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**MechEng**  
Mechanical Engineering



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# DESIGN AN ANAEROBIC MEMBRANE BIOREACTOR (ANMBR) FOR SEAFOOD PROCESSING WASTEWATER TREATMENT

BACHELOR THESIS

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Vietnamese-German University

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Ho Nguyen Anh Duy

## ABSTRACT

The seafood business, among the most significant areas of the economy in Vietnam, accounts for 4-5% of the GDP and 10% of all export revenue (\$8.5 billion). Seafood production through aquaculture and seafood exploitation has grown significantly in the past 25 years, in 2020, 8.4 million tons, up from 1.3 million tons in 1995 – an increase of approximately 8% each year. The fishery produced roughly 4 million tons in 2020. Which cultivation produced around 5 million tons. (1)

With the rise of the fish processing industry, more wastewater discharges into the environment which threatens pollution. Processed seafood includes mollusks (oysters, clams, and scallops), crustaceans (crabs and lobsters), freshwater fish and saltwater fish. Seafood processing activities, like most processing industries, create wastewater with significant amounts of soluble, colloidal, and particle pollutants. The level of contamination varies depending on the specific process; it could be little (for example, washing processes), light (like filleting fish), or heavy (e.g., blood water drained from fish storage tanks). For conventional treatment, contaminant water from seafood processing is removed by anaerobic and aerobic microorganism before entering the environment.

This thesis will provide an alternative way of filtering liquid seafood waste by combining membrane technology with the anaerobic bioreactor. The wastewater organic contents would be consumed by the microorganism and with the existence of the membrane mechanism, blocking the product's garbage, the microorganism together with some of the chemicals, the output water quality can meet the required index.



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## I. Introduction

Vietnam, with 3260 km of coastline and 1 million km square of Exclusive economic zone, has a great opportunity to develop the seafood industry. In 2020, Vietnam's seafood sector exposed 8.4 million tons of products and provided jobs for 4 million people. This is one of the major economic fields in Vietnam (1). However, the fishery industry is also one of the most polluted industries in Vietnam, especially affecting the water environment. Fat, oil, and grease (FOG), nitrogen, along with biochemical oxygen demand (BOD) levels in proceeded waste liquid plants could be quite big. Usually, the wastewater's pollution level is influenced by various factors, such as the style of seafood, the food processing, and the production scale. Depending on the technology and the technique as well as the concern of the company towards the environment, the waste liquid from the process would affect the native environment. For sustainable development in the fishery industry, environmental protection must take into account and carefully control the outlet quality of the wastewater output from the factory.

This thesis was occurred at Basefood 1, located in Vung Tau City – Ba Ria Vung Tau province. Operating in 2015, the company specialized in the production and trading of frozen products, in which the main products are: Octopus, squid, cuttlefish, fish, and mixed seafood. As a result, the wastewater in which the project is treated, is from the seafood processing of the company.

Normal approach, the water from the factory after using in-raw material processing (Cleaning, and removing faece), Food processing, defrosting, and cleaning the working area along with equipment and packaging, would be processed in 2 stages: Mechanical processing and biochemical processing. In the primary stage, we separate liquid and solid through comminutor and screens, the liquid would come to the secondary stage while the solid includes: bones, shells, and ranchiae, then after masticating would be dumbed. The second stage is the chemical treatment stage, here the waste's Nitrogen, Phosphorus, and Biochemical oxygen demand, would be consumed by microorganisms – anaerobic and aerobic.

Currently, the world has developed and achieved considerable marks in membrane technology. Combining the current treatment with new technology, we can benefit the way wastewater treatment in the fishery industry. The aim of this thesis is to design an alternative treatment process using membrane technology in an anaerobic process.

## II. LITERATURE REVIEW:

### 1. Seafood wastewater contents:

Blood, organs, viscera, fish heads, fins, shells, skins, and filleting after the process are the main waste kinds discovered in wastewater from the processing of seafood. The concentration of suspended particles in the waste stream is greatly impacted by these wastes. The majority of the rigid waste, however, can be separated from the liquid and saved for use in animal feed. This type of polluted wastewater contains significant levels of organic matter, including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), and nitrogen. As the environmental report from the Vietnam environment administration in 2009 (3) – the amount of water used in seafood processing according to the products:

- Catfish: 3-5 m<sup>3</sup>/ton of product
- Frozen shrimp: 4-6 m<sup>3</sup>/ ton of product
- Frozen mixed seafood: 4-6 m<sup>3</sup>/ ton of product

The range of the chemical oxygen demand is roughly 500-3000 mg/l, the biochemical oxygen demand is approximately 300-2000 mg/l, the nitrogen in waste is computed at 50-200 mg/l, and the range of the total suspended solids is 200-1000 mg/l.

#### a. Organic content

##### a.1. Biochemical Oxygen Demand:

The term Biochemical Oxygen Demand (BOD) refers to both the average oxygen demand for organic waste that can be degraded aerobically as well as the quantity of molecular oxygen needed for the biological organic compounds oxidizing in water (4). The management of stream pollution control and the evaluation of the self-purification potential of streams both benefit greatly from biological oxygen demand tests. The BOD measures how much oxygen aerobic bacteria require to decompose biodegradable organic matter into byproducts like water and CO<sub>2</sub>. When the BOD is low, the water's organic matter content and microbiological organism counts are also low. BOD can be used to calculate the size of biological treatment facilities, particularly the volume of aeration in aeration ponds. For the purpose of determining BOD<sub>5</sub> concentrations, standard BOD tests are carried out after 5-day incubation. Since BOD is hard to standardize and takes a while (5 days), Chemical oxygen demand is a better representation of organic matter. (5)

##### a.2 Chemical Oxygen Demand:

The Chemical Oxygen Demand (COD) determination transfers organic carbon in examining liquid to CO<sub>2</sub> and H<sub>2</sub>O using a robust chemical oxidant such as acid sulfuric – H<sub>2</sub>SO<sub>4</sub>. There are two types of COD indexes that have historically existed: COD<sub>Cr</sub> and COD<sub>Mn</sub> (potassium permanganate [KmnO<sub>4</sub>] or potassium dichromate [K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>]). COD<sub>Cr</sub> and COD<sub>Mn</sub> are the formulas used to determine COD using K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> and KMnO<sub>4</sub>, respectively. While COD<sub>Mn</sub> is preferred in water bodies that are relatively clean (such as surface water and river water) and has low COD levels, COD<sub>Cr</sub> is mostly used to assess the water quality in water bodies that are moderately or severely contaminated (such as sewage and wastewater) (6). Utilizing titrimetric or photometric techniques, the amount of oxidant used is measured to calculate the oxygen demand. The test is not adversely affected by harmful compounds, and test results are available in one and a half hours to three hours, allowing for quicker process management and evaluation of the water quality.



### b. Fat, oil and grease:

When washing blood, skin, or filleting fresh fish, which generally involves processing fish, fat, oil, and grease enter the wastewater. It is difficult to recover fats, oils, and grease once they have been contaminated by raw sewage. Sludge thickening units may float and clog wastewater treatment equipment as a result. Significant quantities of fats, oils, grease, or lipids present in scum that is supplied to the waste treatment system may obstruct methanogenesis during anaerobic digestion and clog sludge dewatering machinery. These issues may influence the processes of both anaerobic and aerobic. The oil in the water is liquid at room temperature, but as it cools, it becomes hard and sticky and blocks the flow of the sewer system. Scum must thus be removed from the wastewater's surface using a skimming device prior to the wastewater entering the treatment system when applying the grit chambers at the beginning of the procedure. (7)

### c. Nitrogen and phosphorus:

Environmental issues are usually raised by the nutrients phosphorous and nitrogen. If the amount of both nutrients is present in large enough quantities, they may promote the growth of alga and damage marine living quality in a body of water. Wastewater contains a lot of nitrogen and phosphorus, which increases the amount of nutrients in rivers and lakes where it flows. Due to the strong growth of phytoplankton like mosses and algae, it depletes the water's oxygen supply, upends the food chain, lowers water quality, and degrades the water body's clean environment. creates numerous toxins in the water, including  $\text{NH}_4^+$ ,  $\text{H}_2\text{S}$ ,  $\text{CO}_2$ , and  $\text{CH}_4$ , which kills a variety of important aquatic creatures. (8)

### d. Solid content – Total Suspended Solids:

Total suspended solids are used to determine the clarity of a sample of any kind of water or body of water, ocean water, as well as wastewater that has been treated in a wastewater treatment facility.

The aquatic life may be impacted by suspended particles because they block more light from entering the water. 10–30% of total solids are made up of total suspended solids (TSS) (9). In general, effluent from fish processing facilities has significant concentrations of suspended particles, mostly proteins and lipids. The characteristics of the effluent from the preparation of fish units vary based on the make-up of the fresh fish, how the unit is used, where the processing water comes from, and any additives added, such as brine or oil for canning.

The suggested wastewater result from the Vietnam environment accommodation states that the output water from the industry should fulfill the requirement of in order for it to be discharged to the environment (A – water sources with domestic use, B - without any purposes of domestic use from a water source) (2):

Parameters	Unit	Output	
		A	B
PH	-	5,5-9	5-9
BOD <sub>5</sub>	mg/l	30	50
COD	mg/l	75	150
Total Suspended Solid - TSS	mg/l	50	100
Total Nitrogen - TN	mg/l	30	60
Total Phosphorus - TP	mg/l	6	10
Oil, Grease, Fat	mg/l	10	20

Table 1: Vietnam's output wastewater norms

## 2. Overview of the wastewater treatment process:

After processing, seafood wastewater is concentrated in the collection pit and from the collection pit will be delivered to filtering. The primary mechanical pretreatment is located at the beginning of the treatment process, which includes: screening removal and grease separation, sediment filter floor, separate solid waste with liquid from the industrial process.

Screening, which contains tangential screening and a rotary drum, may be used to remove materials that are somewhat big (0.7 mm – 2mm or greater). As a result of its potential to instantly reduce the amount of particles discharged, this treatment procedure is often used in facilities that prepare food. Usually, flow-through static screens with apertures of around 1.2 mm have the simplest structure. To reduce the clogging issue in this operation, a scrapping device may sometimes be necessary. The rates of solids removal might range from 40% to 75%.

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Figure 1: Screening devices – Rotary drum and Tangential screening

Depending on the method employed, the species processed, and the operating procedure, the wastewater from the processing of seafood might include varying levels of oil and grease. If the oil particles are big enough to float to the top and are not emulsified, gravity separation may be employed to remove grease and oil; otherwise, the emulsion must first be disrupted by pH correction. The emulsion can also be broken using heat, however, it may not

be cost-effective unless there is extra steam available. Comparable to the inclined tube separators detailed in the preceding section, gravity separators for oil-water have similar structures. To collect the grease, grease traps are chosen to do the work.



*Figure 2: Oil and grease separating tank*



*Figure 3: Oil and grease collecting device*

After being physically screened, the liquid waste will be taken to the reservoir tank, and prepared for treatment, while the solids after the filter will be removed. The reservoir tank, or balanced tank, performs the task of regulating the flow and concentration of wastewater pollutants before passing through the next treatment stages. In the tank, the air distribution system operates thanks to two air blowers operating alternately to create a disturbance, avoid sedimentation and avoid creating conditions for anaerobic biodegradation to generate odors.

Factories have different manufacturing times and yearly periods which leads to differences in the amount of wastewater. The reservoir tank helps to control the input in the treatment process. Moreover, the Ph level can vary depending on the amount of contaminants in the water and affects the efficiency of the microorganism in the treatment. The reservoir tank also prevents this problem.

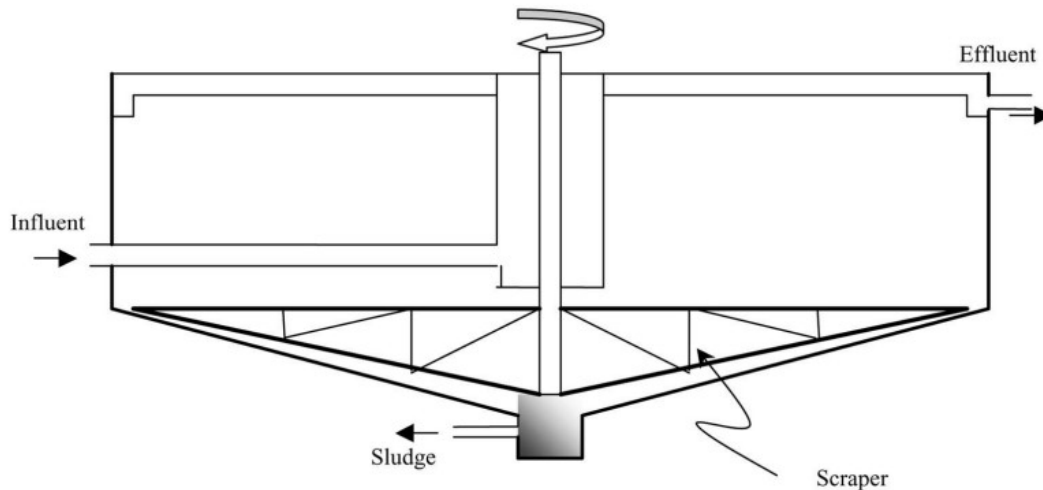


*Figure 4: Conditioning tanks*

Gravity-based settling of the heavier solid particles is how sedimentation separates solids from water (10) Particles that are heavier than water settle to the bottom of a tank or basin in the most basic kind of sedimentation. Sedimentation basins are often utilized in various flow-through facilities for the production of aquatic animals as well as in the wastewater treatment sector. For the purpose of separating the solids produced by biological treatments, such as activated sludge or trickling filters, this operation is carried out both as part of the primary treatment and in the secondary treatment. Sedimentation may happen in discrete, flocculent, or zone settings, depending on the characteristics of the wastewater's solid constituents. Each instance has unique qualities that will be explained.

Because they take up less room than numerous circular tanks, rectangular settling tanks are often employed when several tanks are needed but there is limited space. Solids are typically removed using a number of chain-driven scrapers. The sludge is gathered in a hopper at the end of the tank and may either be pumped out or removed by screw conveyors.

Usually, some chemicals are used to help the sedimentation such as polymer aluminum chloride, ferrous sulfate, sodium aluminate – as coagulant and polymer cation -  $(\text{CH}_2\text{CHCONH}_2)_n$ , polymer anion –  $\text{CONH}_2[\text{CH}_2\text{-CH}]_n$  – as flocculant.



*Figure 5: Sedimentation device structure*

After the pretreatment process, the wastewater will be delivered to the anaerobic tank and then the aerobic tank. The two tanks with microorganism consume all the rich nutrition in the wastewater which increases algae or bacteria in the local water environment. It should be noted that the aerobic tank must have an air blower consistently and sludge removed occasionally.

After leaving the two process tanks, the water will be moved through the post-treatment process with membrane tank and sterilization tank. Here, in at the membrane tank, most of the solid would be separated which reduces the total suspended solid. The Ultrafiltration membrane is a new technology and hasn't been widely used. The efficiency of the process which has membrane filtration is better than normal. It also should be noticed that the membranes need physical and chemical cleaning to avoid membrane fouling. The Membrane in the output water to the sterilization tank with chemicals, usually Chlorufrom –  $\text{CHCl}_3$  or Chloramine B –  $\text{C}_6\text{H}_5\text{SO}_2\text{NCINa}$ .

The water after treatment will be discharged into the environment.

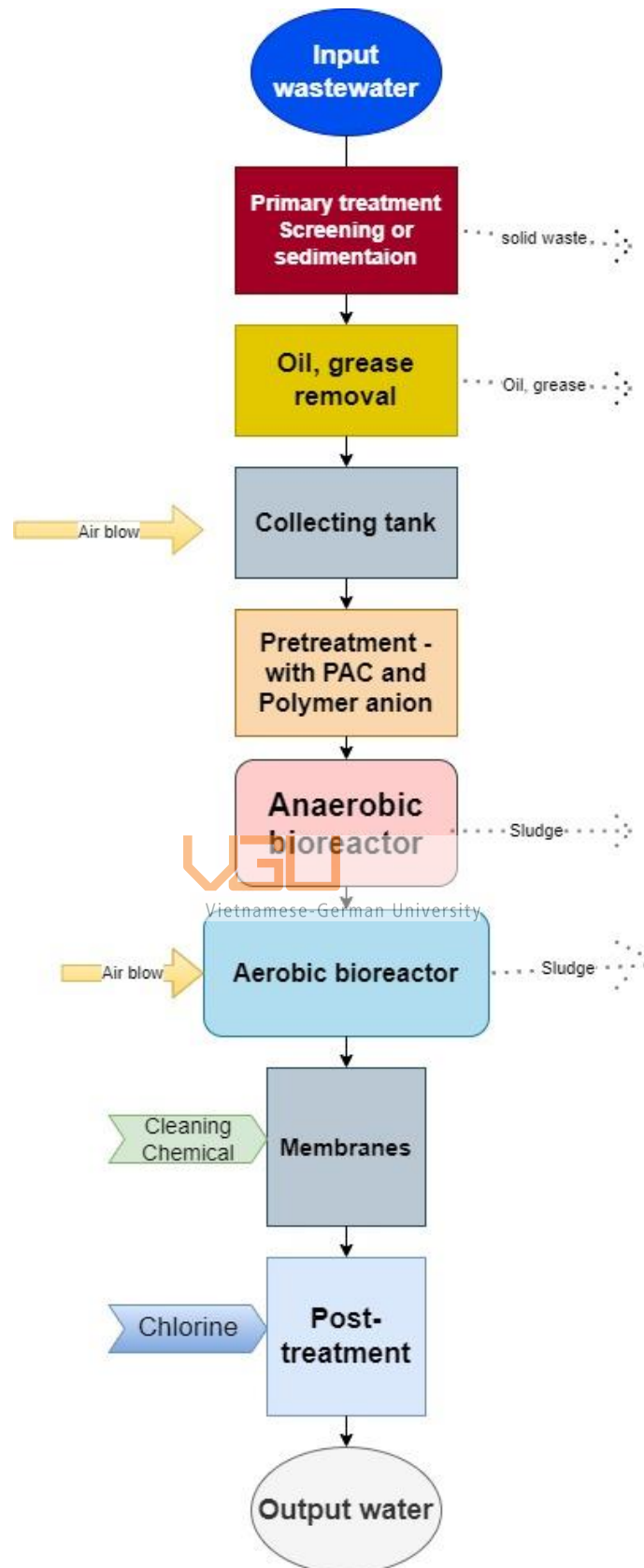


Figure 6: Diagram of the overview wastewater treatment process

### 3. Pretreatment using coagulation and flocculation:

In a variety of fields, including biochemistry, cheesemaking, rubber production, and especially water treatment, coagulation and flocculation are critical procedures. Especially in the treatment of water and wastewater, coagulation and flocculation phenomena are crucial. Pretreatment of seafood wastewater by using coagulation and flocculation helps decrease the level of contaminants which increases the process output quality.

The process through which a system can go from a stable to an unstable state is known as coagulation. The process of coagulation results in the instability of a certain suspension or solution. In other words, the goal of coagulation is to combat the elements that support a system's stability.

The process of destabilized particles, flocculating as a consequence of instability, are stimulated to assemble, and create contact, resulting in the formation of huge agglomerates. The way in which instability manifests varies on the individual system; for instance, apparent floc or precipitate development happens in dispersed suspensions or solutions; dewatering of the sludge mass occurs in highly concentrated suspensions; and so on.

There are two broad groups of frequently used metal coagulants: iron (Fe) based and aluminum (Al) based. Aluminum sulfate, aluminum chloride, sodium aluminate, aluminum chlorohydrate, poly aluminum chloride, ...are among the aluminum coagulants. The iron coagulants include ferric sulfate, ferrous sulfate, and ferric chloride,... Hydrated lime and magnesium carbonate are two more substances used as coagulants.

Poly aluminum chloride, sometimes known as "PAC" -  $[Al_2(OH)_nCl_{6-n}]_m$ , is a common coagulant used in water treatment facilities. PAC often produces huge amounts of sludge, necessitating repeated desludging operations at the treatment facilities, increasing water waste. Additionally, there is a chance that aluminum will recontaminate alum-treated water.

According to the findings, PAC is particularly efficient when fulvic acid concentrations or those of other species with strong coagulant demands are low or whenever the pH level is more than 5.5 to 7.0 also found that PAC is a useful filter aid for low turbidity waters, allowing for the destabilization and subsequent filtration of particles at acidic and neutral pHs. They also found that Poly Aluminium Chlorine are functional at smaller amount than other aluminum preparations for the coagulation of high turbidity waters, especially at cool temperatures or low pH level. (11)

The organic polymer was introduced as flocculant aids to address the issue of temporal sedimentation. Specifically, the removal of organic matter, floc density, and floc sedimentation were considerably improved as a result of flocculation. Important operational characteristics in water treatment operations include floc size and floc growth. The quick floc development rate suggests a quick coagulation process, necessitating a smaller coagulation tank.

The process through which the appearance of instability is called flocculation. After the process of Flocculation involves forcing destabilized particles or particles created as a result of instability to come together, establish contact, and eventually form huge agglomerates. Flocculation affects the physical properties of produced flocs (such as their strength, size, and density) and controls the ultimate concentration of destabilized particle numbers. Flocculation is a crucial component of instability, regardless of how it happens.

Flocculation: Polymer anion –  $CONH_2[CH_2-CH-]_n$

The amount of polymer required when treating water is micro, only about a thousandth. Using a poly aluminum chloride dosage of 50 mg/l with an anion polymer dose of 0.2 mg/l to remove

sludge and decrease the total phosphorus from 1.2-1.7 mg/l to below 0.1 mg/l. Typically, anionic polymer doses range from less than 0.5 mg/l to 1.5 mg/l. The combination of PAC and anionic polymer lowered color by more than 88%, as well as TSS by 96% and COD by 78%. As for Vietnam wastewater treatment, it is recommended that 1- 50mg/l anionic polymer should be used with 800 – 1200mg/l of PAC.

If too much polymer is used, the water will become very viscous, hindering the subsequent processing stages. In addition, the excess polymer in water will increase COD. Therefore, when using Polymer, it is necessary to adjust the dose to be relatively suitable for the type of wastewater, to avoid overloading causing problems that are difficult to solve.

The distinction between flocculant aids and coagulant aids is clear. Coagulant aids help remove color and turbidity by neutralizing charge and assisting in particle disintegration. However, flocculant aids can only help with the physical flocculation process. By bridging between particles, they reduce turbidity but have little effect on color removal. There are many advantages to using polymers as flocculant aids that are not evident in small-scale laboratory experiments.(12)

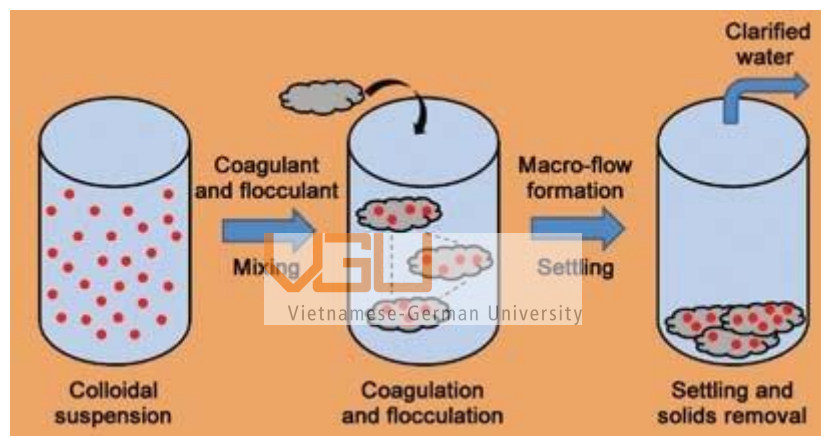


Figure 7: Process of coagulation and flocculation

#### 4. Anaerobic process:

After passing the necessary initial treatment, the wastewater then goes through an additional treatment process utilizing a biological wastewater treatment system. In this system, microorganisms take part in the breakdown of organic debris. The treatment of wastewater generated by the processing of seafood may make use of a variety of different kinds of biological systems.

Anaerobic treatment decreases biological contaminant (COD, BOD<sub>5</sub>) in waste liquid to a negligible quantity of sludge while simultaneously producing a significant volume of biogas. This treatment does not eliminate all of the pollutions, however; part of it remains (methane and carbon dioxide). The most important advantages are the low operating costs, the little amount of space required, the generation of valuable biogas, and the low amount of sludge that is produced, particularly for bigger plants (13). Because anaerobic systems produce sludge that is less strongly stable and can be dewatered more easily, for the treatment of wastewater from fish processing plants, they are well suited. This is due to the fact that it is possible to remove a high level of BOD<sub>5</sub> at a cost that is much lower than that of comparable aerobic systems. In addition to this, the gas that is generated is high in methane, and this gas may be collected and utilized as a fuel. Additionally, one of the advantages of using anaerobic biological treatment over using aerobic process is that the products of microorganisms, when emitted into the



surrounding air environment, can cause negative effects on the well-being of the workers in the area. (14)

The procedures used to remediate wastewater include an essential component known as anaerobic bacteria. They enable the breakdown of macromolecular organic materials into simpler components through methane fermentation of sewage sludge. Methanosarcina, Methanosaeta, and Clostridium are three bacterial genera that are involved in the anaerobic methane fermentation process (15). Fecal bacteria from the genera Bifidobacterium and Bacteroides as well as Clostridium perfringens may be present in the treated effluent.

In an early study by Balslev – Olesen and Mendes R., with the loading of 3 or 4 kg of COD/m<sup>3</sup> per day, anaerobic methods have been used in wastewater from the processing of seafood and have produced significant removal efficiency (75-80%). (16,17)



*Figure 8: Microorganism and treated water from the anaerobic process.*

## 5. Anaerobic Membranes Bioreactor:

The anaerobic membrane bioreactor combines the filtering method using ultrafiltration or microfiltration membrane technology with an anaerobic bioreactor. Independent of the characteristics of the wastewater, the circumstances of the biological process, and the qualities of the sludge, the solid retention time and hydraulic retention time may be completely separated by the AnMBR., because suspended materials, including inert and suspended biomass, may be physically retained by MF/UF membranes.

### a. Reactor configuration

There are primarily two different configurations of membrane bioreactors: internal (also known as submerged or immersed), in which the membranes are placed inside the biological reactor, and exterior or side stream processes that regard the membrane as a distinct element and need a middle pumping step (18). In each of these arrangements, the flow is reversed, changing the maximum trans-membrane pressure that may be reached. The difference between

the two is best summed up as: in the external process, the liquid is forced over the membrane, while in the internal or submerged process, the liquid is pumped across the membrane (10). Therefore, the trans-membrane pressure for the side-stream system may be greater than that of submerge, which results in a reduction in the amount of contact surface required by a particular permeate flow and an increase in the amount of power needed for the former.

*Comparison between the two configurations:*

First, it is important to understand that excellent COD removal effectiveness (with a mean of 98 percent), 98 percent in color, and nutrients (86 percent in total nitrogen and from 86 to approximately 89 percent in total phosphorus) were all provided for both configurations.

*For Submerged system:*

For large-scale applications, the submerged arrangement is preferred since it allows for lower flux operation while still ensuring better permeability (19). Given the substantial energy demand of the recirculation pumps, an internal membrane bioreactor also uses much less energy than a sidestream arrangement. The demand for an internal membrane bioreactor was typically less than 1 KWh/m<sup>3</sup>, in contrast to a sidestream MBR's requirement of nearly 6 KW per hour over a cubic meter of treated effluent. (20) Additionally, because there was no change in cross-flow, as well as the shear forces were reduced without a recirculation pump, there is less stress on the microorganisms. (21)

By employing the generated biogas to be blown back by a compressor or an external stirrer, it is normally assumed that the building of fouling on the exterior will be disrupted and that the anaerobic reactor will be mixed.

On the other hand, blowing with biogas may result in operational problems, especially when the AnMBR is first turned on or when dangerous compounds are present in the input process. The anaerobic consortia's performance may get hampered as a result, which might result in methane production levels that are inadequate to provide appropriate blending in the anaerobic tank. Sometimes, a physical stirrer is attached to the tank to prevent the problem. (22)

*For Side-stream system:*

The side-stream design is more efficient than when removing the filter fouling from the exterior, combine with biogas or use a mechanical stirrer., which speeds up membrane fouling (23). As was already said, it is difficult to chemically clean submerged membranes since the membrane must be removed and AnMBR activity must be stopped before cleaning. The examination or replacement of membranes is also harder for the same reason. (24) Moreover, a smaller membrane surface area is required with side-stream membranes in order to provide the familiar hydraulic standard as the internal configuration. (25)

The side-stream MBR could have less fouling from sudden changes in flow or toxicity shocks as well as improved discharge standard because short-circuiting is prevented since the membrane is not exactly placed into the bioreactor.(24). Since the membrane may be detached without needing to be taken out of the tank, chemical cleaning and module maintenance are also made easier. However, the additional pump for circulation can alter the sediment's properties along with use more energy. The recirculation pump maintains the necessary trans-membrane pressure in the membrane chamber in the side-stream arrangement. Crossflow velocity thereby permanently prevents the filter fouling development on the membrane's exterior. Energy is needed in this process, but any extra may be utilized to mix the suspension in the anaerobic reactor.

The increased Soluble microbial products and Extracellular polymeric substances production caused by the higher biomass content also aided in the submerged MBR's enhanced fouling. Although the Extracellular polymeric substances concentrations in the two bioreactors were comparable, it was found that the Soluble microbial products concentrations, particularly in the colloidal form, were greater in the side - stream MBR when divided by the mixed liquor volatile suspended solids concentration. (25)

The exterior membrane's irreversible fouling rate was noticeably greater even though its reversible fouling rate was lower than that of the membrane that is immersed. The variables that successfully regulate the reversible fouling rate were less efficient in regulating the irreversible one. Practically speaking, reversible fouling is the fouling component that can be eliminated by relaxing or back-pulsing. On the other hand, irreversible fouling refers to the more firmly attached portion that needs chemical cleaning to be eliminated. Improved membrane cleaning efficiency would lower operating costs associated with fouling management, making MBRs more competitive with respect to traditional wastewater treatment. (26)

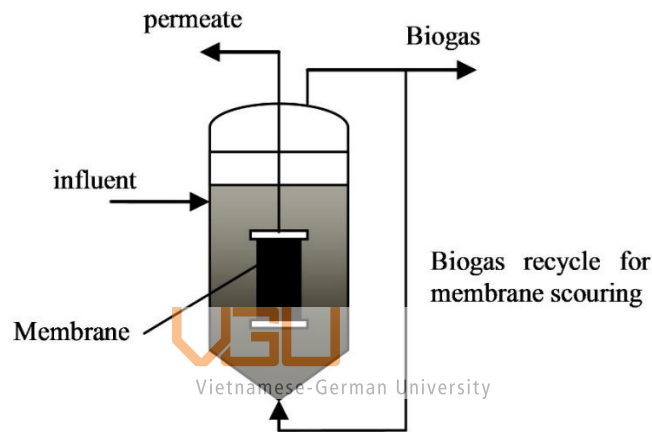


Figure 9: Submerge membrane bioreactors drawing diagram

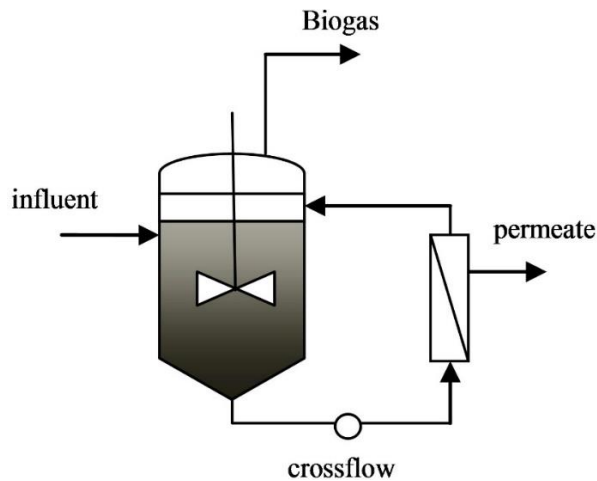


Figure 10: Side stream membrane bioreactors drawing diagram

## b. Membranes

Many different kinds of membranes are used in water treatment processes. Membranes for reverse osmosis, nanofiltration, microfiltration, and ultrafiltration are among them. The highest hole size is found in microfiltration membranes, which often filter out big particles and different microorganisms. Because ultrafiltration membranes have smaller holes than microfiltration membranes, they may reject bacteria as well as soluble macromolecules like proteins in addition to big particles and germs. Since reverse osmosis membranes are inherently non-porous, they successfully filter out particles as well as a variety of low-molar-mass species such as salt ions, organics, and others. nanofiltration membranes, which are still relatively new, are sometimes referred to as "loose" reverse osmosis membranes. Although they are porous membranes, their performance falls between that of reverse osmosis and ultrafiltration membranes since the holes are on the order of ten angstroms or fewer. (27)

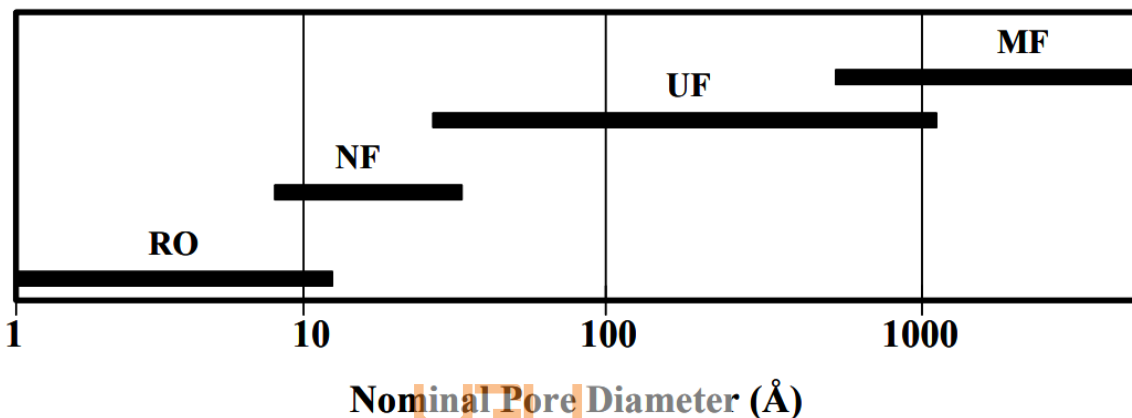


Figure 11: Pore diameter of four different membranes style  
Vietnamese-German University

This module type's capacity to accommodate sizable membrane areas in a single module is a very noticeable benefit. However, owing to the complex nature of the manufacturing procedure and the enormous capital needs, it is exceedingly costly to make. (28)

There are four primary categories of modules: hollow fiber, plate-and-frame, tubular, and spiral wrapped. The simplest arrangement is the plate-and-frame module, comprising spacers, the flat sheet membrane, and two end plates. The membrane is frequently seen on a pipe's internal space in tubular modules, and the feed solution is pumped through the tube. The spiral-wrapped module is the most often used in the industry for nano-filtration or reverse osmosis membranes. This module features a perforated permeate collecting tube covered in a flat sheet membrane. Bundles of hollow fibers are placed in a pressure tank to form hollow fiber modules, which are used to desalinate seawater. They may feature a shell-side feed arrangement, in which the feed leaves the fiber ends after traveling along the exterior of the fibers. In a bore side feed system, where the input is delivered via the fibers, hollow fiber modules may also be employed. Pressure vessels don't always utilize the hollow fibers used in membrane bioreactors and wastewater treatment. The permeate may be collected from one end of fiber bundles that have been hung in the feed solution. (29)

The material of the membrane should also be considered. While many polymers may theoretically be used to create a membrane, the majority of materials—including polyvinylidene difluoride (PVDF), poly-ethyl sulphone (PES), polyethylene (PE), and

polypropylene—are not appropriate for membrane separation (PP). Among all of the above material, poly-ethyl sulphone is one of the most significant polymeric compounds that find widespread use in the area of separation. PES membranes have excellent oxidative, thermal, and hydrolytic stability, in addition to having strong mechanical quality (30).

On the other hand, compared to ceramic or metallic membranes, polymer membranes do have disadvantages, such as poorer permeability and decreased stability against chemical cleaning.(19)

The membranes are created via a procedure that involves phase inversion, and they invariably have an asymmetrical structure. The composition (concentration, solvent, and additives) of the PES solution, as well as its temperature, as well as the final membrane structure is influenced by the non-solvent or combination of non-solvents, coagulation bath, environment, and so forth. The two most common polymer membrane forms are hollow fiber and flat-sheet membranes. The different forms need a different preparation process. Flat-sheet PES membrane often uses the phase inversion technique. To generate a flat-sheet PES membrane, the polymer solution was first applied to a support material (glass, polymer, metal, or non-wovens), which was then immersed in a non-solvent (typically water). For hollow fiber PES membranes, a professional apparatus that includes at least a spinneret and a take-up unit is necessary. Phase inversion-based dry-wet spinning is used to produce PES hollow fibers (wet spinning is seldom employed). (15)

Hollow got much more membrane fouling than flat-sheet (With a flux of 20 to 60 L m<sup>-2</sup> h<sup>-1</sup>, the flat-sheet membrane module was run for six months without any external cleaning. With a flux of 20–45 L m<sup>-2</sup> h from the hollow-fiber membrane module, the operation was carried out for four months without external cleaning. (31,32)

This result illustrates the solution to the backwashing limitation of the flat sheet membrane. Chemical backwashing may be successfully carried out to the pilot without the need to relocate the membrane for washing. (33)



*Figure 12: Hollow fiber membrane and a plate-and-frame membrane structure*

### c. The odds and drawback of Anaerobic bioreact from other methods

Because the membrane can fade concentration and hydraulic peaks, AnMBRs can withstand changes in organic loading unlike conventional anaerobic technologies (34). Due to the membrane's ability to separate the biomass from the effluent, this approach has a lot of promise for treating wastewaters that negatively impact granular biomass in high-rate anaerobic reactors: owing to strong treatment effectiveness, consistent biogas generation, and good operating stability in AnMBRs in difficult environments (35, 36, 37). AnMBRs have the ability to separate suspended particulates as well as retain bacteria and pathogens from wastewater while using little energy (38). Contrary to other anaerobic treatment methods, AnMBR effluent quality is often unaffected by changes in biomass settling or granulation qualities.

Due to the membrane's total preservation of biomass, quick system recovery is possible (39,40). Regardless of the hydraulic retention duration, the membrane acts as a complete barrier to the slow-growing microorganisms that may eliminate certain toxins from industrial wastewater as they collect in the system. For instance, using a membrane to retain slow-growing Anammox microorganisms improved their activity by 19 times (40). AnMBRs provide other important operating benefits than those related to the membrane. For instance, the overall amount of energy used is decreased since the biotransformation of organic matter does not need oxygen. Furthermore, biogas is a beneficial byproduct of the treatment of organic materials. Typically, biogas, a sustainable energy source, is used to provide both heat and power. (41). The heat is then used to maintain the reactor at the proper temperature for anaerobic digestion processes.. (42)

Because AnMBR doesn't need blowers like aerobic therapy, operation expenses for treatment were much cheaper than those employing aerobic treatment. As a consequence, the membrane itself and variables related to membrane fouling account for the biggest portion of both operating and capital expenditures during AnMBR operation. (43). AnMBR produces less excess sludge than aerobic MBRs do. (44) ; 20 times when put in comparison to aerobic MBRs up to 20 times (45), thereby further decreasing operational costs.

Last but not least, compared to Upflow anaerobic sludge blanket reactors, AnMBR also benefits from a shorter start-up duration, while the start-up period for Upflow anaerobic sludge blanket reactors might take several months. (46), both Hu and Stuckey (47) and Lin (48) have said that AnMBR start-up timeframes are just 6 and 12 days, respectively. AnMBRs tend to be more effective than either activated sludge systems or biofilm/biofiltration when treating industrial wastewater under difficult conditions, such as high suspended solids content, high salinity, presence of fat and oil or other inhibiting compounds. When compared to other technologies used in wastewater treatment, such as activated sludge process, advanced oxidation processes (AOPs), and biofilm filtration. (49).

Membrane bioreactor has a wide range of uses: Industrial wastewaters and waste streams with high solids content Effluents from the pulp and paper, chemical, pharmaceutical, petroleum, and textile sectors are examples of non-food processing industrial wastewaters, household wastewater, wastewater from food processing. Furthermore, compared to typical treatments (aerobic, aerobic), the working area for this kind of therapy is smaller. (50)

Due to the narrow hole width of the membrane, the MBR technology has the benefit of being able to biodegrade the waste chemicals and separate the treated water from the mixed liquor. Since the membranes generally feature pores with a diameter of 0.01 to 0.1 m, the presence of microorganisms and suspended materials may be prevented from entering the effluent (51)

#### d. Disadvantages of membrane bioreactor and solution:

The fundamental drawback inhibiting wider adoption and quicker commercialization of membrane technology in the area of wastewater treatment is thought to be membrane fouling, which reduces flux. Thus, the overall operating expenses directly related to the usage of the membrane must take into account membrane fouling, flux reduction, and lifetime, as well as cross-flow pumping or gas scouring of the membrane. AnMBR is often operated at lower fluxes than aerobic MBR in part because of this.

The biggest barrier preventing the more widespread use of AnMBR in wastewater treatment is still membrane fouling. Membrane fouling may lower system productivity, need more frequent cleaning, which may shorten the membrane lifetime and raise the cost of replacement, and raise the energy needed for sludge recirculation or gas scouring (52). The components of the sludge suspension interact with the membrane material to cause membrane fouling. Although the membrane used in an aerobic MBR may generally also be utilized in an anaerobic MBR, the sludge suspension in the anaerobic compartment differs greatly from that in the aerobic compartment and has certain particular effects on the membrane fouling properties. It is now possible to describe membrane fouling using a variety of methods, which makes it possible to comprehend membrane fouling in the AnMBR system better.

Fouling generally reduces flux and may happen either on a membrane's surface or within its pores. Fouling may be categorized into four main categories: bio-fouling, scaling, organic, and colloidal. A biofilm forms on the membrane's surface as a consequence of bio-fouling, which is caused by microbial contamination of feed water and raises the membrane's barrier to water permeability. Salts precipitate and settle on the membrane surface, which causes scaling. Organic fouling is caused by chemicals like hydrocarbons that cover the surface of the porous support layer or clog its pores. The major cause of colloidal fouling is the accumulation of particles, such as clay or silica, on the membrane's surface. By using disinfectants, anti-scaling chemicals, and other pre-treatment procedures, fouling may be somewhat managed. However, they are not fixes for the issue, and fouling is still a significant area where RO membranes may need to be improved. (53)

Cross-flushing, back-pulsing with water, and back-pulsing with gas are three techniques often used in cross-flow filtering systems to reduce fouling. Forward filtration is followed by reverse filtration in a cycle that results in back-pulsing. Reverse filtration includes reversing the sign of the trans-membrane pressure to reverse the flow across the membrane. For back pulsing, the back pressure is given intermittently during the course of the procedure in the form of a very quick pulse (pulse duration typically less than 1s). Reversible deposits of particles on or in the membrane are removed by the reverse flow, and the jamming agent is washed away by the cross flow, which considerably lowers fouling and increases the forward flux.

Water back-pulsing is accomplished by applying reverse trans-membrane pressure to force water (or permeate) back through the membrane. Gas back-pulsing is an alternative method for periodically pulsing nitrogen or another gas through the membrane from the permeate side. By maintaining flow across the membrane while sometimes pausing the permeate flow, the related in situ cleaning technique of cross-flushing eliminates the pressure drop across the membrane and enables the shear force of the cross flow to dissolve the fouling layer. Since cross-flushing does not need a pressurized tank or pump for back-pulses, it is less complicated than back-pulsing with water or gas. Cross-flushing's shear force, however, does not remove fouling contaminants as well as back-pulsing does, particularly when internal fouling inside the

membrane pores takes place. The most effective way to reduce non-adhesive fouling is believed to be achieved by all three hydrodynamic techniques. (54)

Another method to stop membrane fouling is to modify the membrane. There are three techniques for changing PES and PES-based membranes: blending, which is also regarded as a surface modification, bulk modification of PES material followed by the manufacture of a modified membrane, and surface modification of generated PES membrane (30). The modification techniques allow for the achievement of a balance between hydrophobicity and hydrophilicity, localize the hydrophilic material specifically in the membrane pores, where they have a positive impact on the reduction of flux and fouling, and endow membrane functions like good blood compatibility and stimuli-responsivity.

Several methods were used for the polymeric membrane surface alteration, such as: physical, chemical, or bulk modification, among the most popular techniques for membrane modification are surface coating, chemical treatment (fluorination, crosslinking, pyrolysis), annealing with heat treatment, and solvent treatment. PSF/PES nanofiltration (NF) membranes' hydrophilicity was increased using chemical (and physicochemical) modification techniques. PES membranes may be altered in a number of ways to increase their hydrophilicity. After the membrane has been formed, physical or chemical membrane modification methods provide more hydrophilic surfaces.

For example, graft polymerization chemically bonds hydrophilic monomers to the membrane surface; plasma treatment adds various functional groups to the membrane surface; and physical preadsorption of hydrophilic components to the membrane surface are other examples of modification procedures.

In reality, a wide variety of modification techniques have been used to alter PES membranes. These techniques include physical ones like blending and surface coating as well as chemical ones like photoinduced grafting, gamma ray grafting and electron beam grafting, plasma treatment and plasma-induced grafting, thermal-induced grafting and immobilization. As science and technology advance, several novel polymerization techniques are created. These techniques, such as click chemistry and reversible addition fragmentation chain transfer (RAFT) polymerization, might be employed to modify PES membranes.

One of the other ways to prevent the membrane fouling is to add chemicals into the treated fluid such as chlorine. However, this may not possible as the chlorine might reduce the efficiency of the microorganism. (55)

Furthermore, one of the objective reasons for the popular of the technology is popularity of the membranes. The developing country does not have the ability to manufacture the membrane and have to import the membrane from others. As the result, the membranes are not common there and the price is more expensive than in countries that have the technologies to manufacture the membrane.

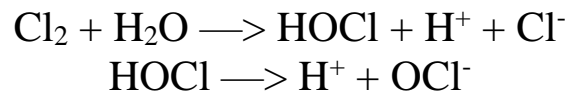
## **6. Post-treatment:**

Chemical oxidants like ozone, chlorine, chlorine dioxide, chloramines, etc. have the potential to disinfect (microorganisms) and oxidize (controlling taste and odor, removing micropollutants, etc.). Chlorine is the most popular chemical oxidant used to purify drinking water because of its inexpensive cost. This chemical is often applied in the process of purifying drinking water at one or more points, such as pretreatment (to initiate at the start of the



treatment process) and/or posttreatment (to maintain a disinfectant residual in the distribution system) (55). Chlorine is often utilized for a variety of reasons in home and industrial wastewater, which is called Chlorination. Despite having little effect on the microorganisms in biofilms, chlorine may significantly reduce the amount of bacteria that are planktonic. (55) Chlorine is crucial for preventing the development of heterotrophic microbes since it is added just before the water is released into the distribution system (post chlorination), close to the conclusion of the treatment process.

In fishery effluents, their main function is to either kill bacteria or algae or to prevent their development. This process usually takes place at the end of the whole treatment which is called post-treatment. The latter is simpler to handle, and either chlorine gas or hypochlorite solutions may be employed for this operation. However, owing to their reactivity with the elements of the water matrix or micropollutants, oxidants may sometimes cause the creation of potentially harmful by-products or transformation products. (56) Chlorine creates hypochlorous acid, which then creates hypochlorite in waste solutions. Chlorine creates hypochlorous acid, which then creates hypochlorite in waste solutions:

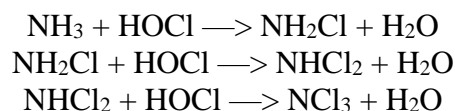


Because of their acid-base properties, two types of ammonia (NH<sub>3</sub> and NH<sub>4</sub> Plus Aqueous solutions include). There is very little chlorine reactivity with NH<sub>4</sub> + species. Hypochlorous acid combines with NH<sub>3</sub> to produce NO<sub>3</sub> and N<sub>2</sub> for [HOCl]b[NH<sub>3</sub>] during aqueous chlorination. This oxidation is the outcome of subsequent reactions that first cause the creation of chloramines (mono-, di-, and trichloramine) (56)

These findings demonstrate that when the chlorine atoms on the nitrogen grow, the chlorine reactivity decreases. This is evidence for the first mechanism of HOCl's electrophilic assault on chloramine nitrogen.

Chloramines (NH<sub>2</sub>Cl, NHCl<sub>2</sub>, and NCl<sub>3</sub>) and organic chloramines indicate combined chlorine in contrast to free chlorine (i.e. HOCl, ClO, and Cl<sub>2</sub>). Combination chlorine possesses oxidative characteristics, much as free chlorine. In order to maximize disinfection and reduce the development of unwanted byproducts, it is crucial to forecast chloramine generation and breakdown when NH<sub>3</sub> is present during chlorination.(56)

for the purpose of stop biofouling, chlorine disinfection is often employed in pretreatment. Following chlorine disinfection, certain chlorine-resistant bacteria may persist, and the composition of the microbial population in provided water drastically alters, changing the biofouling potential.



Following the procedure, the number of active bacteria in the foulants on the fouled membrane remained constant regardless of the chlorine dose, however, the fouling layer thickness considerably increased with the chlorine dosage. Furthermore, the increased total organic carbon content suggested that foulds included more extracellular polymeric compounds (EPS). These findings showed that the RO membrane fouling potential of the water samples dramatically rised with an increase in chlorine content. (55)

## 7. Mechanical and Electrical design

### a. Mechanical design

The design should consist of tanks (for containing microorganisms and membranes) and stirring tubs (For pretreatment) with motor frames and stirrer. All the components should be connected with tubes and connectors. Flexible plastic pipes with a diameter of 10mm is used to connect all the mechanical parts of the pilot. This provides the advantages of price, flexibility and maintenance for the pilot. Tanks should be designed with 1 glass face so the operators and researchers can look into the microorganism in the tanks. A Pumps stander for all the pumps placing at one area which will help the operation and maintenance more flexible.

The stirrer motor frame for the pretreatment process should be considered as well. As the motor has poles with input hertz provided, the output RPM should be calculated as

**RPM at no-load** =  $(\text{Hz} * 60 * 2) / \text{number of poles}$

⇒ **RPM with gear box** =  $(\text{Hz} * 60 * 2) / (\text{number of poles} * \text{gear ratio})$

### HYDROSTATIC PRESSURE for anaerobic tank design:

Hydrostatic pressure depends on the height (depth) of the object.

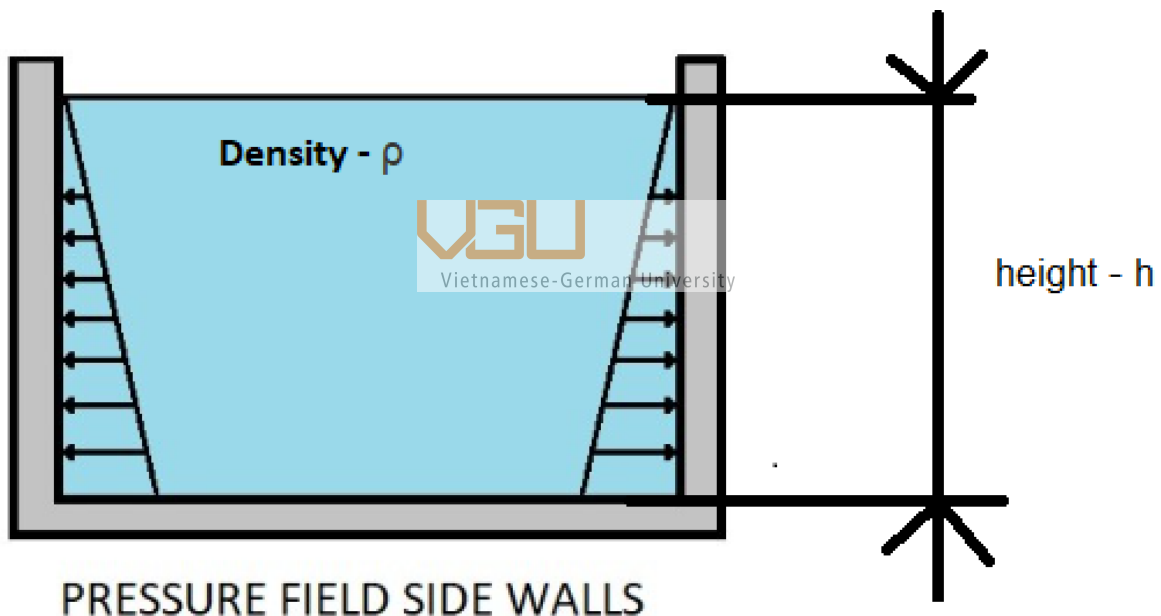


Figure 13: Hydrostatic pressure analysis

$$P = \rho * h * g$$

With P = Hydrostatic pressure;  $\rho$ : Specific density of the fluid, g: gravitation

$$\Rightarrow p = \rho * h * g * w$$

With p: Hydrostatic pressure's distributed load; w: width of the tank

The average force would be placed at 1/3 of the height (57)

## b. Electrical design

An industrial computer that has been ruggedized and adapted for the control of manufacturing processes, such as assembly lines, machines, robotic devices, or any activity that requires high reliability, ease of programming, and process fault diagnosis is known as a programmable logic controller (PLC) or programmable controller. This controls the enabling or disabling of electrical devices used in the pilot. Furthermore, there is a screen control, connected to the plc as a dedicator and receiver of manual tasks given to the pilot.

As the main electrical supply is 220V – there must be another converter that reduces the Voltage from 220V to 24V to power the small voltage devices. Domino, A terminal, also known as an electric Domino, is a device that connects wires with control or motivation devices, helping to seamlessly connect the electricity in the electrical system. Circuit breaker (CB) is a safety mechanism that halts current flow when an electrical circuit has a problem – due to short circuit. If there is a leak in the electricity, the pilot may get damaged and cause accidental injuries to the operators or passing by people. Wire with cable lug for electrical connection in the pilot.

To the transfer of the fluid throughout the pilot, diaphragm pumps (24V) and submersible pump (220V) are used with solenoid valves.

## III. Methodology:

The membrane used in the project was from Microdyn-Nadir, Germany. The pilot uses a plate-and-frame membrane structure, a flat sheet poly- ethyl sulphone membrane was stablized between solid frame with a pipe-connected hole. The fluid would be sucked from the environment through the membrane and be delivered by piastic Pvc pipe – diameter of 10mm.



*Figure 14: Pilot's membrane*

The pilot figuration is based on the side-stream membrane bioreactor. The design should have consisted of a pretreatment tank - PAC and polymer anion processing with a stirrer, an anaerobic tank, an external membrane tank.

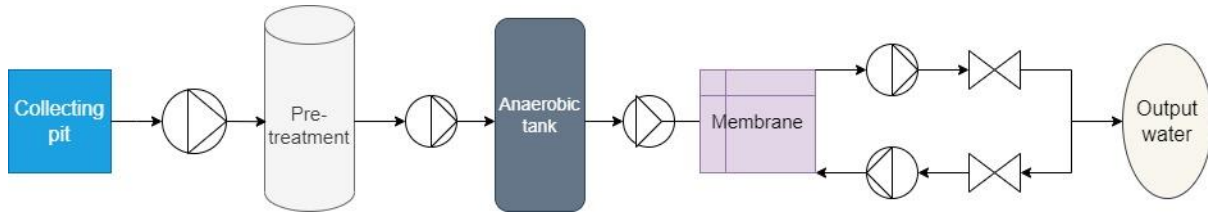


Figure 15: Treatment process diagram

The wastewater would be pumped by a submersible pump from the collecting pit to the pretreatment tank. Diaphragm pumps would help deliver liquid in between tanks: from pretreatment to anaerobic and membrane. However, it must be noted that to avoid membrane fouling, the pilot used back-pulsing mechanism. As the result, there are two pumps between the membrane tank and the output sources, one moving forward from membrane through a solenoid electrical valve to output water. The other one, however, would only be activated for small certain amount of time, when the reverse pump runs, the valve on the forward pump closes so the pump does not lose pressure.

The overall design of the pilot – demonstration as technical drawing:

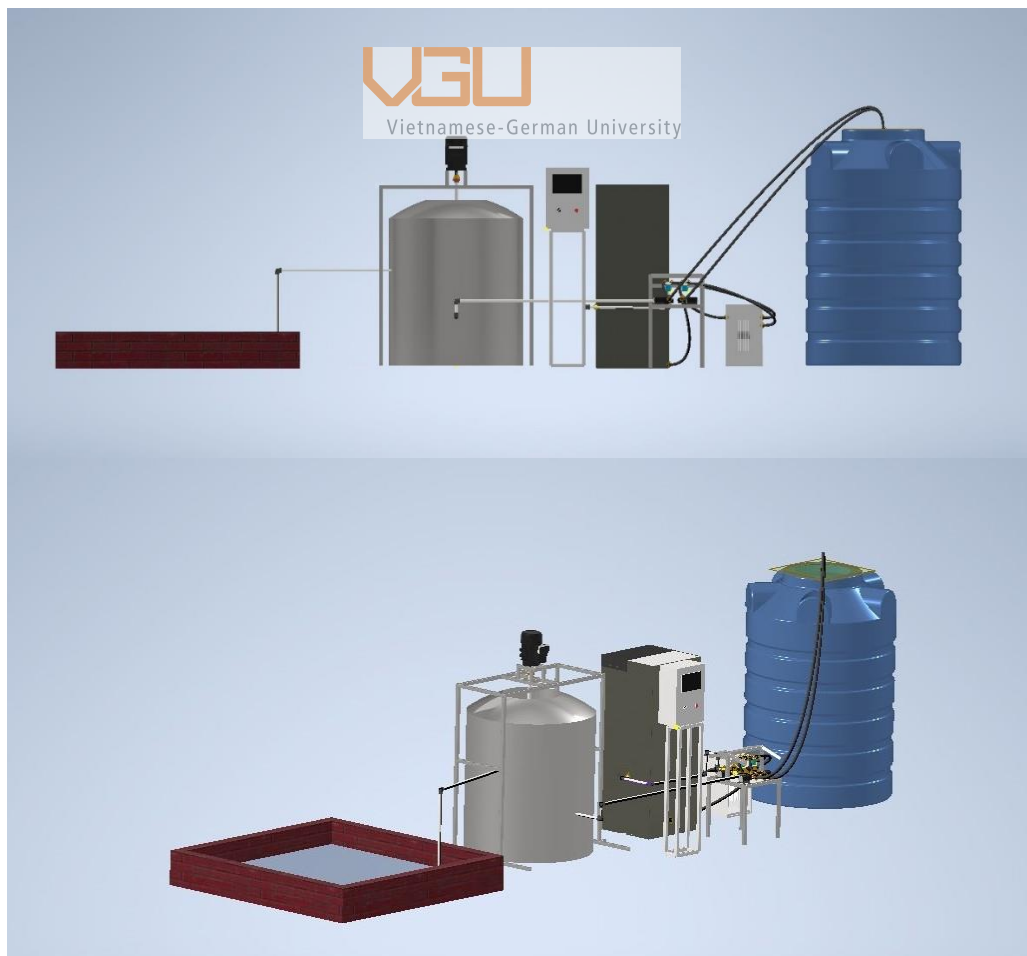


Figure 16: The design overview

Pretreatment process:

Stirrer and motor frame are located above a cylindrical tank. As the usual design in most industrial cases, the pretreatment state often contains 2 tanks combined with stirrers as the first one for Poly aluminum chloride adding and then the water would be delivered to the secondary tank for adding Polymer anion as flocculant. However, as the project lacks of space and material, we agree to build one tank with stirrer only and as one working cycle for pretreatment, the chemicals alternatingly added. As the result, Poly Aluminum Chloride would be added first then mixed, after that Polymer anion would be put in. As the 2 steps are completed, the liquid is pumped to the anaerobic tank for microorganism consump.

As the motor used as stirrer is a 3 phases induction motor 240VAC which has 6 poles with a maximum hertz of 50Hz and a maximum round per minute (RPM) of 1400RPM. The gearbox with a ratio of 20:1 is attached to the motor. The output RPM should be calculated as

RPM at no-load =  $(\text{Hz} * 60 * 2) / \text{number of poles}$

⇒ RPM output with gear box =  $(\text{Hz} * 60 * 2) / (\text{number of poles} * \text{gear box ratio}) = (30 * 60 * 2) / (6 * 20) = 30\text{RPM}$

An inverter, from Sinovo Shenzhen Sinovo Electric Technologies CO., LTD is used to control the speed of the stirring motor.



Figure 17 Motor with gear box and inverter for stirring design

The motor frame is used to support the motor and a propeller for stirring. For this part, we used stainless steel as the outdoor environment of the pilot might damage iron structure due to

corrosion. The stainless steel bars have the cross-section area of 30\*30mm. After the frame design, we ran a simulation on the material and the structure as it could withstand the weight of the stirrer components – at 25kg. The motor frame design:

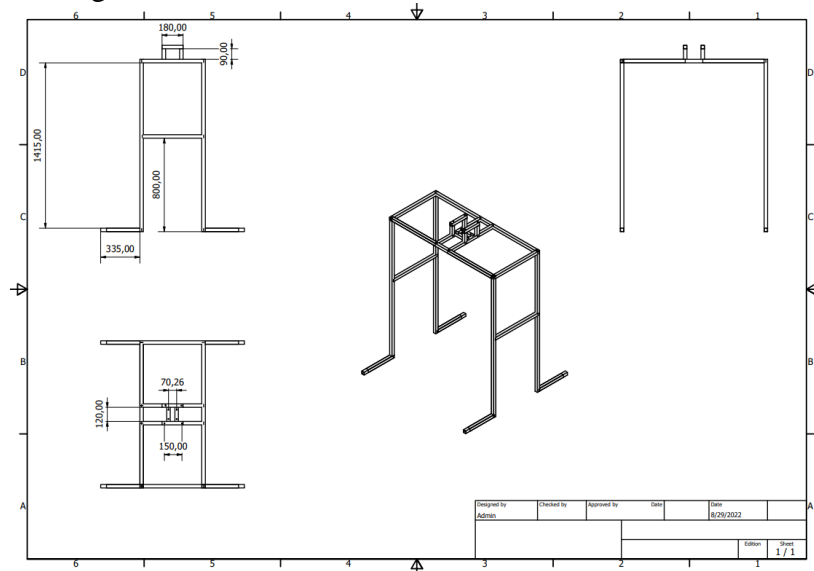


Figure 18: Technical design of the motor frame

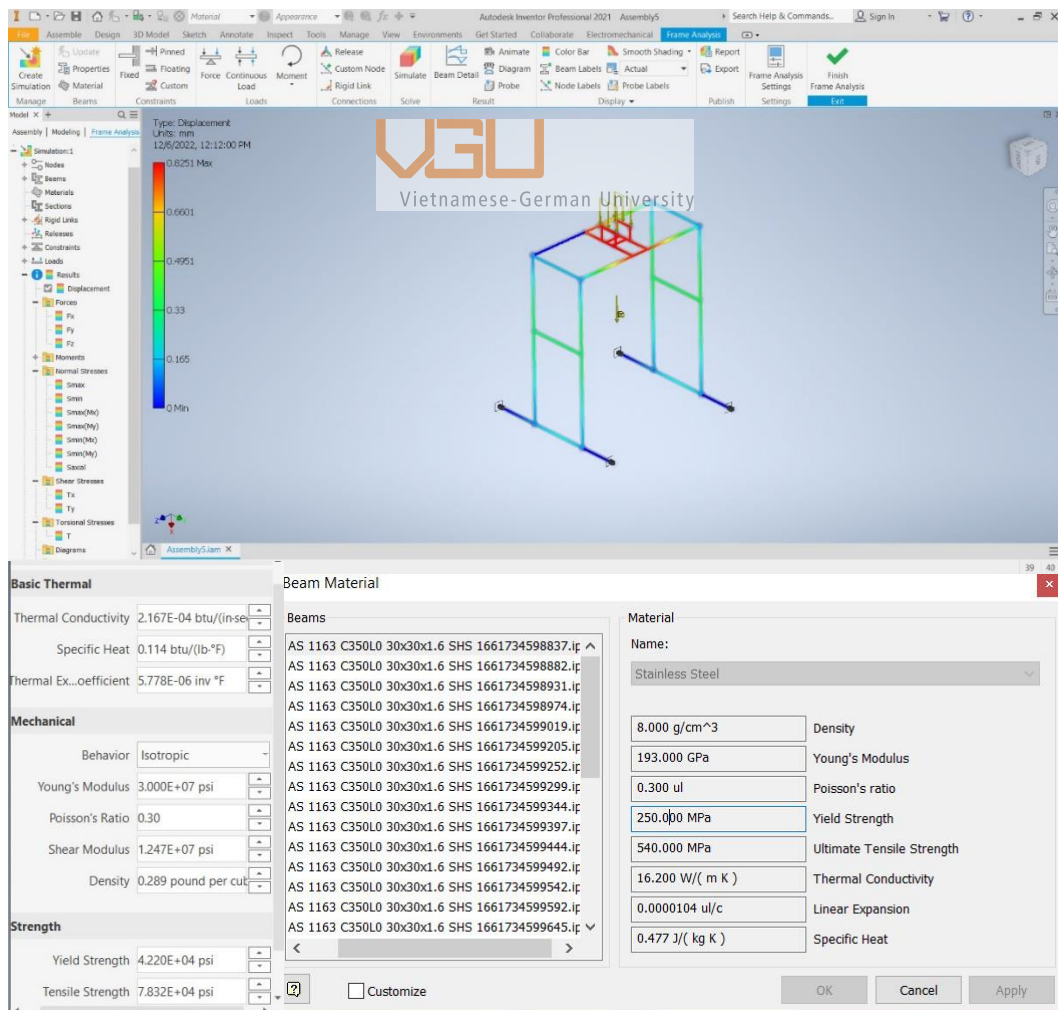


Figure 19: Simulation task on the stirrer

As the result, the structure was successful in stirring. Beneath the frame, we placed an old tank which is one and a half cubic meters. This tank is from inside Basefood 1 factory. As the pretreatment part has done:



Figure 20: the finish stirrer and pretreatment tank



The microorganism tank and membrane tank design:

The two tanks are also made of stainless steel to withdraw the environment corrosion.

The design technical and then would be handed to a mechanic workshop to build which the workpiece would be cut then get mechanical punches along the red marked line so it can get into shape.

As the tanks contain water, the pressure that contributes to the tank's wall should be considered.

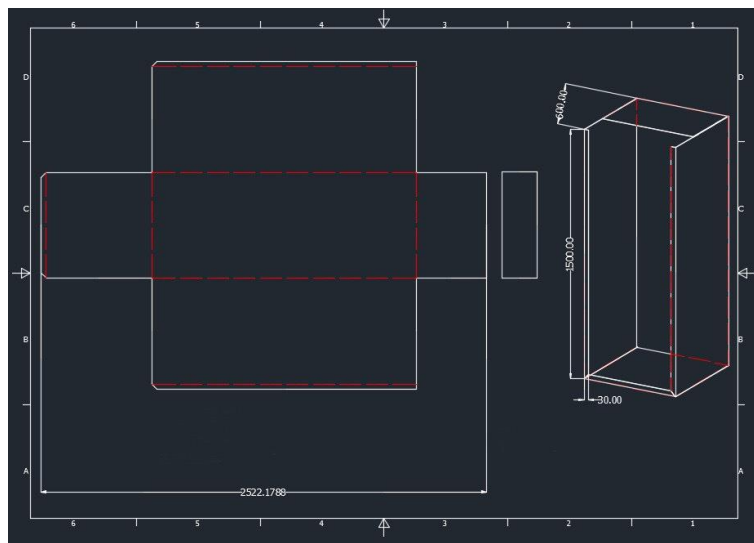


Figure 21: Technical drawing of the anaerobic tank

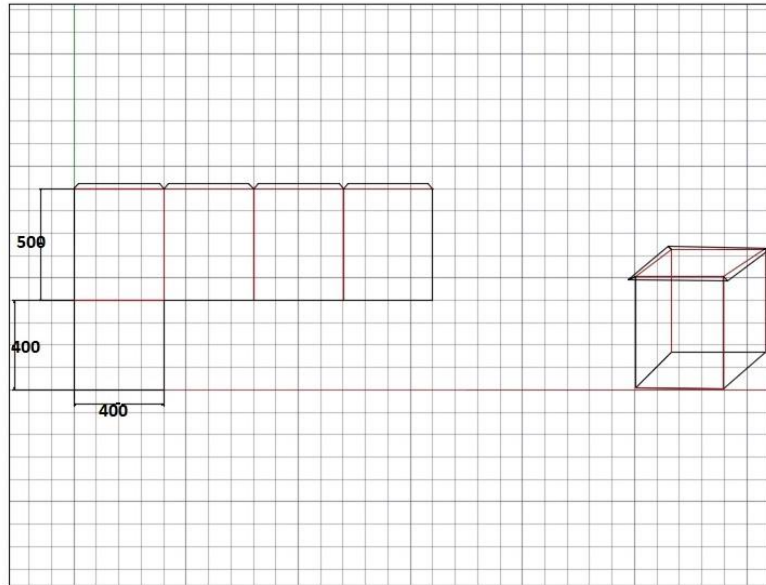


Figure 22: Technical drawing of the external membrane tank

As the tanks contain water, the pressure contributes to the tank's wall should be considered. The anaerobic tanks which could hold up to 540 liters of liquid would be damaged as time flies. The density of the sludge in the tank should be  $1030\text{kg/m}^3$  and the tank's height is 1500mm with a bottom square width is 600mm. The solution to prevent the problem is to build a frame around the tank.

The pressure's distributed load on the anaerobic tank – The average force would be placed at 1/3 of the height:

$$\Rightarrow p = \rho * h * g * w = 1030 * 1.5 * 0.6 * 9.8 = 0.3634 \text{ (N/mm)}$$

The simulation from computer given that the frame meets the requirement of protecting the tank. On the other hand, the membrane is much smaller – only holds 50 liters of liquid with the height of 500mm then the membrane tank pressure can be neglected.

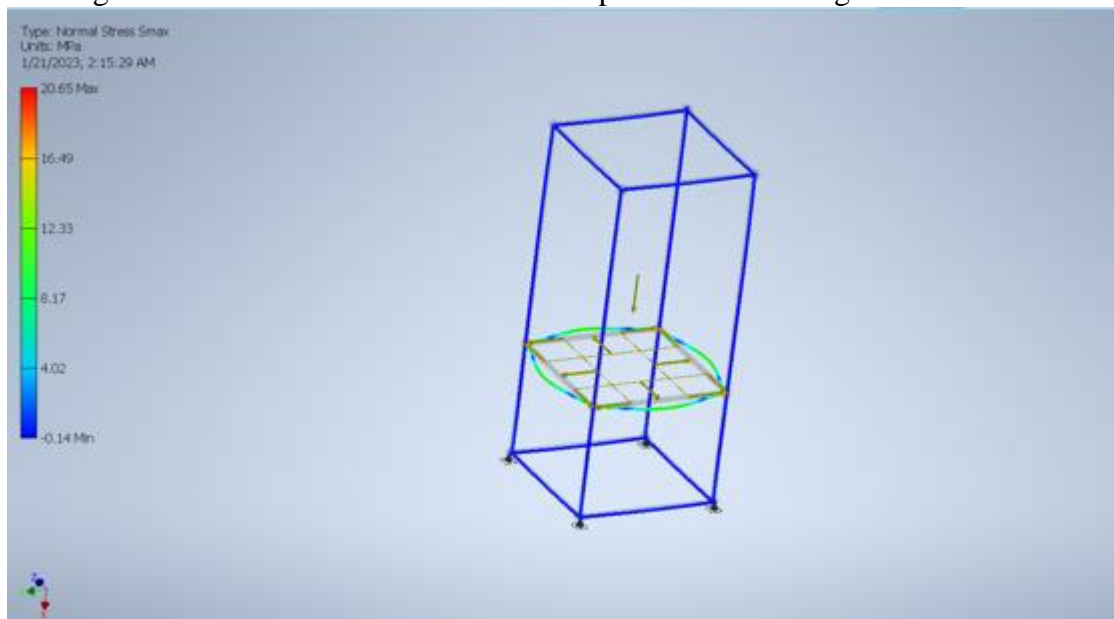
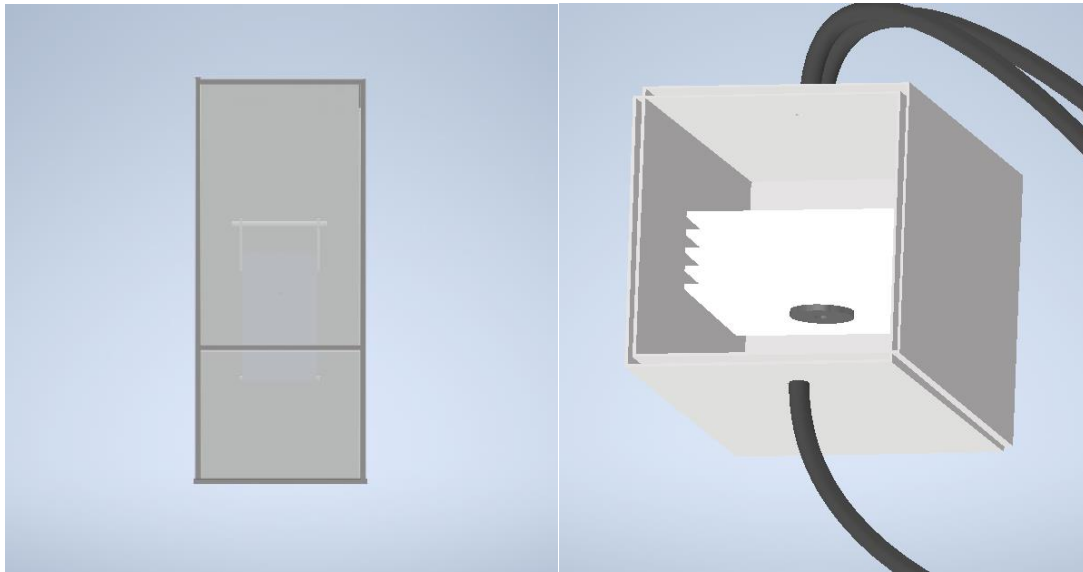


Figure 23: Simulation on tank's frame





*Figure 24: 3D design of the anaerobic and the external membrane tank*



*Figure 25: Anaerobic tank and external membrane tank as 3D modelling and finishing*

For the prototype, a line of programmable logic controllers (PLCs) called the S7-1200 series from Siemens was chosen, which can manage several automation applications. The S7-1200 is the ideal choice for managing a wide range of applications thanks to its small size, inexpensive price, and robust instruction set.

Membrane fouling – 9:1 minutes back-wash to avoid membrane fouling. When the forward pump is working, the solenoid valve on the back washing pump which is not working, is closed. This prevents pressure loss and helps the pump efficiency. The opposite also happens, when back washing, the forward pump is turned off and the solenoid valve with the forward pump is closed. The PLC programming which controls all the pumps and valves is under the Appendix.



Figure 26: solenoid valve and diaphragm pump

Diaphragm pumps 24VDC – Current Flow of 60L/h which is located in one place:  
  
 Vietnamese-German University



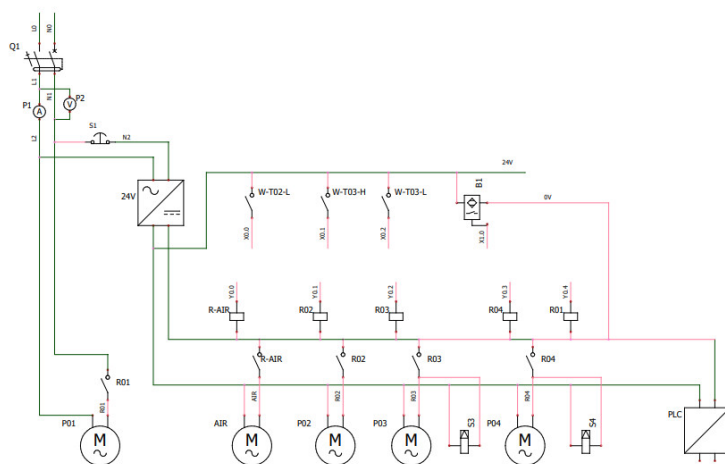
Figure 27: Pump and Valve attached on the stander

A submersible pump helps carry the wastewater from the collecting pit to the pretreatment tank. The pump is electrically connected to a float switch, when the water level is low, the circuit would be closed to the pump starts and when the water level has reached, the pump stopped. The pump runs under 240VAC and has the power of 0.5kW.



Figure 28: Submersible pump with float switch

Electrical wiring diagram:



Power		REV.	DATE	REQUODCAT	CHANGES	REVISION
CONTRACT:		0	11/2/2021			0
LOCATION:	L1					SCHIEFE
Main electrical closet		User data 1			User data 2	04

Figure 29: Wiring diagram

Electrical cabinet:



*Figure 30: Electrical cabinet after finish*

Post-treatment: with Chlorine and PAC at laboratory scale:  
The after treatment wastewater was collected and analyzed.  
The liquid then would be added with Chlorine and Poly aluminum chloride combined with Polymer anion –  $\text{CONH}_2[\text{CH}_2\text{-CH-}]_n$  as post-treatment process. The post-treatment was carried out with jar testing to find out the effect of the post-treatment chemical on the output water from the process. We added different dosages then analyzed with 5 targets, which consist of: Ph level, Total suspended solid, Chemical Oxygen Demand, Total Nitrogen, Total phosphorus.



*Figure 31: Jar testers*

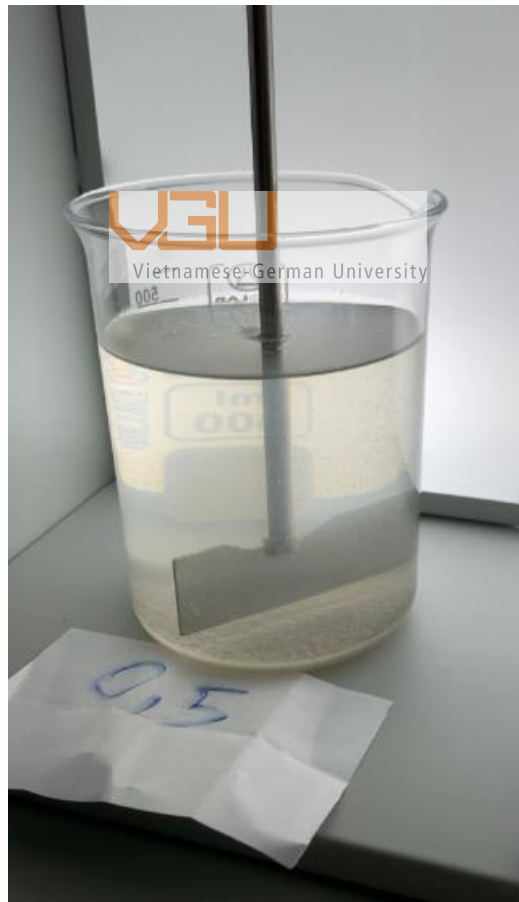
For Chlorine:

Experimental layout: The chlorine used in the experiment was Chlorine 70, there are 5 different dosages from 1mg/l to 10mg/l, which was: 1mg/l, 2mg/l, 4mg/l, 6mg/l and 8mg/l.

After adding the Chlorine, the jar testers was run at 70 RPM for 20 minutes for mixing the chemical.

For Poly aluminum chloride and Polymer anion:

Experimental layout: Chemical used in the experiment was Poly aluminum chloride -  $[Al_2(OH)_nCl_{6-n}]_m$  as coagulant and polymer anion  $CONH_2[CH_2-CH-]_n$ . Firstly, the coagulant was added and stirred at 30 RPM for 15 minutes then rest for 5 minutes as the chemical reaction and sedimentation with the dosage of 500mg/l, 550mg/l, 600 mg/l, 650 mg/l and 700 mg/l. After stirring the coagulant, 30 mg/l of polymer anion was added to each jar as flocculation. The motor would be run at 30 RPM also for 15 minutes and then rest. After resting, the output wastewater was analyzed to choose the optimal dosage for coagulant and the chosen dose would be used as for finding the optimal polymer anion dosage. There are 5 different dosages from 10mg/l to 50mg/l, which was: 10mg/l, 20mg/l, 30mg/l, 40mg/l, and 50mg/l.



*Figure 32: Sedimentation of Poly Aluminum Chloride after mixing*

#### IV. Result and Discussion:

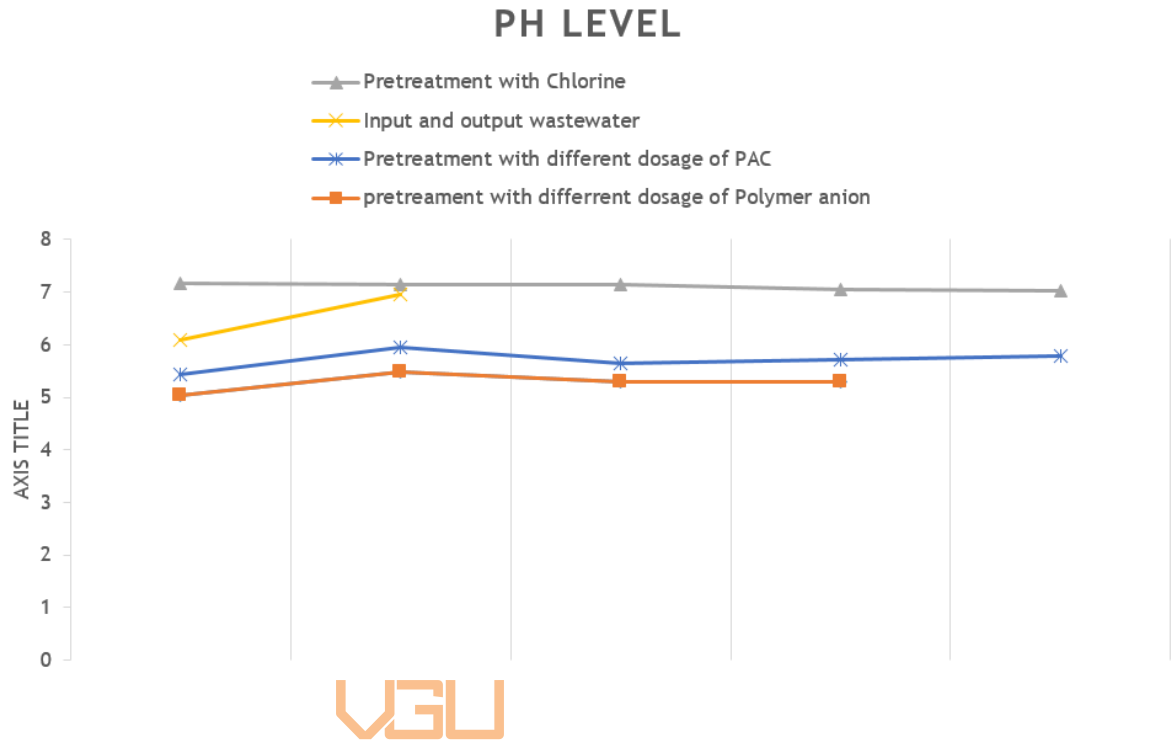
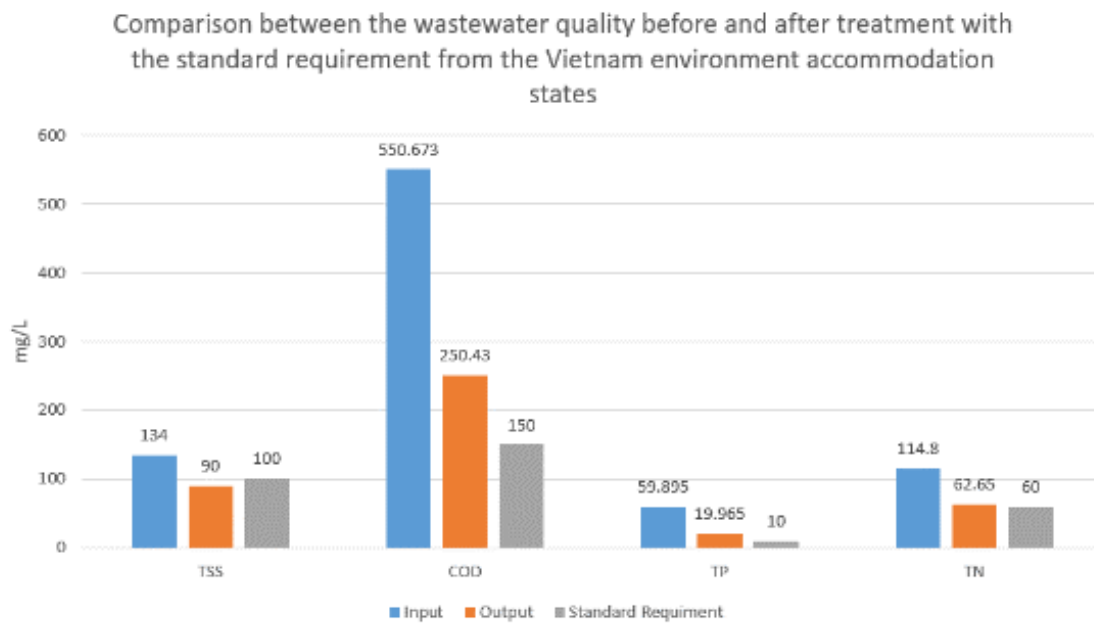


Figure 33: Diagram of Ph level on samples

After taking samples before and after treatment, the first index should be considered is the Ph level. It is fortunate that the Ph level does not vary much throughout the project and always stay in the permitted area. This could be the result of applying the biological technology which is using the anaerobic microorganism which did not need much chemicals.

Considering other indices, we can see that the Chemical Oxygen Demand and Total phosphorus are significantly high which is about 3 times the standard output for COD and 5 times for TP. However after treatment, the number has a huge decrease. Even though the index does not meet the requirement but it should be noted that the pilot has the potential to developing in the future with room for improvement. Furthermore, the pilot's result is promising as it has decreased the indices by half as much.



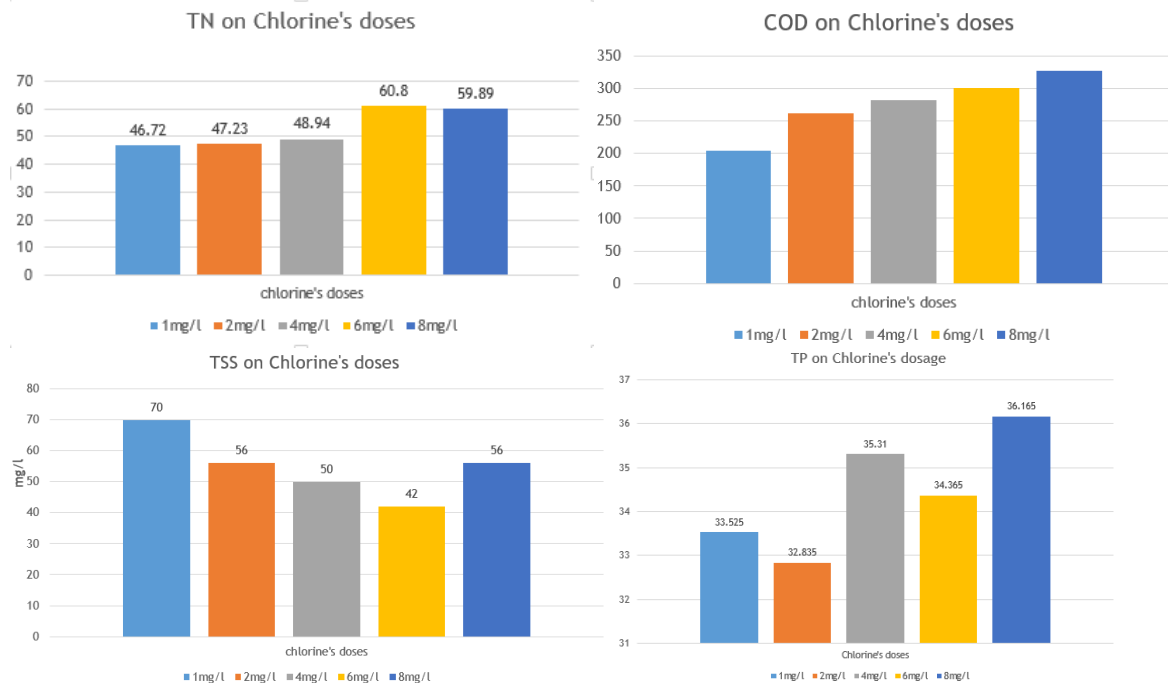
*Figure 34: Comparison between samples and standard requirement*

Vietnamese-German University

As one of the membrane advantages, it was simple to observe that the value of Total Suspended Solids is now under the threshold for wastewater treatment. This outcome is due to the fact that the membrane holds all the solid in the water so only the fluid comes through.

Additionally, it must be noted that the total phosphorus and total nitrogen indexes are near the required range, which is excellent news.

*For Chlorine post-treatment:*



*Figure 35: Chlorine samples indices*



Vietnamese-German University

Chlorine is well-known for domestic water treatment as a strong oxidant and bacteria elimination, however, as our project mainly revolves the seafood wastewater treatment, the index analyzed are Total Nitrogen, Total Phosphorus, Total Suspended Solids and Chemical Oxygen Demand.

As chlorine dose increasing, the COD index can get larger which could be an error created by chlorine when COD is determined by using spectrophotometer. However, after running the test again, the COD index shown the same result, this can relate to the oxidation of chlorine.

With small doses of Chlorine, there has an effect on as it decreases and meet the standard requirement in TN and TSS. The larger doses may lead to chlorine redundancy which causes the increases in the index. Chlorine might not have much impacts on Total Phosphorus as the index indicators are disorganized and not shown properly.

This result might relate to the fact that the input water for chlorine post-treatment meets the A standard issued by the Vietnamese government on seafood wastewater (for Domestic water source). The Chlorine post-treatment is promising but the indices must meet the requirement first.

In future work, the output water source if achieves the requirement indices, can deliver and adding chlorine to the water moving to the pressure tank as a post-treatment process for the pilot scale.



*For Poly Aluminum Chloride post-treatment:*

With fixed flocculant dose:

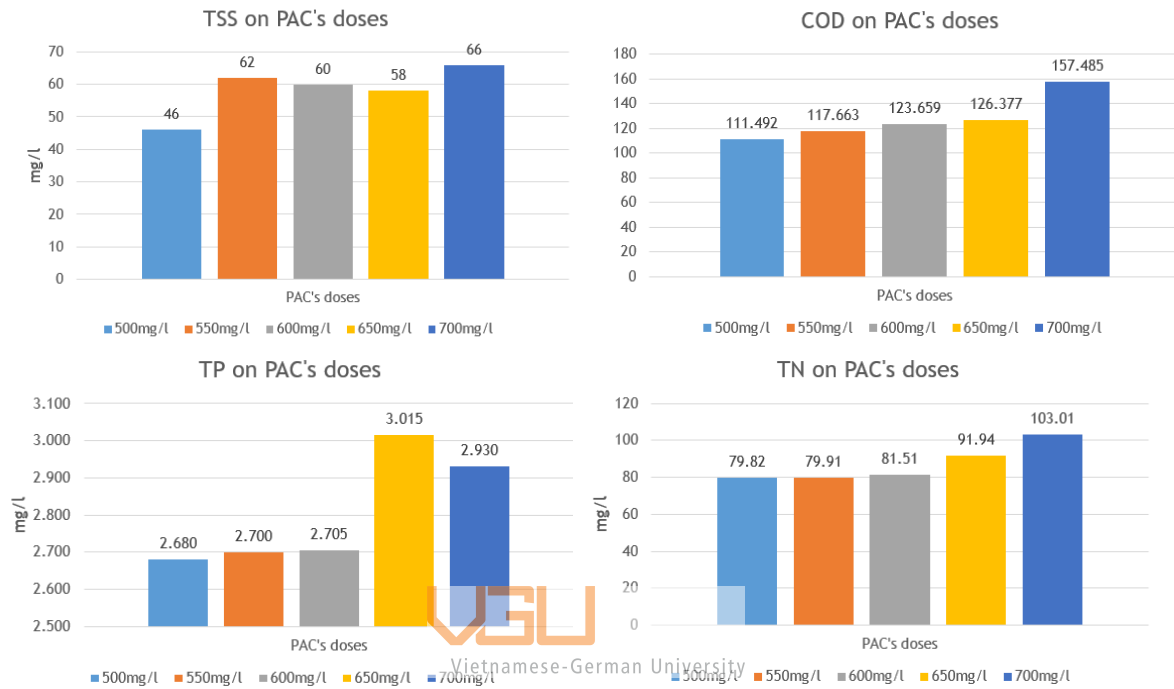


Figure 36: PAC samples indices

The TSS is noticeably lower during the first test run as a result of the deposits being sedimentation. The TSS index reached domestic water by government regulations. But when the dose was raised, the concentration of both COD and TN markers rose and did not meet the required indices. There are not much impacts on TP in this case, most index indicates not much difference in the long run but the index achieved the requirement.

For all the results dedicated, the most promising one would be 500mg/l of Poly Aluminum Chloride. As a consequence, we chose this dose for the next experiment as a fixed coagulant dose.

With fixed Coagulant dose:

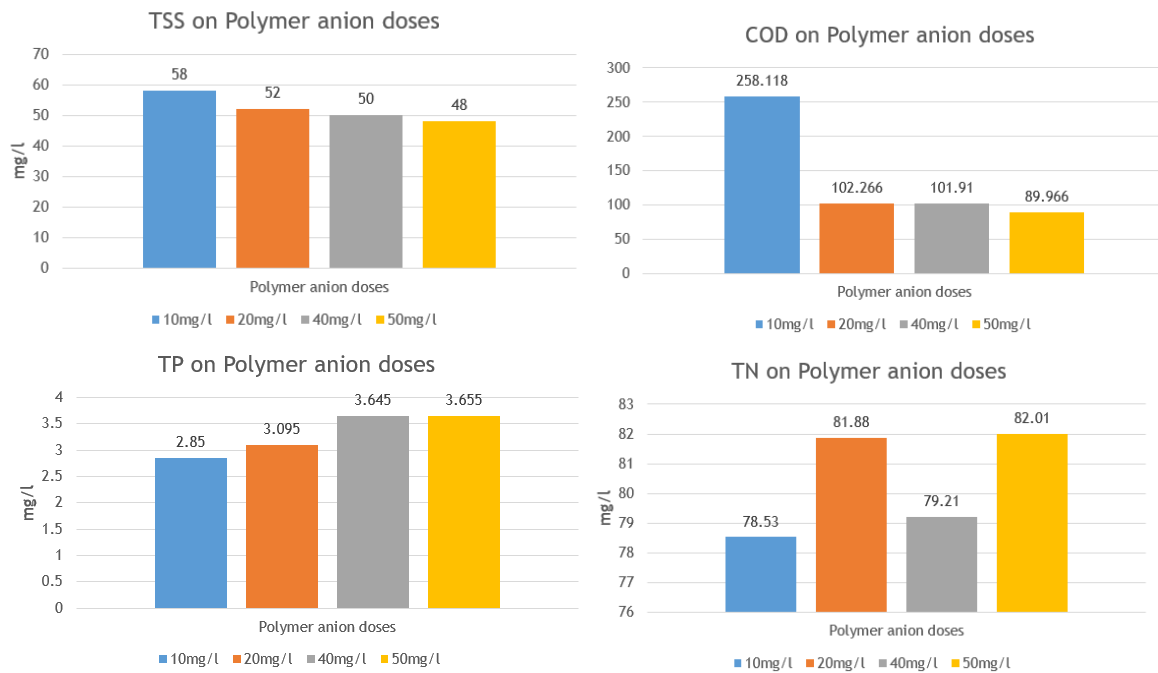


Figure 37: Polymer anion samples indices

At 500mg/l of PAC, the more polymer anion added to the liquid, the better result on TTS. As the polymer anion doses increase, the amount of suspended solid settled to the bottom increase. The same happens to COD index, adding more polymer anion helps decrease the COD in the wastewater.

The Total Phosphorus, on the other hand, is increasing when adding more Polymer anion but not too significant. The Total Nitrogen is not reliable, adding more polymer anion or less, might not have must impact on TN in the water, the difference between samples also is not much. From the two tests, we can see that for optimal dose of coagulant and flocculant, which is specifically poly aluminum chloride and polymer anion, should be 500 mg/l coagulant with 30 mg/l of flocculant. This dosage would help control and

## V. Conclusion:

The seafood wastewater industry is a large manufacturing industry in Vietnam and the protection of the environment from waste products from this industry is a major issue and needs attention.

The use of anaerobic membrane technology gives many advantages when it comes to reducing the amount of nitrogen and phosphorus in wastewater as well as greatly limiting the amount of suspended solids in the water. Combined with pretreatment of flocculation and coagulation to support better output water quality.

In this project, we have both designed and launched new solutions for wastewater treatment. These measures are being implemented a lot around the world but not really popular in Vietnam. It can be seen that this is a promising new technology with many improvements to research and implement to suit the needs of environmental conditions in Vietnam.

Combining wastewater treatment techniques results in flexibility and adaptation to various circumstances. Even though this is simply a modest research model, the information it produces is very useful for both the learning process and the development of artificial intelligence. The research team hopes that this technology will be used and extensively disseminated.

# Appendix:

The image displays three screenshots of the Siemens TIA Portal software, showing the Main [OB1] program block for a PLC. The screenshots illustrate different parts of the ladder logic program.

**Top Screenshot:** Shows the Main [OB1] program block. The variable declaration table is as follows:

Name	Data type	Default value	Comment
Input			
Initial_Call	Bool		Initial call of this OB
Remanence	Bool		=True, if remanent data are available

The ladder logic consists of two main rungs. The first rung has two parallel branches: one with normally open contacts 'S0.1 \*WTD2-L' and 'S0.4 \*PO1', and another with normally open contacts 'S0.3 \*WTD3-L'. Both branches lead to a coil 'Q0.4 \*PO1'. The second rung has two parallel branches: one with normally open contacts 'S0.1 \*PO2' and 'S0.3 \*WTD3-L', and another with normally open contacts 'S0.2 \*WTD3-H'. Both branches lead to a coil 'Q0.1 \*PO2'.

**Middle Screenshot:** Shows a different section of the ladder logic. It features a normally open contact 'S0.0 \*AB-AUF' leading to a coil 'Q0.0 \*AIR'. Below this, there is a timer block 'IEC\_Timer\_0' (T0) with a setpoint 'SMD1 \*TIME-ON-PO3'. The timer is triggered by a normally open contact 'S0.2 \*PO3-PLUG2'. The timer's output is connected to a coil 'S0.3 \*PO3-PLUG2'. A data block 'Data\_block\_1' is also shown, with a reference to 'TIME-ON-PO3'.

**Bottom Screenshot:** Shows the Main [OB1] program block, similar to the top screenshot, but with a different set of logic. The variable declaration table is the same as in the top screenshot. The ladder logic has two main rungs. The first rung has two parallel branches: one with normally open contacts 'S0.1 \*WTD2-L' and 'S0.4 \*PO1', and another with normally open contacts 'S0.7 \*PO1-ON/OFF'. Both branches lead to a coil 'Q0.4 \*PO1'. The second rung has two parallel branches: one with normally open contacts 'S0.1 \*PO2' and 'S0.3 \*WTD3-L', and another with normally open contacts 'S0.2 \*WTD3-H'. Both branches lead to a coil 'Q0.1 \*PO2'.

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