Main Treatment Plant	602	1,050	418	850	650	670.00	740.00	513.00	626.00	534.00
	mg/l	Final Outlet (After Main Treatment Plant)				88	14.00	86.00	18.00	81.00	85.00	107.00
Ammonia	mg/l	Outlet OF Meat Processing Effluent Treatment	46	94	51	46	21.00	13.00	26.00	9.00	25.00	23.00
	mg/l	EQ Tank of Main Treatment Plant	36	59	34	37	25	27.00	20.00	23.00	37.00	30.00
	mg/l	Final Outlet (After Main Treatment Plant)				36	9.50	15.00	9.00	9.00	9.70	26.00
FOG	mg/l	Outlet OF Meat Processing Effluent Treatment	165	199	95	170	26.00	3.00	14.00	35.00	8.00	6.00
	mg/l	EQ Tank of Main Treatment Plant	52	127	64	244	45	24.00	75.00	6.00	46.00	70.00
	mg/l	Final Outlet (After Main Treatment Plant)				6	< 1.8	3.00	2.00	< 1.8	< 1.8	3.00



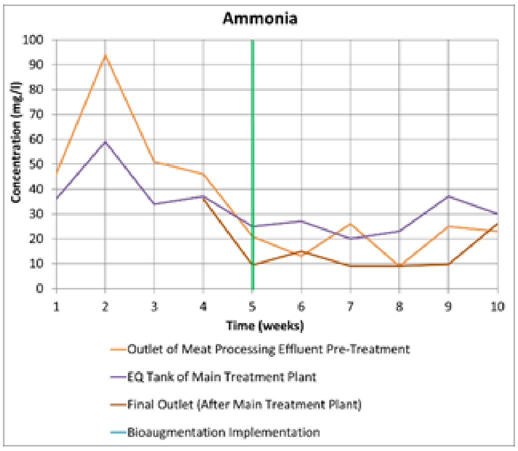
Graph 1: BOD levels before and after bioaugmentation



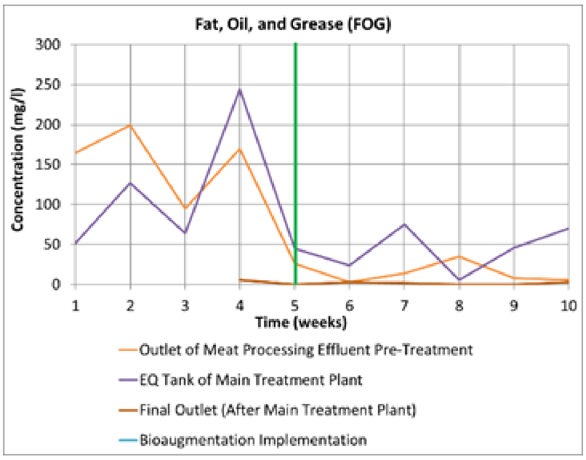
Graph 3: TSS levels before and after bioaugmentation



Graph 2: COD levels before and after bioaugmentation



Graph 4: Ammonia levels before and after bioaugmentation



Graph 5: FOG levels before and after bioaugmentation

Figure 2: Sludge tank before Bioaugmentation

Figure 3: Sludge tank after Bioaugmentation

Table 5: % reduction for BOD, COD, TSS and Ammonia before and after Bioaugmentation

Parameter	Unit	Sampling Location	Average Before Bioaugmentation	Average after Bioaugmentation	% Reduction using Bioaugmentation Technology
BOD	mg/l	Outlet OF Meat Processing Effluent Treatment	650	356	45%
	mg/l	EQ Tank of Main Treatment Plant	768	443	42%
	mg/l	Final Outlet (After Main Treatment Plant)	246	50	80%
COD	mg/l	Outlet OF Meat Processing Effluent Treatment	1,721	934	46%
	mg/l	EQ Tank of Main Treatment Plant	2,159	1,075	50%
	mg/l	Final Outlet (After Main Treatment Plant)	632	175	72%
TSS	mg/l	Outlet OF Meat Processing Effluent Treatment	620	452	27%
	mg/l	EQ Tank of Main Treatment Plant	730	622	15%
	mg/l	Final Outlet (After Main Treatment Plant)	88	65	26%
Ammonia	mg/l	Outlet OF Meat Processing Effluent Treatment	59	20	67%
	mg/l	EQ Tank of Main Treatment Plant	42	27	35%
	mg/l	Final Outlet (After Main Treatment Plant)	36	13	64%
FOG	mg/l	Outlet OF Meat Processing Effluent Treatment	157	15	90%
	mg/l	EQ Tank of Main Treatment Plant	122	44	64%
	mg/l	Final Outlet (After Main Treatment Plant)	6	3	56%

Average reduction for each parameter from the 3 sampling locations are shown in table 5. The data indicates bioaugmentation had a significant impact on all the parameters at all the 3 sampling locations. There was a noticeable shift in the floating sludge's texture. Before the introduction of Bioaugmentation, it was rigid and dense, but it transformed into a softer consistency within a few weeks. During routine sludge pumping operations, the operator previously had to manually break down the solid and heavy sludge to facilitate pumping to the truck. Following a couple of weeks of Bioaugmentation implementation, the sludge became soft and lightweight, making it easily pumpable. Recognizing this significant change, the plant manager decided to decrease the frequency of sludge pumping from monthly to once every three months. As a result, there was a substantial 60% reduction in the cost associated with hauling the solid sludge.

4. Conclusion

The implementation of the bioaugmentation technology program in both meat and seasoning processing not only showcased remarkable efficiency improvements but also delivered substantial benefits for the entire upstream - downstream treatment plant. The program's impact was particularly evident in the reduction of fat and grease content, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia, and Total Suspended Solids (TSS), highlighting its versatility in addressing multiple components of wastewater. Beyond immediate gains, the long - term application of bioaugmentation has the potential to further enhance the overall efficiency of the treatment plant, ensuring sustained positive outcomes. This extended period of implementation contributes to the establishment of stable results for the final treated effluent, providing a reliable and consistent quality of treated water. One notable advantage of bioaugmentation is its role in minimizing the sludge pumping frequency, which, in turn, leads to substantial cost savings in sludge handling. By promoting the biological breakdown of organic matter and pollutants, the technology contributes to a reduction in sludge volume, easing the burden on pumping mechanisms and ultimately lowering associated operational expenses. In conclusion, the implementation of bioaugmentation technology not only demonstrates immediate efficiency improvements in critical wastewater parameters but also offers a pathway for long - term stability and cost - effectiveness in the operation of treatment plants, making it a valuable and sustainable solution for the meat and seasoning processing industry.

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