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The Use of Chemicals and Recycled Oil Palm Plantation Production Waste and Impact on Groundwater Quality

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Abstract: The use of wetlands for oil palm plantation is associated with a negative impact on the environment. Meanwhile, oil palm plantation plays a crucial role in supporting the social economy of the community. This study aimed to analyze the productivity of private oil palm plantation in wetlands and the impact on groundwater quality. The experiment was carried out by calculating the amount of production mathematically and taking groundwater samples to be tested in the laboratory. Data were obtained on the amount of PH, BOD, COD, DO, NO_3-N, NH_3, Cd, Cu, Pb, Zn, CI, and SO_4^2 in groundwater. The results showed an increase in Fresh Fruit Bunch (FFB) production of up to 42.44%, but there was a change in groundwater quality. Water quality decreased due to an increase in the amount of BOD 312.31%, NO_3-N 23.95%, NH_3 100%, Cd 166.67%, Cu 433.33%, Pb 200%, Zn 3.800%, Ci 1,672.59%, and SO_4^2 16.19%**.** Based on the results, it is necessary to increase the amount of compost used while reducing the application of inorganic fertilizers and recycled materials left over from PKS production. Pesticides and herbicides should be used effectively according to standard requirements.
Keywords: groundwater, wetlands, oil palm plantation

1. Introduction

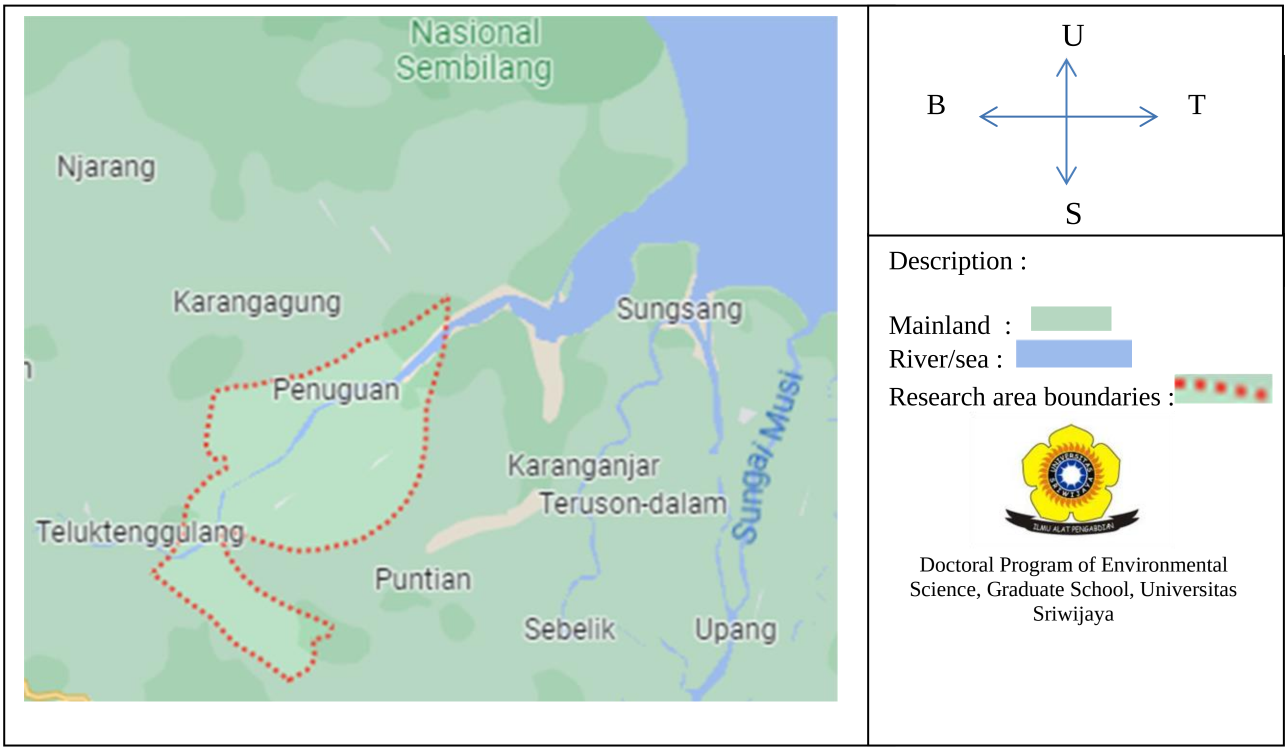
Indonesia is the largest country in Asia, with a total area of 7.81 million km², 17,499 islands, an ocean area of 3.25 million km², an exclusive economic area of 2.25 million km², and a land area of 2.01 million km² [1]. Geographically located between the continents of Asia and Australia as well as between the Indian and Pacific Oceans, Indonesia is an agricultural country due to the fertile soil suitable for various types of plants [2]**.**

Indonesia has 38 provinces, including South Sumatra Province. This province has a swamp area of around 14,836.62 km^2, including Banyuasin Regency, with 19 Tidal Swamp (RPS) and 1 Lebak Swamp (RL) area. In this regency, there are Pulau Rimau and Penagukan Strait sub-districts included in the water area category [3]. These sub-districts have 11 palm oil companies, including PT. Cipta Lestari Sawit (PT.CLS) [4]. Private or state and community oil palm plantations have positive and negative impacts on the environment [5-10]. The negative impacts include groundwater, underscoring the need for further studies.

2. Material and Methods

2.1. Study Location

The study was conducted in Pulau Rimau and Selat Penugukan Sub-districts, Banyuasin Regency, within oil palm plantation owned by PT.CLS, namely MWE (Majatra Wonosari Estate), BAE (Bumi Asih Estate), and BRE (Bumi Rejo Estate). The area is estimated at $\pm$52.13 km^2, geographically located at 2039'08.332" LS-104030031.860E and 2042'03.873" LS-104030056.842E. To the west of this land, there is the Hantu River with a width of $\pm$10M and an average depth of <5M. In the southern part, there is the Banyuasin River with a width of $\pm$400 M and a depth of > 5 M which is directly connected to the Bangka Sea. The closest settlement to the plantation is $\pm$4 KM. To the left, right, and in front of the core plantation, there is a PT.CLS plasma plantation covering an area of 63.39 km^2



(Figure 1. Map of the research area, Scale 1 : 20,000)

Data were obtained through mathematical calculations on FFB, and water samples from monitoring wells at coordinates 02038'46.6” S and 104032'20.5” E as well as recycled materials at pond outlets around oil palm plantation area at coordinates 02” 39'20” S and 104”32'12” E. Water samples and recycled materials were taken using equipment according to sampling standards by competent personnel and tested at the Komite Akreditasi Nasional (KAN)-certified Banyuasin Regency Dinas Lingkungan Hidup (DLH) laboratory. The parameters tested include the potential of hydrogen (pH), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), nitrate-nitrogen (NO3-N), ammonia (NH3), cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), chloride (Cl), and sulfate (SO4^2-). Outlet waste tests were carried out by providing the parameters pH, BOD, COD, oil-fat, Cu, Cd, Pb, and Zn. Data were also obtained from oil palm plantation company PT. Citra Lestari Sawit (CLS), concerning maintenance actions as factors that influence groundwater quality.

2.2. Data Analysis

The quantitative data analysis method was used to determine the appropriate treatment. Data was obtained through sampling followed by testing in the laboratory which was grouped into dependent (output) and independent variables (input).

2.2.1. Quantity Calculation

Mathematical calculations were carried out to determine changes in the amount of FFB production, basic plant materials, and maintenance (fertilizer, Plant Pests and Diseases, and weed management), in terms of percentages.

2.2.2. Quality Calculations

To determine the quality of groundwater and fertilizer originating from recycled materials, samples were taken and tested in a KAN-certified laboratory. The water quality parameters tested include pH, BOD, COD, DO, NO_3-N, NH_3, Cd, Cu, Pb, Zn, CI, and SO_4^2, while for recycled materials the parameters used were pH, BOD, COD, oil-fat, Cu, Cd, Pb and ZN. Each change in the amount of pollutant over an annual period was calculated mathematically.

2.2.3. Maintenance

Maintenance was conducted by applying compost derived from empty fruit bunches (EFB) as an organic fertilizer. EFB compost improves soil structure, enhances nutrient availability, and reduces the reliance on chemical fertilizers, contributing to more sustainable palm oil cultivation. The application rate and composting process were adjusted to maintain optimal levels of essential nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K). Monitoring included pH, heavy metals (Cu, Cd, Pb, Zn), and nutrient content to ensure compliance with environmental standards. This approach not only reduces chemical input but also lowers production costs and mitigates environmental impact, especially on groundwater quality [11].

3. Results and Discussion

3.1. Plantation Planting Area

PT CLS's production oil palm plantation consists of the Pulau Rimau (PRE), Majatra Wonosari (MWE), Bumi Asih (BAE), Kualo Puntian (KPE), and Bumi Rejo Estate (BRE). This consisted of an estimated area of ±4,492.45 hectares (ha) as a core oil palm plantation and 6,338.28 hectares (ha) for community partnership oil palm plantation with PT CLS (Plasma). The planting started in 2006 and was completed in 2018, with an average number of 136 plants per hectare (plants/ha). Therefore, in the core plantation, there are 678,973 plants, and in the plasma plantation, there are 862,006 plant

3.2. FEB Production

Several factors influence the amount of production, including the use of fertilizers, pesticides, and herbicides. The PT.CLS oil palm plantation, which was founded in 2004, started the planting process in 2006 and the production stage in 2009. Therefore, at the time of the study, the highest plant age was 16 years and the lowest was 4 years.

Table 1. Fresh Fruit Bunch (FFB) production data

No	Planting Year	Production				Average kg/year	Land area (Ha)
		2019 kg/year	2020 kg/year	2021 kg/year	2022 kg/year		
1	2006	1.448.724	1.274.013	2.995.962	1.356.474	1.768.793	46,47
2	2007	4.165.848	3.933.123	13.228.140	4.652.260	6.494.843	157,83
3	2008	3.334.556	3.359.812	14.634.988	3.695.361	6.256.179	146,74
4	2009	10.253.909	9.967.790	22.428.627	11.082.043	13.433.092	385,91
5	2010	7.764.895	8.134.871	17.625.889	8.102.901	10.407.139	328,15
6	2012	3.763.432	4.120.858	9.624.584	5.106.880	5.653.939	188,61
7	2013	35.690.595	39.347.041	49.530.836	54.988.386	44.889.215	2.095,51
8	2014	7.615.978	8.466.341	12.906.199	14.791.599	10.945.029	1.022,75
9	2015	0	36.791	80.654	84.090	67.178	8,77
10	2016	0	151.918	329.643	447.138	309.566	31,69
11	2017	0	0	688.311	965.305	826.808	70,49
12	2018	0	0	59.247	186.213	122.730	9,53
Total		74.037.937	78.792.558	144.133.080	105.458.650		4.492,45

(Source: Fresh Fruit Bunch Production data PT.CLS 2022)

Table 1 shows that production in 2021 was relatively high, reaching 144,133,080 kg/year or 32,083 kg/ha/year. An increase in production occurred from 2019 to 2021, reaching 42.44%. Optimal oil palm production occurred when the trees reached 10 to 20 years old with production reaching 20 to 22 tons/ha/year. FFB production was influenced by the amount of fertilizer applied in 2020, while the highest number of Management of Plant Disease Pests and weeds occurred in 2020 and 2021.

3.3. Use of organic and chemical materials

To obtain the maximum amount of Fresh Fruit Bunch (FFB) production, the company uses various methods, including organic and chemical materials. This was aimed at enhancing soil and plant fertility, as well as reducing or eliminating pests.

3.3.1. Fertilizer

In addition to chemical fertilizers, the company also incorporates organic compost and bio-fertilizers to improve soil structure and nutrient content. The balanced application of fertilizers is carefully monitored to prevent over-fertilization, which can lead to soil degradation and water pollution. These methods support long-term productivity and environmental sustainability.

Table 2. Amount of fertilizer used

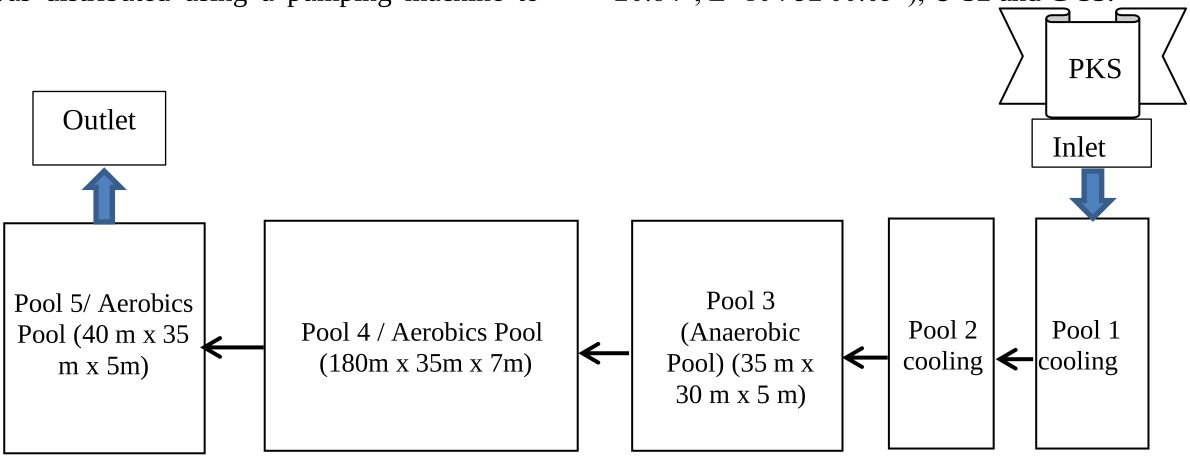
No	Type	Action total/date period (kg)/(date.month.year)				Change (%)	Type of material
		2019	2020	2021	2022		
1	Inorganic fertilizer	42.479,45	5.501.870	4.879.383	3.864.772	8.997,98	Kubor, Kaptan, MOP, NPK

Source: PT. CLS 2022 data

Fertilizer use increased by 8,997.98%, according to the nutrient needs of the soil and plants. Data showed that the highest amount of fertilizer use occurred in 2020.

3.3.2. Use of fertilizer from recycled materials

Due to the existence of an active palm oil mill in the plantation area, special treatment was given to liquid waste produced using a land application (LA) system. Factory waste distributed to the first and second cooling ponds was channeled to the third and fifth aerobic ponds. Subsequently, the waste in the Wastewater Treatment Plant (WWTP) pond at a pH <300 was distributed using a pumping machine to the outlet pond on oil palm plantation land block B- 31 (S=02038'33.77”, E=104 31'45.55”), B-32 (S=$02^0$38'27.26”, E=104 31'53.48”), B-33 (S=$02^0$38 '20.84”, E=104 32'00.05”), C-32 and C-33.



Source: PT. CLS WWTP handling scheme data 2022

Figure 2. Land Application (LA) system waste management scheme

The company uses recycled materials from production waste for fertilizer, specifically in blocks with outlet pools, and records the amount applied.

Table.3 Total use of LA recycled materials

No	Month	Total Usage/Year (M3)				Average
		2019	2020	2021	2022	
1	January	66.060	395.256	153.975	608,95	153.975
2	February	36.720	938.148	12.164	628,76	246.915
3	March	61.380	1.679.292	11.076	571,88	438.080
4	April	47.160	2.377.380	11.684	526,68	609.188
5	May	65.700	2.978.622	9.859	611,79	763.698
6	June	62.100	3.460.560	12.222	643,03	883.881
7	July	117.180	368.260	10.450	458,71	124.087
8	August	116.100	956.180	13.545	716,63	271.635
9	September	102.420	1.651.080	1.144	718,75	438.841
10	October	79.020	2.653.500	329	656,65	683.376
11	November	84.240	3.783.3604.	515,09	671,60	28.476
12	December	81.900	4.870.780	816,15	674,54	1.238.543

Source: PT. CLS data for 2022

The use of recycled materials from outlet pools was found to be greater from July to December, specifically in 2020, with relatively high rainfall. This implied that contamination due to the use of recycled materials would spread and penetrate the soil layers.

3.3.3. Management of Plant Disease Pests and Weeds

Various types of pests threaten the survival of oil palm plants, hence, food processing measures using materials capable of addressing the pests are needed. The study found actions that have been taken by PT.CLS management to address PDP.

Table 4. Actions for handling PDP

No	Type	Sat	Action total/date period				PP (%)	Type of material
			2019	2020	2021	2022		
1	Liquid/ solid	kg	12.209,12	35.131,84	7.475	4.642,78	-61,97	Decis, pertalite, Solar, Klerat, racumin, ratgon, starlone, zinc phosphite, Ziphos 80P, Cymbush

Source: PT. CLS data 2022

Table 4 shows that for PDP handling carried out, a reduction of 61.97% was found, but apart from pests, various types of plants disturbed oil palm and the FFB (weed) production process. Apart from disrupting the production process, weeds can also become nests for PDP. This study discovered the actions taken by the company in handling weeds.

Table 5. Weed handling measures

No	Type	Sat	Action total/date period				PP (%)	Type of material
			2019	2020	2021	2022		
1	Liquid/ solid	kg	655,87	12.857,84	17.853	11.647,81	1.649,26	galastick,goldstick, gramaxon, Starane, Bionasa, Kenrane 288sc, starlone, Winson 20 wg

Source: PT. CLS data 2022

Table 5 shows that there has been a significant increase in the use of weed handling materials, namely 1,604.4%. This implies that the potential for environmental pollution around oil palm plantations is increasing.

3.4. Groundwater Quality

Measurements were carried out by taking water samples from monitoring wells in oil palm plantation areas. Subsequently, samples packaged using glass bottles were taken at a maintained temperature to a KAN-certified laboratory. This test was intended to determine the effect of maintenance actions (fertilizer, handling Plant Pests and Diseases weeds) and disposal of recycled materials in outlet ponds in the garden on groundwater.

Table 6. Groundwater test results.

No.	Test parameters	Sat	Analysis results				RI Minister of Health Regulation No. 2 of 2023
			2019	2020	2021	2022	
1	PH	Unit	4,37	5,45	7,60	7,10	6,5-8,5
2	BOD	mg/l	0,65	0,68	3,91	2,68	3
3	COD	mg/l	6,11	5,15	6,11	5,10	25
4	DO	mg/l	2,22	2,28	5,82	5,52	4
5	NO^3	mg/l	3,80	0,146	4,62	4,71	20
6	NH_3	mg/l	0,03	0,895	0,19	0,06	1,5
7	Cd	mg/l	<0,0015	<0,013	<0.004	<0.004	0,003
8	Cu	mg/l	<0,003	<0,054	<0,016	<0,016	2
9	Pb	mg/l	<0,01	<0,20	<0,030	<0,030	0,01
10	Zn	mg/l	0,01	<0,12	0,270	0,39	3
11	Ci	mg/l	5,4	372	161,5	95,72	-
12	SO_4^2	mg/l	17,6	87,2	34,28	20,45	400

Source: Data from PT. CLS laboratory testing result

The laboratory results in Table 6 show that there has been a decrease in water quality in the parameters BOD, NO^3, NH_3, Cd, Cu, Pb, Zn, Ci, and SO_4^2. The average increase in the amount of pollutants in 2022 was 745.86% but the largest amount occurred in 2020 with NH_3, Cd, Cu, Pb, Zn, Ci, and SO_4^2 increasing by 1941.12%. This increase occurred in line with the reduced use of fertilizers, pesticides, and herbicides, considered the strongest factor in environmental pollution.

3.5. Total contamination in recycling ponds

Sampling was carried out using glass bottles that had been washed and dried by competent personnel. Samples from the Land Application (LA) recycling pond in oil palm plantation area were collected from the outlet pipe and packaged using glass bottles, then taken at a temperature <30^{o}C to a KAN-certified laboratory for testing.

Table 7. Test results for recycled materials in LA

No	Test parameters	Sat	Analysis results				Minister of Environment Decree No. 28 of 2003
			392.24.06.19	572.20.07.20	645.23.06.21	1012.28.06.22	
1	PH	Unit	8,15	7,20	7,85	6,92	6-9
2	BOD	mg/l	1.631	805	733	3.411	<5.000
3	COD	mg/l	3.269	2.401	2.669	14.899	-
4	Oil and fat	mg/l	6.61	5,60	2,90	18,3	-
5	Cu total	mg/l	-	<0,054	<0,118	0,507	-
6	Cd Total	mg/l	-	<0,013	<0,0189	<0,008	-
7	Pb Total	mg/l	-	<0,20	<0,267	<0,132	-
8	Zn Total	mg/l	-	0,070	0,070	0,498	-

Source: Primary data and PT. CLS data for 2022

3.6. EFB Compost and Its Functions

Compost derived from empty fruit bunches (EFB) has great potential as an organic fertilizer due to its beneficial chemical and physical properties, which enhance soil fertility. Compared to other organic fertilizers, EFB compost provides superior results, primarily because of its relatively high potassium (K), nitrogen (N), and phosphorus (P) content. The use of EFB compost significantly reduces the need for inorganic fertilizers, while simultaneously improving nutrient availability and lowering groundwater pollution [12].

4. Conclusion

In conclusion, oil palm plantations in the water area at PT CLS are in a productive condition but the quality of groundwater is negatively impacted. The contamination is still below the quality threshold limit. The results showed an increase in FFB production of up to 42.44%, but there was a change in groundwater quality. Water quality decreased due to an increase in the amount of BOD 312.31%, Nitrate 23.95%, Ammonia 100%, Cadmium 166.67%, Copper 433.33%, Lead 200%, Zinc 3,800%, Chloride 1,672, 59%, sulfate 16.19%**.** This increase was attributed to the use of pesticides, herbicides, and recycled materials from PKS production waste. Based on the results, it is necessary to increase the amount of compost used and reduce inorganic fertilizers as well as recycled materials from PKS production waste in plantation areas. Pesticides and herbicides should be applied effectively according to needs.

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