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Design of Seaweed Liquid Waste Processing Installation in the Alkali Treatment Process as Recycled Water Based on Physics and Chemistry

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Abstract: World seaweed production in 2020 published by the Food and Agriculture Organization of the United Nations (FAO), Indonesia was ranked second as the largest seaweed producer with production of 11.8 million tons. The aim of this research is: To analyze the characteristics of seaweed liquid waste at PT. XYZ. To design a seaweed liquid waste processing process at PT. XYZ based on physics-chemistry as recycled water. Methods include analysis and experiments. This method is used to analyze the characteristics of liquid waste and determine the design of the seaweed liquid waste processing process at PT. XYZ. Research results: The characteristics of the seaweed liquid waste produced do not meet the quality standards in Kep.08/Men. LH/2009 concerning Industrial Waste. A physic-chemical based liquid waste processing process with neutralization, filtering and aeration can be used as recycled water in the alkali treatment process.

Keywords: Alkali treatment; Liquid waste; Physical chemical processes; Recycled water; Seaweed

Introduction

Indonesia's role and strategic position in the global seaweed arena is very vital. Along with the increase in basic demand for seaweed-based colloids and various other derivative products that are concerned with the issue of back to nature (Khan et al., 2024; Shukla et al., 2021; Siddik et al., 2023). Indonesia is an archipelagic country that has the potential for 26 million hectares of marine and coastal fishery areas. Apart from being a fishing ground, coastal waters are also used for marine aquaculture. Increasing aquaculture production is a mainstay in realizing this vision. With economic growth and technological developments, the industrial and business world is experiencing very rapid development with the emergence of various goods and services to meet consumer needs. But on the other hand, it can produce a lot of waste and can pollute the environment if it is not handled properly.

The Indonesian seas, with their high diversity of seaweed types and potential as cultivation areas, are an opportunity for seaweed bio pigment exploration. Seaweed bio pigments, which have been neglected so far, will be able to add value to the benefits and selling value of seaweed (Merdekawati et al., 2009). Seaweed or algae is a marine plant that cannot be differentiated between roots, leaves and stems, so its entire body is called a thallus. Seaweed has functions both directly and indirectly. Directly or ecologically known, seaweed provides food for fish and invertebrates, especially

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young thallus (Da Gama et al., 2014). Indonesian waters have great potential in seaweed cultivation due to the easy processing process and small capital, resulting in the development of the seaweed industry in Indonesia.

The regional potential and biodiversity of seaweed is actually one of the keys to supporting the development of seaweed in Indonesia (Basyuni et al., 2024; Cotas et al., 2023; Sultana et al., 2023). Residents of coastal areas and islands in Indonesia, in general, have long used seaweed for their daily needs (Aslan et al., 2018; Rimmer et al., 2021). Seaweed cultivation in Indonesia is now increasingly being encouraged, both intensively and extensively and cultivation activities are carried out by farmers in coastal areas as the main livelihood (Akrim et al., 2019). With so many seaweed industries growing in Indonesia, of course it creates various kinds of problems. From a resource value perspective, seaweed has promising characteristics. Seaweed trade between countries in the form of exports indicates that almost all national seaweed products (Msuya et al., 2022; Tawakal et al., 2019). International demand for seaweed is relatively high so it has high economic value (high value commodity) (Oedjoe et al., 2019).

PT. XYZ in Maros Regency, South Sulawesi which processes seaweed types Eucheuma cottonii and Eucheuma spinosum. As a semi-finished material (intermediate product) in the form of Semi Refine Carrageenan or SRC in the form of chips and powder. For export needs to various foreign countries such as England, France, Chile, South Korea. In order to apply the MBKM (Free Learning Campus) Program, PT. XYZ, which has been facing obstacles in processing liquid waste using the alkaline treatment process, requires sustainable appropriate technological innovation from universities. Waste water or waste water is the remainder of a business and activity which is in liquid and generally contains materials or substances that can be harmful to human health and disrupt the environment. These limits state that wastewater is a combination of liquids and liquid waste of industrial origin, together with groundwater, surface water and rainwater that may be present.

Wastewater or liquid waste has a larger quantity than other types of waste and has a typical pollutant content that is more diverse, including; oil, alcohol, phenol, synthetic dyes, and heavy metals. The expected quality standards for suitable-for-use water usually have varying characteristics and are adapted to its purpose, including for drinking water, irrigation water, or process water used for certain industrial process needs (Carrard et al., 2019). Liquid waste from industrial processes, including seaweed, contains various chemicals and contaminants that have the potential to damage the environment if disposed of without proper processing. By implementing a physics-based chemical processing process, it is hoped that it can reduce the negative impact of liquid waste on the surrounding environment (Damayati et al., 2021).

Liquid waste management involves various technologies and methods, such as physical, chemical and biological processing to remove or reduce contaminants in liquid waste before being discharged into the environment or further processed for reuse. Liquid waste that has been processed and meets specified standards can be reused for other purposes. Including the recycling process (Rohmanna et al., 2021). Basically, the aim of liquid waste processing is to reduce BOD, dissolved particles, kill pathogenic microorganisms and neutralize or suppress to a minimum possible toxic chemical. Waste processing can be done physically, chemically and biologically. So, the waste processing process really depends on the characteristics of the category, type and condition of the waste to be processed.

Various wastewater treatment techniques to remove pollutants have been tried and developed over time. The wastewater treatment techniques that have been developed are generally divided into three processing methods, namely physical processing, chemical processing and biological processing (Saleh et al., 2020). Chemical wastewater treatment is usually carried out in various stages to remove particles that do not settle easily (colloids), heavy metals, phosphorus compounds and toxic organic substances. This is done by adding certain necessary chemicals. The process of removing these materials in principle involves changing the properties of these materials, namely they cannot be deposited to become easily deposited, either with or without oxidation-reduction reactions, and also take place as a result of oxidation reactions (Cuerda-Correa et al., 2019).

Meanwhile, physical wastewater treatment is usually carried out before further processing of wastewater. Large suspended materials that settle easily or floating materials are set aside first. Screening is an efficient and cheap way to remove large suspended materials. With a combination of these two process approaches. Starting from the initial stage of filtration (filtering) then pH neutralization is carried out by adding Sulfuric Acid (H_2SO_4). Next, the aeration process involves circulating air to reduce the values of biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved substance size (TDS) and suspended solids (TSS) (Fanani et al., 2023). So, researchers chose the factory location as a research location to provide alternative solutions. With the hope of effective waste processing, PT. XYZ can reduce production costs and improve the company's image as an environmentally friendly company. In addition, effective waste processing can also prevent pollution of the surrounding environment, such as groundwater and rivers, which can endanger human health and local ecosystems.

Method

The sample used in this research was liquid waste from washing seaweed which was used to produce Alkali Treated Cottonii (ATC). The waste water is washed seaweed at the factory. XYZ. The sampling technique is carried out by collecting the first washing waste up to the fifth washing waste. The seaweed washing waste that is collected stops at the fifth waste because the seaweed washing lasts up to five times. The time of the research was carried out from January-June 2023, the research object was PT XYZ which is located in Allepolea Village, Lau District, Maros Regency. As stated in the map with longitude coordinates 119°34'22.95"E and latitude 4°59'28.37"S which can be seen in the following image:

Figure 1. Sampling point

In general, the seaweed production process uses alkali treatment in two phases, namely high alkali and low alkali treatment (De Gisi et al., 2016; Liu et al., 2022; Maneein et al., 2018). One of the first seaweed processing companies in Eastern Indonesia was PT. XYZ. The process of processing seaweed into ATC chips can be done using an alkaline treatment. Seaweed liquid waste samples were taken and analyzed in the laboratory. Samples of seaweed washing wastewater were collected in empty bottles. In this study, waste water was taken up to the fifth wash. Overall, the results obtained after testing the parameter values of TSS, TDS, BOD, COD and pH tended to fluctuate until the fifth washing.

Result and Discussion

Seaweed and its extracts contain many protective chemical compounds that function as antioxidants, including phenolic compounds, dietary fiber, PUFA and photosynthetic pigments (Ismail et al., 2023; Quitério et al., 2021; Sanger et al., 2018). As is well known, seaweed is a resource that has the potential to be utilized in various aspects of life, including health and industrial aspects. Of course, after knowing the benefits of seaweed in industrial and health aspects, people will be more open in their minds to developing the potential of this seaweed (Choudhary et al., 2021; Gomez-Zavaglia et al., 2019; Merkel et al., 2021). Cultivating seaweed really requires a joint business group in community life, if cultivating seaweed is not done in mutual cooperation then losses will occur (Winarni et al., 2022). One of the problems faced in the seaweed industry is related to waste problems. The main waste in the development of the seaweed industry is seaweed washing water waste which is alkaline in nature (Farghali et al., 2023; Offei et al., 2018; Zhang et al., 2022).

Waste Water Test Results

The sample test results are listed in the following table 1:

Table 1. Wastewater Test Sample Results

Parameter	1	2	3	4	5	Information
TSS	11	1.36	0.77	0.55	0.5	Gravimetry
TDS	6150	1750	993	461	402	Gravimetry
pH	14	13	12	11	9	pH meter
BOD	25	25	30	35	40	Titrimetry
COD	50	55	60	70	90	Reflux closed

TSS (Total Suspended Solid)

Based on the test results carried out on the 1st sample, the test results showed a value of 11.0 mg/l then decreased to 1.36 mg/l in the 2nd sample and the 5th water sample showed a value of 0.5 mg/l. For TSS parameters, in all seaweed wastewater samples the TSS content value already has the quality standards set by Kep.08/Men LH/2009. This is thought to be because the waters where seaweed grows are not muddy or sandy and tend to be clear.

TDS (Total Dissolved Solids)

The TDS parameters were tested using the gravimetric method, where the results obtained from consecutive samples of seaweed washing wastewater were, 6150 mg/l; 1750 mg/l; 993 mg/l; 461 mg/l; 402 mg/l. In the first sample, the value was above the quality standards set by Kep. 08/Men. LH/2009, but the results of the 4th and 5th seaweed washing wastewater tests have shown values below 500 mg/l, where this value is already below the quality standard Kep.08/Men. LH/2009. It can be said that this seaweed waste water cannot be channeled into the environment because the first waste water has a very high TDS value.

pH

Based on the test results using litmus paper (pH paper), the results were found to continue to decrease. From the 1st seaweed washing wastewater showing a value of 14, which means the wastewater is alkaline, to the 5th wastewater which shows a value of 9. The first washing water is very alkaline, so it shows the number 14, this is because it is influenced by time. Cooking, seaweed is cooked using a KOH solution which is a strong base and seeps into the seaweed thallus.

BOD

In the test results, the test results that have been carried out show that the values of the BOD parameters from the first to the last waste water do not meet the required quality standards. In the first wastewater sample, the test results showed a value of 25 mg/L and then continued to show a value of 25 mg/L. Furthermore, it continued to increase until the 5th wastewater sample reached a value of 40 mg/L.

COD

The results of the tests that have been carried out show that the values of the COD parameters from the first to the last waste water do not meet the required quality standards. In the first wastewater sample, the test results showed a value of 50 mg/L and then continued to increase until the fifth wastewater sample was 90 mg/L. This is possible because the stirring when washing the seaweed is not perfect, so the COD levels do not dissolve completely in the washing wastewater.

Source of Seaweed Liquid Waste

The source of liquid waste for seaweed production activities in Maros Regency comes from seaweed washing and cooking activities. The plan is to use 90 m3 of clean water for washing and 10 m3 for cooking. Operational activities of employee activities at PT. XYZ is described as follows:

Table 2. Sources of Seaweed Wastewater at PT. XYZ

Source	Water usage (liters)	Water usage (m^3)
Seaweed washing	50.000 L/day	90 m^3
Cooking seaweed	50.000 L/day	10 m^3

In calculating the amount of seaweed wastewater in the PT XYZ is carried out by referring to water usage standards for various activities as seen in Table 2. Based on this table for seaweed waste activities, it can be estimated that the total amount of seaweed waste water is 80% of water use or 80 m^3/day.

Existing Water Treatment Process Flow

The waste water produced is all channeled to a control tank with a capacity of 320 m^3. The control tank functions to separate washing water and seaweed cuttings that come from the alkaline treatment process. As well as to deposit dirt in the form of sand, shells or other compounds that cannot be biodegraded. Next, the waste water collected in the control tank is pumped to the equalization pond which functions as a waste storage area and flow control tank. As shown in the following process flow image:

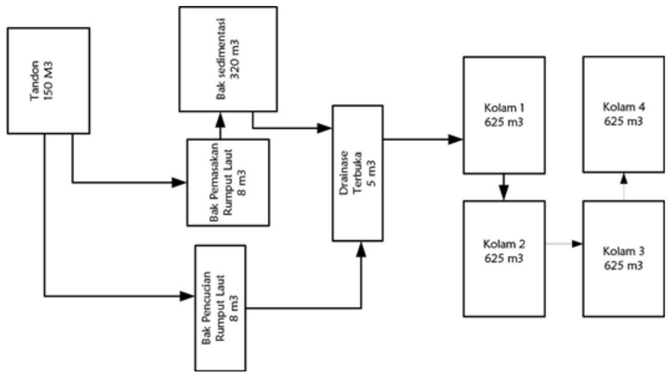

Figure 2. Existing wastewater treatment process flow

Existing wastewater processing process flow by PT. XYZ Maros has a process starting from a water tank with a capacity of 150 m^3, then entering a seaweed washing tank with a capacity of 8 m^3 and a seaweed cooking tank which also has a capacity of 8 m^3. In the cooking process, an alkaline solution is used to increase the strength of the gel so that it can be used for a longer period of time. The seaweed that has been cooked using Alkali Treatment is then washed and soaked for a while using water from the tank in a washing tank with a volume of 8 m3 then directly channeled into the drainage for the next process. The water from the drainage is drained and then flows into pool 1, which consists of 4, as an equalization and flow control tank and after that it flows into the river body.

Design for Adding a WWTP Tank, 10 m^3 pH Neutralization Tank and 25 m^3 Aeration Tank with a Total Capacity of 35 m^3

In the design of the waste water treatment process, three processing processes will be added, namely pH neutralization tank, filtration and aeration tank. In the pH neutralization tank, H_2SO_4 will be added to reduce the alkaline nature of seaweed liquid waste, then it will go through filtration, which works in a similar way to the process of refilling drinking water. After passing through filtration, the seaweed waste water flows into an aeration tank to reduce BOD and COD levels in seaweed liquid waste and after that it flows into a closed drainage system. This is to prevent waste water from mixing with other solids, especially rainwater. The design capacity of the IPAL plan for seaweed washing activities is 35 m^3 where the design sequence is 10 m^3 pH neutralization tank, 3 filter tubes for the filtration process and, 25 m^3 aeration tank. Maximum capacity for water uses with the following calculations:

Planned Industrial Wastewater Capacity

The planning tank that will be proposed is in accordance with the average daily waste capacity using a simple gravity type. The tank consists of three rooms:
Average Daily Waste: 80 m^3 per day
: 3.34 m^3 per hour
: 0.05 liters per minute
Planning criteria : Retention Time = ± 30 minutes
Required tank volume: = $\frac{30}{60 \, x \, 24}$ day x 80 m^3 /day = 1.67 m^3 atau 1670 liters

pH Neutralization Bath 10 m^3

Waste water discharge: 80 m^3/day
Initial pH: 14
Efficiency: 50%
Final ph : 7
The chemical process of neutralizing pH (addition of KOH and H_2SO_4)
H_2SO_4 + 2KOH => K_2SO_4 + 2H2O
Time spent in the tub= 1–3 hours
Required tank volume = 3/24 dayx 80 m^3/hr
= 10 m3 or 10.000 liters
Dimensions are set:
Wide: 2 m
Effective water depth: 1.6 m
Long: 3.80 m
Free space height: 0.4 m (adjusted to field conditions)
Construction: Fiberglass Reinforced Plastics
Fiber Thickness: 0.2 m
Check:
Average Retention Time (T):
T = $\frac{3.80 \, m \, x \, 2 \, m \, x \, 1.6 \, m}{80 \, m3/day}$ x 24 hour/day
T = 3.64 hour
Surface load (surface loading)= (80 m^3/day)/(2 m x 3.80 m) = 10.52 m^3 / m^2 day. Residence time at peak load = 1.82 hours or 109.2 minutes (assuming the amount of waste is 2x the average amount)
Average surface load: = 15.78 m^3 / m^2 day
Surface load at peak = 21.04 m^3/m^2 h
Standard: Residence Time = 2 – 4 hours
Surface Load = 21.04 m^3/ m^2 day. Japan Water Works Association (JWWA).

The design of the pH Neutralization Tank is according to the following picture:

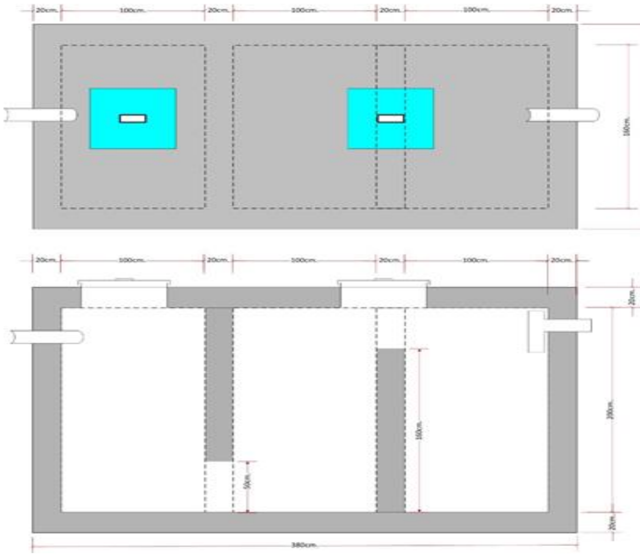

Figure 3. pH neutralization tank

25 m^3 Aeration Tank (BOD and COD Removal)

Waste discharge: 80 m^3 / day
Entrance BOD: 40 mg/l
Outgoing BOD: 20 mg/l
Residence time in the tub: 4 – 6 hours
Required tank volume : $\frac{6 \, hours}{24 \, hours/day}$ x 80 m^3 = 20 m^3
Dimensions:
Width: 2.5 m
Effective water depth: 1.6 m
Length: 6.6 m
Free space height: 0.4 m (adjusted to field conditions)
Construction: Fiberglass Reinforced Plastics
Fiber Thickness: 0.2 cm
Check:
Average retention time =
= $\frac{6,6 \, m \, x \, 2,5 \, m \, x \, 1,6 \, m}{80 \, m3 \, /hari}$ x 24 hours/day = 7.92 day
Surface load (surface loading)
= $\frac{80 \, m3 \, /hari}{6,6 \, m \, x \, 2,5 \, m}$ = 4.8 m^3 / m^2 day
Residence time at peak load = 3.96 or 237 Minutes (assuming the amount of waste is 2 x the average amount).
Average surface loading = 7.2 m^3/ m^2 day
Surface load at peak time = 9.6 m^3/ m^2 day
Surface Load = 20 – 50 m3 / m2 day.
(JWWA) (Japan Water Works Association).

The design of the Aeration Tank is as follows:

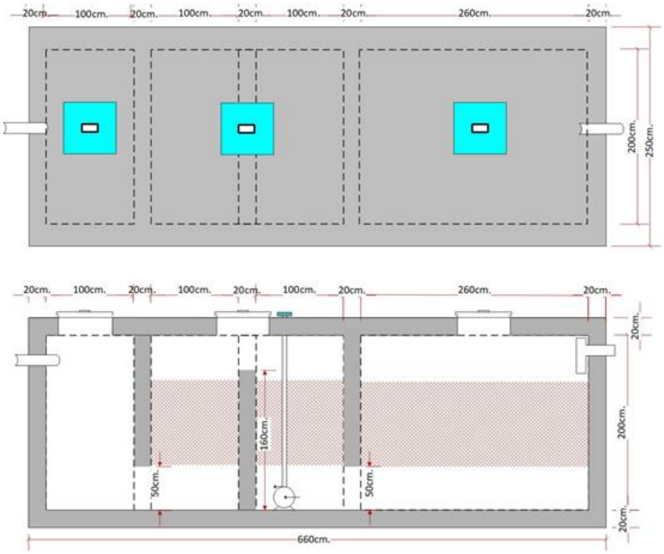

Figure 4. Aeration tank

After knowing the design of the tank that will be added, here is the waste water treatment process scheme:

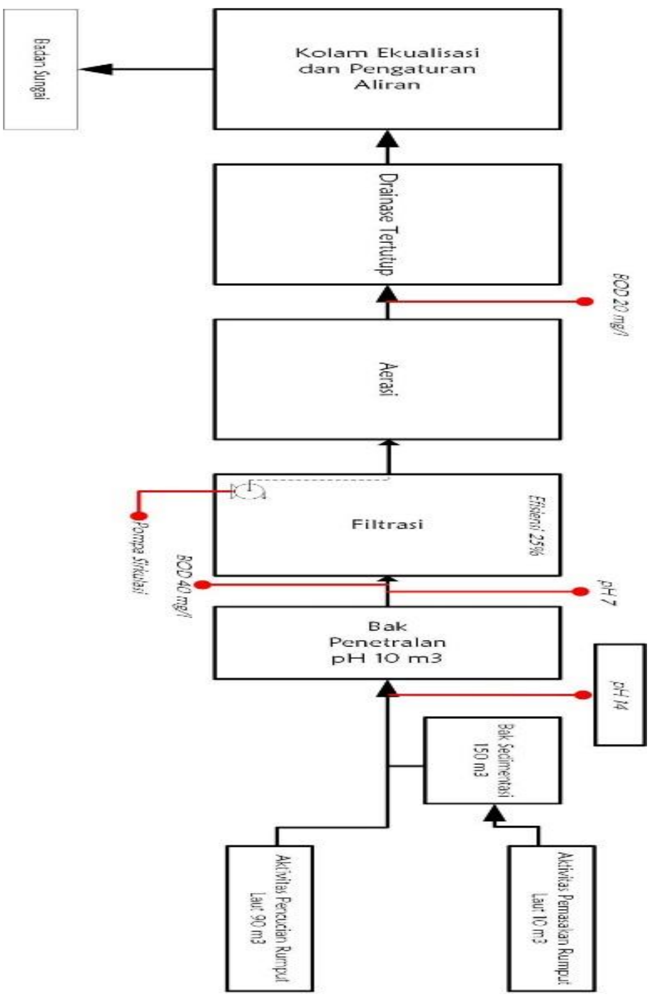

Figure 5. Wastewater treatment scheme

Design Seaweed Liquid Waste Process Design Process

The operational technical process of the WWTP is as per the Seaweed Liquid Waste Processing Plan in the following scheme:

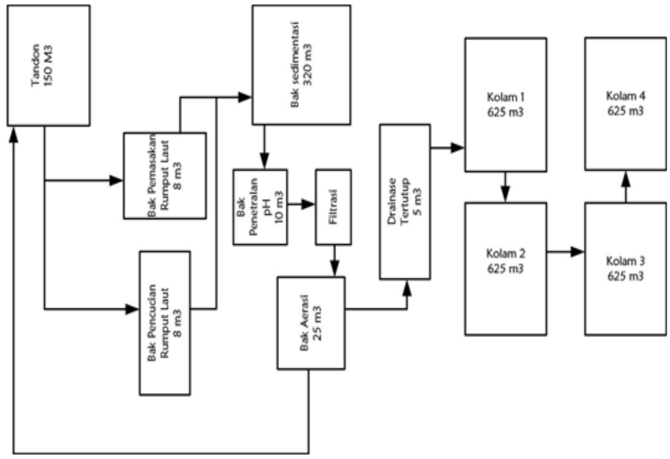

Figure 6. Seaweed liquid waste processing plan

So, the operational technical process for communal IPAL for seaweed waste water is as follows: Water from the reservoir will be channeled to the washing tub and the cooking tub; Waste water from the cooking and washing tanks will be channeled into a sedimentation tank with a volume of 320 m3 to separate waste water from solids such as oil, mud, sand and other impurities. This sedimentation tank also functions as an equalization tank; then from this sedimentation tank it will be pumped into the pH neutralization tank; The waste water from the pH neutralization tank is then channeled to the water treatment using a push pump through a pipe. The purpose of filtering is to separate suspended solids from the treated water (Mulligan et al., 2009; Peperzak et al., 2022). In its application, filtration is used to remove remaining suspended solids that were not deposited during the sedimentation process by building up material at the interface between the two phases (Cescon et al., 2020; Eyvaz et al., 2017; Serbruyns et al., 2024).

In general, solutes collect at the interface. This adsorption process uses two tubes with materials inside, namely Silica Sand, Activated Carbon, and Maganize; Waste water from filtration will go through an aeration process to reduce BOD and COD levels. From this aeration, the recycling process occurs where the water from the aeration is not only channeled into the drainage but also flowed into the reservoir to be reused in the cooking and washing processes (Radcliffe et al., 2020; Silva, 2023): From the aeration tank, liquid waste flows through the drainage and then flows into the equalization tank and also as a flow control tank. In this tank, the waste water is then channeled into the river body.

Conclusion

Based on the research that has been carried out, the author can draw the following conclusions: Characteristics of seaweed liquid waste produced by PT. XYZ does not meet the quality standards in Kep.08/Men. LH/2009 concerning Industrial Waste. Seaweed Liquid Waste Processing Installation Design at PT. XYZ is a physic-chemical based liquid waste processing process with neutralization, filtering and aeration that can be used as recycled water in the alkali treatment process. Apart from that, this research still has various limitations so that future researchers are expected to be able to discuss: The efficiency of using recycled water from the aspect of Clean Technology Production (green technology); Biologically based processing of seaweed liquid waste using Bioreactor Technology; Adding the characteristics of seaweed liquid waste with other parameters such as DO and Ammonia.

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Author Contributions
Conceptualization; D. A.; methodology.; S.; validation; formal analysis; M. F. J.; investigation.; A. Z. S.; resources; N. A.; data curation: H.; writing—original draft preparation. R.; writing—review and editing: D. A.; visualization: S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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